The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 107, Number 1 January-March 1993

The Ottawa Field-Naturalists' Club

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The Canadian Field-Naturalist

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Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: January-March 1993 (February 1994).

Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club*, 1879-1886, and *The Ottawa Naturalist*, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Adult Whooping Crane, *Grus americana,* standing beside nest 23–87 containing two eggs, 21 May 1987, "Snoopy Lake" area, Wood Buffalo National Park, Northwest Territories. Photo by E. Kuyt, Canadian Wildlife Service. See article, pages 1–12.

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FIELD-NATURALIST

Volume 107

1993

THE OTTAWA FIELD-NATURALISTS' CLUB

OTTAWA CANADA

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Whooping Crane, *Grus americana*, Home Range and Breeding Range Expansion in Wood Buffalo National Park, 1970-1991

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Kuyt, Ernie. 1993. Whooping Crane, *Grus americana*, home range and breeding range expansion in Wood Buffalo National Park, 1970-1991. Canadian Field-Naturalist 107(1): 1–12.

From a 1970 breeding population of 15 pairs, Whooping Cranes nesting in the Wood Buffalo National Park area increased to 33 breeding pairs in 1991. During this 21-year period, the migratory Wood Buffalo National Park - Aransas National Wildlife Refuge population has also more than doubled, from 57 birds to 132 as of November 1991. Since 1983, there has been a remarkable increase in the numbers of juveniles and surviving subadults, and a consequent increase in the breeding population. Home ranges were 12.0 - 18.9 km^2 for isolated breeding pairs, but in relatively dense nesting areas varied from 3.2 to 4.2 km^2. Mean size of home ranges of 13 identifiable pairs in the three core nesting areas (Sass, Klewi, and Sass-Klewi) was 4.1 km^2. Many new pairs began nesting on the peripheries of the existing breeding range along the Sass and Klewi rivers, but at least 12 pairs initiated nesting in other areas. Most of the pioneering breeding pairs occur farther south. Three breeding pairs now nest within the Alberta portion of Wood Buffalo National Park, with the southernmost nesting pair at 59°45'N., 113°20'W. Without habitat degradation in the Park, and in the absence of losses elsewhere along the migration route, the Whooping Crane breeding range should continue to expand, most likely in a southerly direction.

Key Words: Whooping Crane, *Grus americana*, home range, breeding range expansion, Wood Buffalo National Park.

In Wood Buffalo National Park (WBNP), the first recorded sighting of a pair of adult Whooping Cranes, *Grus americana,* with an unfledged juvenile was made on 30 June 1954 near the Sass River (Figure 1) by G. M. Wilson from a helicopter piloted by the late D. Landells. A later flight on the same date, with W. A. Fuller, Canadian Wildlife Service (CWS), resulted in sightings of an additional pair of Whooping Cranes (hereinafter called cranes) near the Sass River and a lone adult near the Nyarling River (Allen 1956). Aerial surveys in 1955 by Fuller revealed a single nest near the upper Sass River and two nests near the Klewi River (Figure 1), and suggested the presence of at least three crane families in the Sass River area. An additional family observed on 30 August in the north end of the Sass area was believed to have walked in from the Klewi River. Three flights to the Klewi River failed to show any cranes, and Fuller excluded that area from further surveys, concentrating instead on the Sass area (Allen 1956).

Allen (1956), on the basis of Fuller's reports, assumed a 1955 breeding population of four pairs near the Sass River with an additional two to four breeding pairs along the Klewi River. Two of the Sass River pairs raised two young each that year and a total of eight young (including the two sets of siblings) arrived at the Aransas National Wildlife Refuge (ANWR) in Texas that fall. The total wintering population of 28 birds also included four birds believed to be nonbreeders.

Novakowski (1966) concentrated his 1956-1965 aerial surveys in the Sass River portion of the crane breeding range, although he found two pairs nesting sporadically (1958, 1963) near the Klewi River. On the basis of winter arrivals of family groups at ANWR he estimated that three to six pairs nested outside the Sass River area.

My first flight over the Sass River area was on 10 May 1966, and on 18 May I found five nests near nest sites located the previous year by Novakowski. Five families, each with a single juvenile arrived at ANWR in fall 1966. In 1967, surveys were extended to the Klewi River where I found two nests and a family with two flightless young, in addition to six nests located in the Sass River area. Even though the number of juveniles arriving at ANWR in the fall of 1966 and 1967 was identical to the number of family groups observed in WBNP those years, breeding pair data were considered incomplete for 1966 and 1967 (Kuyt 1981a). I conducted or directed all CWS crane surveys in WBNP from 1967 to 1991.

Methods

All surveys in 1966 and 1967 were made in 2-place Bell G-2 helicopters flying at or above 150 m. In 1967, I only had 1:250 000 scale topographic maps, and these were of little use other than for navigation between Fort Smith and the crane breeding range. For plotting observed cranes and nests, I used airphoto mosaics of scale 1: 58 071 (1 cm = approximately 580 m). These rather primitive navigational aids and the author's and pilots' unfamiliarity with the crane breeding range made the surveys in early years a difficult task.

In 1968, I began making spring surveys in fixed-wing aircraft (Cessna 180), thus reducing the cost of surveys and the disturbance levels, and increasing the scope of the surveys, as my increasing familiarity with the breeding range and with breeding crane habitat requirements suggested was desirable. All aerial surveys over the crane breeding range since 1968 have been carried out in fixed-wing aircraft (almost exclusively Cessna 185), with the aid, since 1970, of aerial photographs of scale 1: 11 811 (1 cm = approximately 120 m). Surveys are now flown usually at above 500 m. In 1990 and 1991, through the cooperation of the United States Fish and Wildlife Service (USFWS), I carried out aerial surveys in a twin- engine aircraft (Partenavia PN68). All observations of cranes and crane nests are plotted on aerial photograph overlays and in this way an annual register of all crane nests is obtained.

The only times when workers were on the ground in the breeding range occurred during the removal of crane eggs (Kuyt 1976) and during the application of coloured leg bands (hereinafter called colour-bands) on juvenile cranes from 1977 to 1988 (Kuyt and Goossen 1987), when we used helicopters (float- or skid-equipped Bell 205, Bell 206B, or Bell 206L).

Five to eight aerial surveys, of 3–5 h duration each, are flown in spring, concentrating on areas previously occupied by breeding cranes. For many years, all or most of the nesting pairs were within an area of 400 km^2. The total breeding range is now about 500 km^2, just over 1% of 45 000 km^2 WBNP. Thanks to the colour-banding work (which allows the identification of many breeding pairs) and the experience of the primary observer, there has been close agreement between number of nests found each year in WBNP and number of families with young arriving in the fall at ANWR. Since 1967 only a few nests or nesting pairs have remained undetected (T. Stehn, personal communication), and all of these were located one or two years later. An annual winter census figure is obtained from ANWR, and although total population counts of cranes are not attempted in WBNP, aerial surveys over the cranes' summer range in 1989 and 1990 accounted for over 84% of these years' winter populations (Kuyt 1989, 1990 unpublished reports).

An area defended by a bird or pair of birds against individuals or pairs of its own species can be referred to as territory, and a breeding territory can include areas where mating, nesting, roosting, and feeding by adults and their young may occur (Pettingill 1970). A Whooping Crane pair will often nest in the same marsh where it nested the previous year. These two breeding territories often overlap in part, but may also include additional areas, depending perhaps on habitat conditions and on the capability of the wetland to produce sufficient food for the adult cranes and their young.

I used the term "composite nesting area" (CNA) to signify the superimposition of nesting territories of a pair of cranes over a number of years (Kuyt 1981a). The term was first used before individual Whooping Cranes could be identified, but results of the colour-banding work (Kuyt 1979) showed that identifiable crane pairs remained associated with a specific territory in successive years (one or two exceptions in 1991 as yet unconfirmed). By extrapolation, the same statement can be made for unbanded cranes. The composite nesting areas can be delineated by repeated observations of identifiable (colour-banded) adult cranes and their young, and, as these areas contain the total use area (nesting, roosting, feeding) of a family or pair of cranes, the CNA falls within the definition of home range (total area habitually occupied, Pettingill 1970). I used the terms CNA and home range interchangeably.

In a previous paper (Kuyt and Goossen 1987) several nests had not yet been assigned to a CNA. These nests are now included in their appropriate CNAs in this paper. Some pre-1984 CNAs have been redrawn to give a more accurate portrayal of areas used by resident cranes. The sizes of home ranges of pairs or family groups were calculated from aerial observations plotted on air photos. Description of colour-bands and identification of banded birds follows Kuyt and Goossen (1987).

Results

1. *Sass and Klewi Areas*

Four of five Sass River nests I found in 1966 were close to 1964 nest sites reported by Novakowski (1966). These four 1966 nests were respectively 1.5 km N, 2.2 km N, 3.5 km NE and 5.5 km ENE of a conspicuous Sass River escarpment used as a reference point by Novakowski (1966). Novakowski's fifth 1964 nest (a site also used in 1965) was located 4.5 km SW of the escarpment in an area that became vacant after 1965 as I found no cranes in this area until 1983. The fifth Sass nest in 1966 was located 10.0 km NE of the Sass escarpment where Novakowski had not found nests before. Data obtained in later years show that Novakowski's and my fifth nests could not have been used by the same pair of cranes in successive years. I did not survey the Klewi River area in 1966.

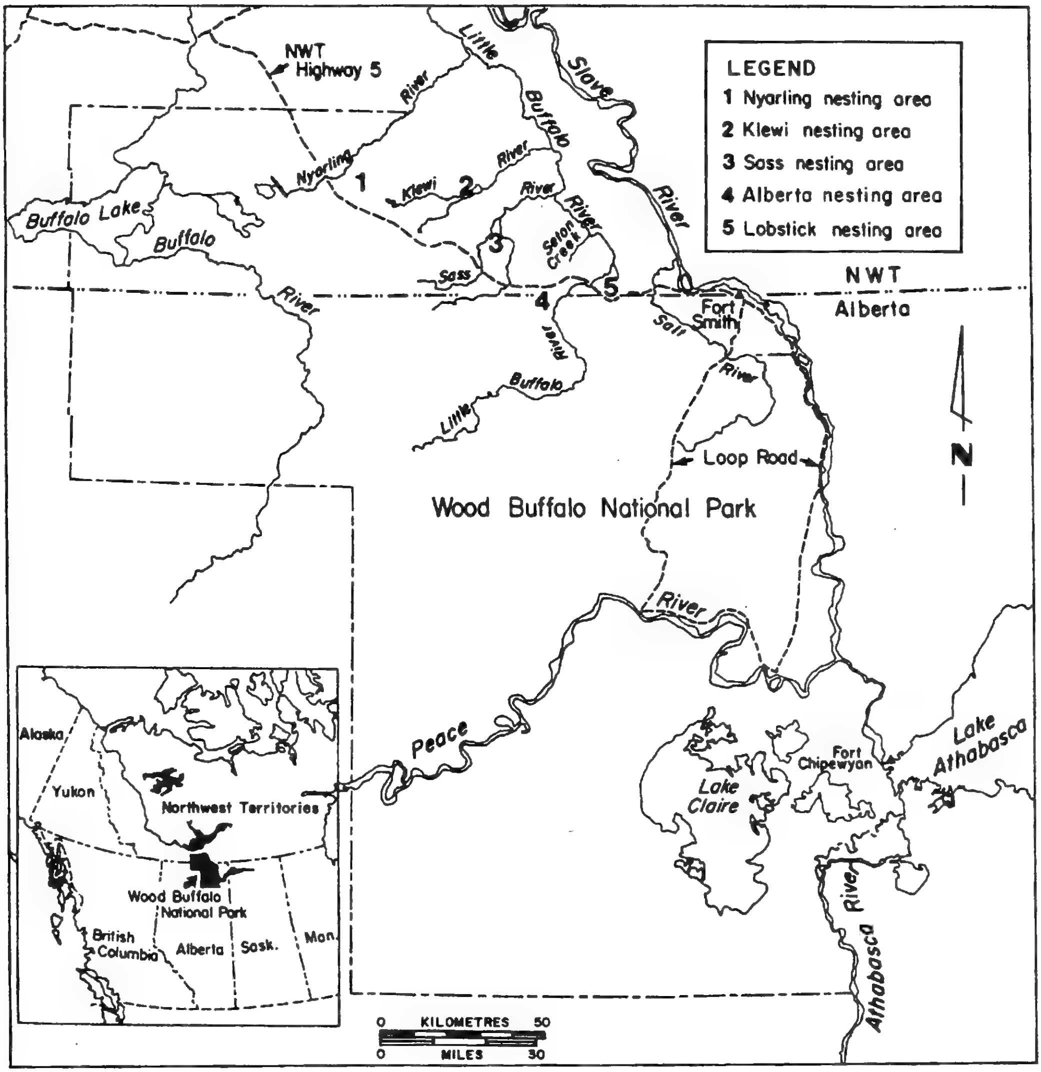

FIGURE 1. Whooping Crane nesting areas, Wood Buffalo National Park.

In 1967, I found three of the Sass nests (nests Number 2, 3, 4) in previously occupied territories. Pairs occupying nests 1 and 8 may have been overlooked in 1966 because in 1967 they were found near nest sites discovered by Novakowski. Nest Number 7, located about 8 km east of the Sass escarpment may have been a new nest site as Novakowski (1966) did not record it. However, the nest was located in the same large wetland complex along Sass River and Preble Creek (Figure 2) where other nests were located.

In the Klewi River area I found nests Numbers 5 and 6 in 1967 as well as a pair (nesting pair Number 9) with two flightless young. It is not known if Novakowski found nests there in 1958 and 1963 as those locations are not on record.

Kuyt (1981a) considered nest records for 1966 and 1967 to be incomplete. As no accurate nesting records then were available from areas other than the Sass and Klewi rivers, I have taken these two areas as the starting point for this analysis of breeding range extension. Sass and Klewi breeding ranges in 1967 occupied about 81 km^2 and 98 km^2, respectively (Figure 2).

No permanent breeding range extensions are known to have occurred in 1967-1969 even though the number of nesting pairs found in the Klewi area increased from three to seven. Three of these four

TABLE 1. Size (km^2) of Whooping Crane Composite Nesting Areas (Home Ranges), 1966-1991.

Sass		Klewi		Nyarling		Alberta		Lobstick		Nonbreeder (Sass-Klewi)	
S-1*	7.1	K-1*	3.3	NY-1	18.9	AB-1	17.9	LOB	12.0	SK-1	4.3
S-2	1.9	K-2	2.2	NY-2	3.3**					SK-2	3.4
S-3	1.7	K-3	2.2	NY-3	4.8**					SK-3	2.5
S-4	1.3	K-4	4.8							SK-4	2.4
S-5	4.4	K-5	5.5							SK-5	2.0**
S-6	4.8	K-6	11.2								
S-7	1.9	K-7	4.7								
S-8	2.5	K-8	2.4								
S-9	5.7	K-9	2.1								
S-10	1.1**	K-10	2.3								
S-11	5.3	K-11	4.0								
S-12	2.7	K-12	5.5								
S-13	6.8	K-13	5.2								
S-14	4.2	K-14	4.7								
S-15	3.2	K-15	2.8								
S-16	1.8**	K-16	4.0								
Mean	3.8		4.2		18.9		17.9		12.0		3.2
Mean+	4.4		4.5								2.8

* Data for S-1 to S-8, K-1 to K-7, from Kuyt (1981a).
** Nesting areas of three or fewer years of tenure not used in calculations.
\+ Mean of CNAs of colour-banded birds (see text).

new nests were in the same 98 km^2 block where three nesting pairs were found in 1967. The fourth nest (nest 12–69) was also along the Klewi River but about 10 km from the nearest 1967 nest site (Figure 2). That pair returned to breed in 1970 (nest 14–70) and then vanished.

Although in earlier years the Sass and Klewi portions of the breeding range may have been of equal importance as young-producing areas (except in dry years, when the Klewi area was the better producer, Kuyt 1981b), in recent years the Klewi area has exceeded the Sass area in numbers of nests and young produced even in years of good habitat conditions.

2. *Nyarling Area*

In 1970, breeding pairs in the Sass and Klewi River returned to previously occupied nest sites, but the first possible range extension became evident on 2 August when a WBNP fire-fighting crew reported several Whooping Cranes, including a flightless young, near the Nyarling River (Figure 2). I searched the area on 27 August 1970 and again on 17 and 19 May 1971 without finding cranes. On 23 May 1971 pilot G. Fink, with WBNP Warden F. Coggins, sighted a Whooping Crane nest in the Nyarling area and the following day I plotted the nest in the south portion of a large wetlands complex. The nest was close to the site where the flightless juvenile and other Whooping Cranes had been seen in 1970.

I cannot confirm that the 1971 Nyarling site was new, as Fuller sighted a lone adult near Nyarling River in 1955, but it was new as a known breeding area. One unmarked pair nested in the Nyarling area each year in 1970-1990. A second pair, also unbanded, nested in 1977-1979 immediately northeast of the earlier known territory. The second pair, in CNA NY-2 (Kuyt and Goossen 1987), failed to raise a chick in any of the three years it nested and was not seen again after 1979.

Cranes nested in the same area from 1970-1982. In 1983, the nest site was just northeast of the main Nyarling marshes. As neither bird was banded, I have no proof that the pair nesting from 1970-1982 was the same pair which nested there in later years. The different nest location in 1983 suggested that one of the adults was a new bird nesting for the first time that year. That assumption is more plausible because the 1983 nesting occurred later in the year than in any of the previous 13 years (new breeders nest later in the season than experienced breeders, Kuyt 1992). It is likely therefore that only a single pair nested in the main Nyarling marshes in 1970-1976 and after 1979. From 1970 to the present, the Nyarling pair occupying CNA NY-1 used a home range of about 18.9 km^2 (excluding the 1983 nest area).

3. *Little Buffalo (Alberta) Area*

The first few breeding pair surveys each year from Fort Smith are made in aircraft equipped with wheels or ski-wheels. When the float plane base (6.5 km south of Fort Smith) becomes ice-free, surveys are made from that lake in float-equipped aircraft. On 9 May 1977, the seventh survey of the season was the first from the float base and for that reason the crane breeding area was reached some distance south of

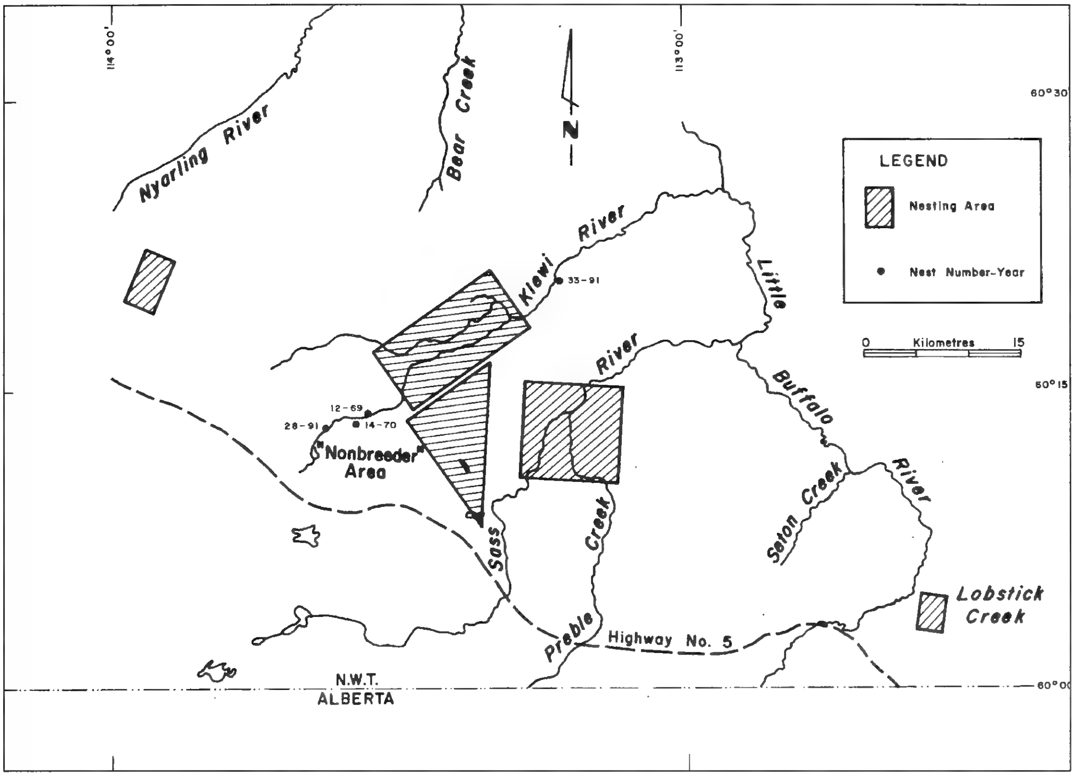

FIGURE 2. Whooping Crane nesting areas, Northwest Territories.

the usual flight track. Enroute we examined likely looking habitat just west of the Little Buffalo River and south of Highway Number 5. Here two Whooping Cranes were sighted, one on a nest with two eggs about 2.5 km south of the NWT-Alberta border. It was the first Alberta Whooping Crane nest recorded since 1914 or 1922 when these cranes may have nested near Wainwright and Birch Lake in east-central Alberta (Bent 1926).

A pair of unbanded cranes nested near the Little Buffalo River each year since 1977 except 1980 when the resident pair, although present, failed to breed. In 1984 the pair moved north to nest in a large shallow lake only 3 km south of Highway Number 5 and 200 m north of the NWT-Alberta border, the only year since 1977 that the cranes have not nested in Alberta (Kuyt and Goossen 1987). The area (CNA AB-1) used by this pair for nesting and feeding of young covers about 17.9 km^2 (Figure 3).

4. *Nonbreeder Area*

The wetland between the Sass River and Klewi River portions of the breeding range was conveniently called the "nonbreeder" area (Kuyt 1979) when seven of nine yearlings colour-banded in 1977 were observed there in 1978, confirming for the first time that, contrary to Novakowski (1966), yearlings also spend the summer in or near WBNP. Since then, other yearlings and subadults have often been sighted here, and in other parts of the crane summer range. Nesting has also occurred in the area but the name has been retained for the sake of convenience. Novakowski (1966) recorded four nests in this area between 1957 and 1965. The "nonbreeder" area (also called the Sass-Klewi area) is triangular in shape and measures about 54 km^2 (Figure 2).

4.1 CNA SK-1

I first found a nesting pair in the NE corner of the "nonbreeder" area in 1980 (Kuyt and Goossen 1987). Neither bird was colour-banded, and a pair, presumably consisting of the same birds, nested here each year between 1980 and 1987. One adult from this pair disappeared after reaching ANWR in fall 1987 and was presumed to have died. Although the surviving adult remated (T. Stehn, personal communication), the previously occupied territory remained vacant after 1987. The CNA measures about 4.3 km^2 (Figure 4).

4.2 CNA SK-2

On 4 August 1983, a six-year-old colour-banded male crane (Blue-Red), its unbanded mate and a large flightless chick were observed in the southern

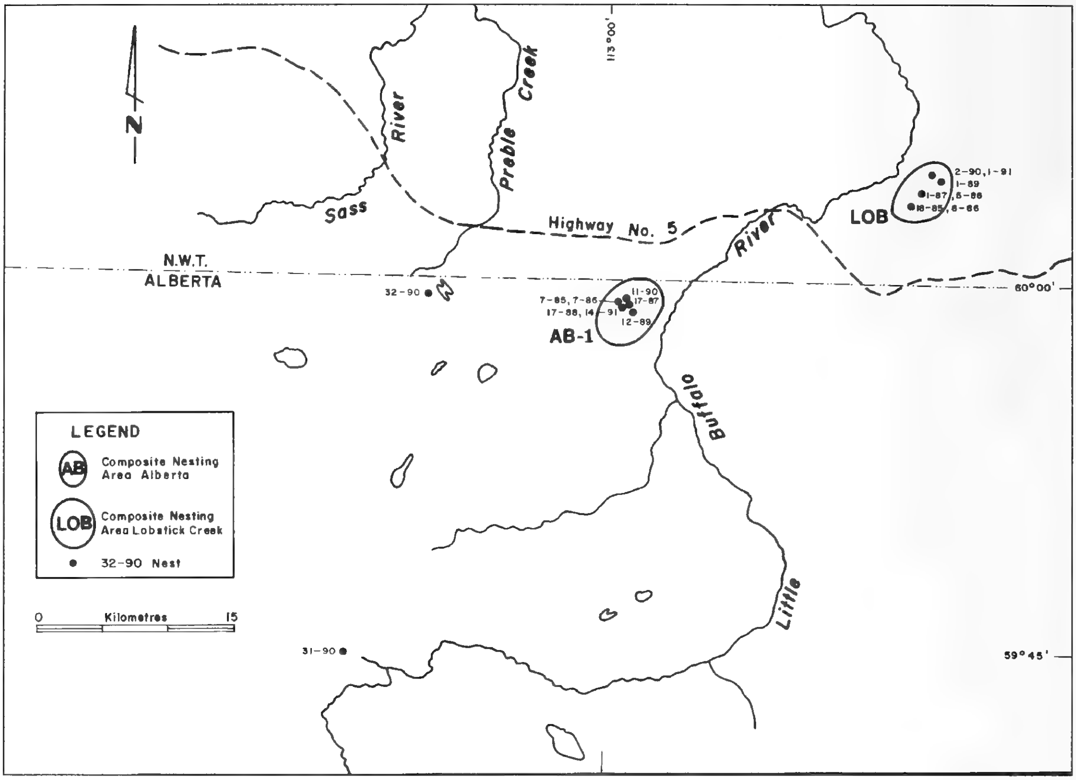

FIGURE 3. Lobstick and Alberta Composite Nesting Areas, 1985-1991, and new 1990 Alberta nest sites.

portion of the nonbreeder area. I had failed to locate the pair's nest during spring surveys. No nests had been found there since Novakowski (1966) recorded nests in 1964 and 1965.

In spring 1984, I found a nest near the birds' August 1983 location and a pair of cranes has nested in the territory each year thereafter. The pair, although successful in 1983, failed to hatch one of its eggs in 1984, and both eggs failed in 1985. On 24 May 1986, the banded male was found dead near the nest, as a result of heart muscle degeneration (G. Wobeser, personal communication). Of the two salvaged eggs, one hatched and the other was non-viable. Later in the season we saw a single adult (presumably the surviving mate of the banded crane) and still later a pair of unbanded cranes in CNA SK-2 (Figure 4).

The following spring a pair (neither bird banded) returned, and on 29 April 1987 the birds were found with a nest (9–87) close to the nest sites of the previous three years. Neither of the two eggs laid in 1987 was viable.

T. Stehn (personal communication) advised he was unable to find this breeding pair on its winter territory in Texas in January 1988, and he believed one of the birds may have mated with the widowed bird from another pair. On 10 May 1988 I found a relatively late nest (26–88) in the south end of the nonbreeder area 1.3 km from the previous year's nest. A pair of cranes and a nest were also located here the following year, but again the pair from this territory encountered problems, as T. Stehn (personal communication) reported that the unbanded female disappeared in winter and was presumed dead. The male then found a new mate, a bird colour-banded in 1986 (Red-Yellow).

This pair was found nesting in CNA SK-2 in 1990 and 1991. The nesting in 1990 was late in the season (as is usual for inexperienced breeders), and the single egg failed to hatch. In 1991, the pair's two eggs both hatched. The pair using this area (not always consisting of the same two individuals) has been utilizing a CNA of about 3.4 km^2.

Our records show that within a period of nine years, the pair nesting in CNA SK-2 lost one member on three different occasions without a break in its nesting series.

4.3 CNA SK-3

On 7 May 1984, I found a new pair nesting in a shallow pond in the northwest corner of the nonbreeder area. One of the adults was colour-banded (BWB band on right leg, no band on left leg). Our records showed it to be the former Red-BWB, a bird banded in 1979 and, because of its large size at banding, presumed to be a male. For seven consecutive years, a pair of cranes has nested in a small stand of emergent vegetation in the same 100 x 75 m shallow pond. Each year, from 1984-1989, the pair successfully raised a chick. T. Stehn (personal communication) in fall 1989 reported that the pair's winter territory was occupied by an unbanded bird and 1985 female BWB-GWG. Although it was first believed that this was a new pair, the persistent use of the same wintering area (although the pair also used a different area for short periods), and my 11 May 1990 observation of BWB-GWG and her unbanded mate at a new nest in the same small nesting pond in CNA SK-3, indicated that the male was likely the same bird as in previous years but that all identifying bands had fallen off. My observations have shown that male cranes return to their previously used nest areas with new breeding partners after the loss of former mates.

The pair in CNA SK-3 has occupied an area of about 2.5 km^2 (Figure 4).

5. CNA Lobstick

On 6 August 1981, Fort Smith pilot B. Bourque advised me that early that morning he had seen two Whooping Cranes near Lobstick Creek about 40 km west of Fort Smith. Later that day I confirmed the sighting and noted that one bird was colour-banded RWR-Blue, a bird banded in 1978 and judged to be a

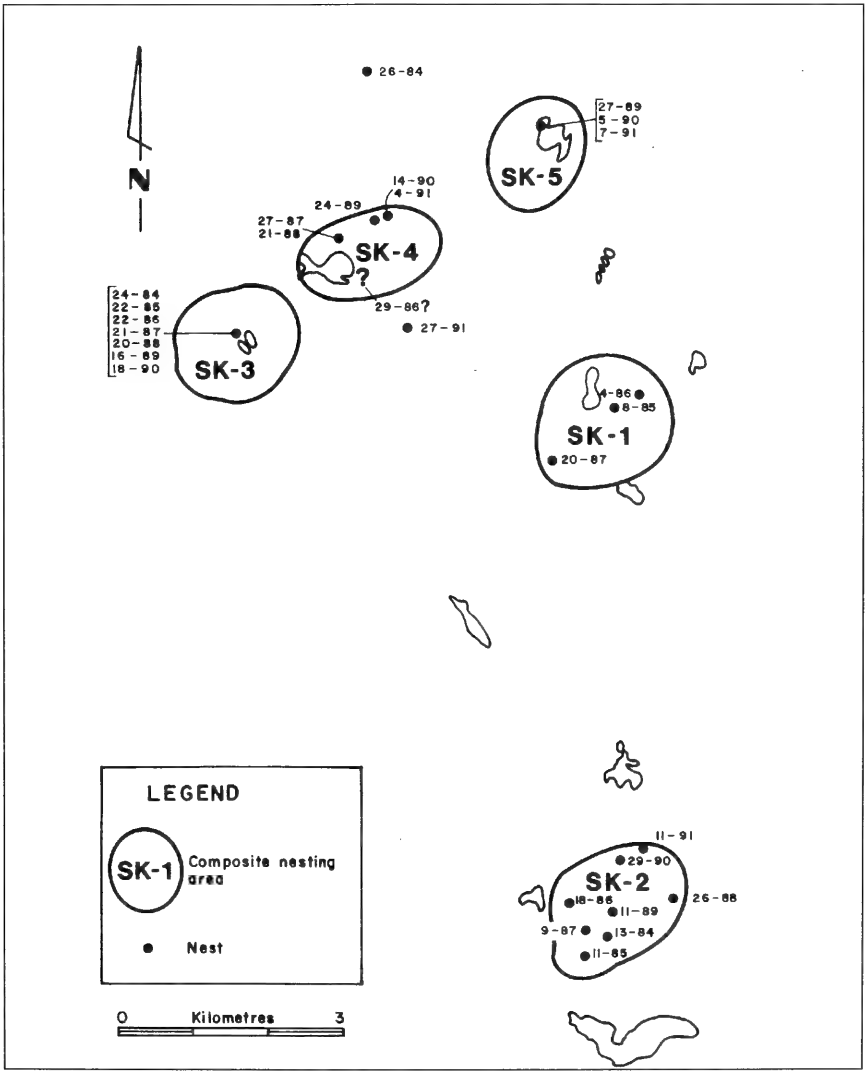

FIGURE 4. Sass-Klewi (nonbreeder) Composite Nesting Areas, 1984-1991.

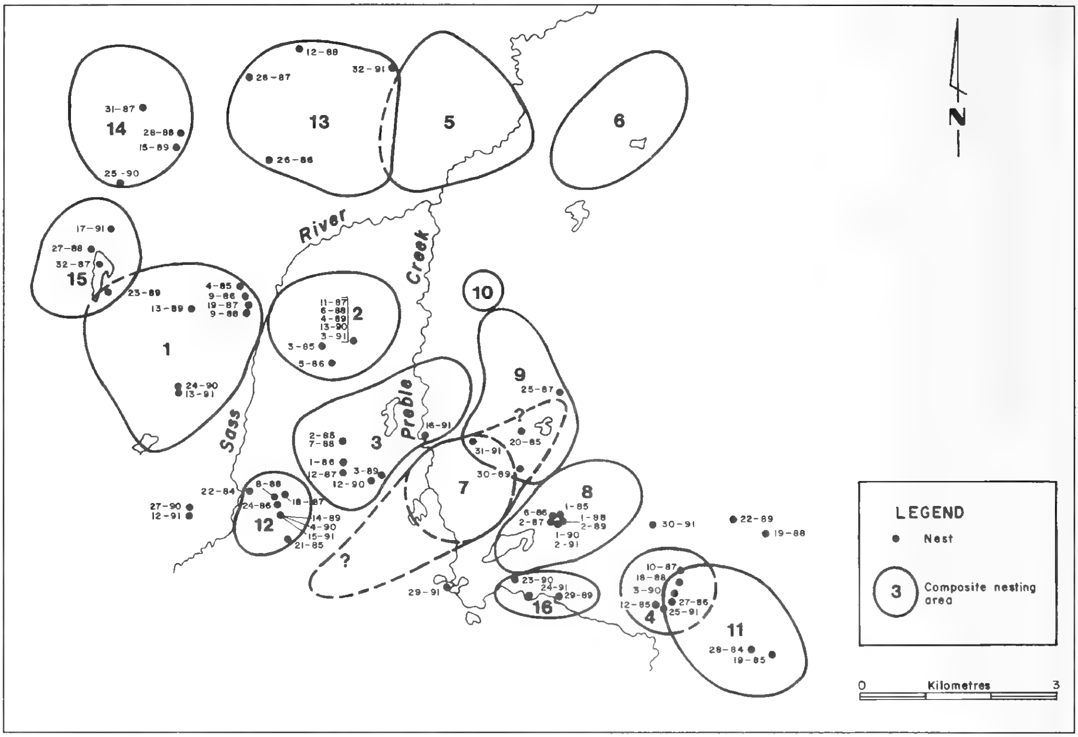

FIGURE 5. Sass River Composite Nesting Areas, 1984-1991.

male on the basis of behaviour at ANWR (Bishop 1984).

In 1982, the two birds returned to nest in the same wetland. By 1987, the male's colour-bands had disappeared but the crane could still be identified by the metal band low on the right leg. The pair has nested in the Lobstick marshes each year in 1982-1991, using an area of about 12.0 km^2 (Figure 3).

6. *Breeding Range Extensions*

6.1 *Sass River*

Since 1984, new pairs have begun nesting in the Sass River portion of the breeding range (CNA S-11, S-12, S-13, S-14, S-15, S-16). In addition, other recent nests (27–90 and 12–91; 29–91; 19–88, 22–89 and 30–91, Figure 5) have not yet been assigned to a definite CNA. All nine new nesting pairs are identifiable because of colour-bands on one or both members of each pair. All of these new CNAs and nests are located on the periphery of existing territories but are within the Sass River breeding range.

Several vacant CNAs (S-4, S-5, S-7), as well as the western portion of the large CNA S-1 (Figure 5) not used since 1970 (Kuyt and Goossen 1987), have now been encroached upon by new breeders. The borders of CNA S-7 are indeterminate and the area has been vacant except for the northeast portion used since 1983 by a pair in S-9. In 1990 a pair of colour-banded subadult cranes spent part of spring and summer along a section of Preble Creek near the centre of CNA S-7. The continuous use of the area by the cranes (1987 male BWB-YBY and 1985 female White-Green) implied they would return to breed in 1991. They did so, but nested (late in the season) just south of CNA Sass-7 (nest 29-91, Figure 5).

In 1988 and 1989, two colour-banded cranes (1985 male Yellow-Green and 1984 female White-Blue) nested at nests 19–88 and 22–89 north of CNA Sass-11 (Figure 5). None of the three eggs produced (2 eggs in 1988, 1 egg in 1989) was viable nor did the birds hatch a live substitute egg. In December 1989, the banded male lost the female on the winter range. He was subsequently seen there with subadults but apparently did not re-pair that year.

In 1990, I saw Yellow-Green near his 1988 and 1989 nest sites on at least seven occasions. Each time he was accompanied by a bird tentatively identified as a 1987 crane Y/G-Yellow. T. Stehn confirmed this association late in 1990. In 1991 the two birds constructed a late nest (30-91).

6.2 *Klewi River*

New nesting pairs have also begun to show up in the Klewi River portion of the breeding range and more particularly along its southern border.

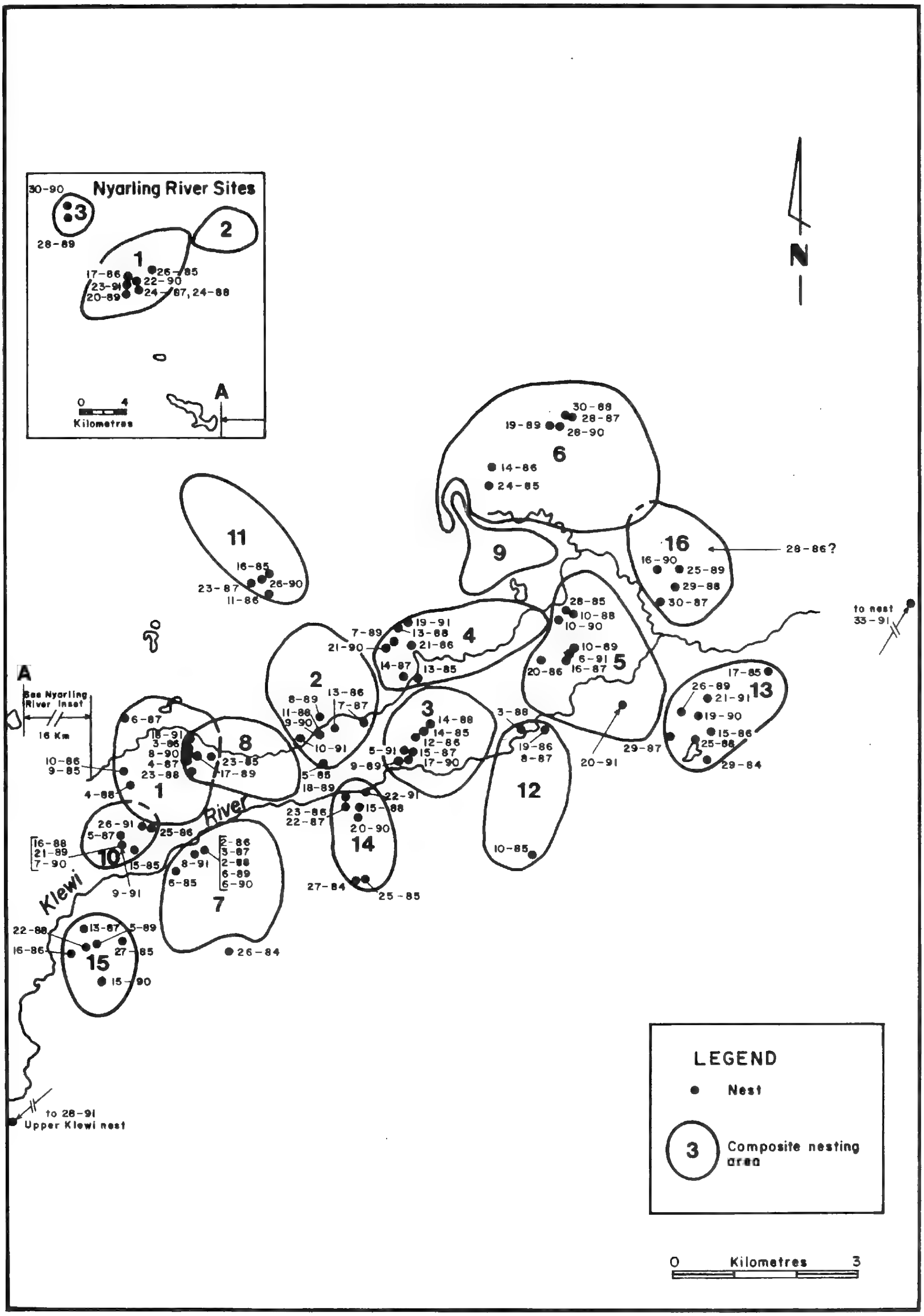

FIGURE 6. Klewi River and Nyarling River Composite Nesting Areas, 1984-1991.

In 1984, two new nesting pairs appeared in territories referable as CNA K-13 (two unbanded birds) and CNA K-14 (one of the two birds is 1979 male R/W-BWB). In 1985, cranes began nesting in K-15 and, one year later, in K-16 (Figure 6). These two pairs each consisted of a colour-banded bird (1981 male Green-R/W; 1983 male Yellow-B/B) and an unbanded bird. All of these new territories fall within the Klewi River nesting area shown in Figure 2.

On 15 June 1991, we sighted a Whooping Crane family (two adults, small chick and nest 33–91 containing a single egg) in an area we do not often survey (Figures 2, 6). The adult cranes (1985 male Blue-RWR and 1985 female WBW-BYB) had been paired for several years (T. Stehn, personal communication). We had not seen the birds in WBNP in 1989 or 1990. In September 1988, I saw a flying pair of cranes in the same area but could not determine if the birds were banded.

On 19 May 1991, we found nest 28–91 in the upper Klewi River (Figures 2, 6). Both birds were banded: the male (1985 RWR-Orange) was seen in the same area in 1988 (with an unbanded bird), in 1989 (with 1986 female WBW-Orange) and in 1990 and 1991 with its present mate RWR-YBY (1987). Nest 28–91 is a short distance from nest sites used in 1969 and 1970 by an unknown pair which did not return after 1970.

Within the Klewi River nesting area, CNA's K-1, K-9 and K-12 have been vacant since 1988, 1983, and 1988 respectively, and some encroachment on these or other CNAs has been observed (Figure 6). The part of CNA K-5 south of the Klewi River has not been used by the resident birds since 1984. In 1990 two colour-banded subadults (1985 male White-RWR and 1987 bird YBY-Y/G) were observed in the area and in 1991 the same birds built their first nest there (nest 20–91).

A pair of cranes, consisting of a colour-banded bird and an unbanded mate, was found on 5 May at nest 9–91 in CNA K-10. The birds which had nested here since 1981 were not banded. Subsequent surveys indicated that the banded crane (Green-R/W) was the former resident of CNA K-15 (Figure 6). An unbanded pair nested at 26–91 (late in the season) in the east portion of CNA K-10. I believe this to be the resident pair which found that the earlier arriving pair 9–91 had taken over part of its nest territory.

6.3 *Nyarling River*

In 1970-1976 and in 1980-1989, a single pair of unmarked cranes nested in the main Nyarling marshes (Section 2).

In 1987 and 1988, an apparently unbanded, nonbreeding pair showed up in the north end of the Nyarling marshes, about 5 km north of the original pair's nest. The following spring, the original unbanded Nyarling pair nested in its usual place, but 5.6 km northwest I found a new nest, attended by two apparently unbanded cranes. On a 31 August 1989 visit to the Nyarling area I located two unbanded adults and their chick 400 m south of the new pair's nest but I could not find the other pair. The original pair arrived at ANWR that fall with its chick (the pair's winter territory is well known, T. Stehn, personal communication).

A third Nyarling crane pair was observed on 29 and 31 August 1989, only 200 m from the long-since vacated nest of the original Nyarling pair. Both cranes carried orange bands.

New light was shed on the situation in spring 1990 when the original pair was found at nest 22–90 in its accustomed area (CNA NY-1) as well as a pair (one adult was 1986 female O-R/B) and a nest (30–90) in the north end of the Nyarling marshes about 1.5 km north of the 1989 nest in that area (Figure 6).

For many years only a single pair has nested in the Nyarling area but now there is a potential for growth in view of the sighting of a third pair in the area and of a yearling crane on 11 May 1990, presumably the 1989 offspring from the original Nyarling pair.

T. Stehn (personal communication) advised that female O-R/B's mate was found dead on 5 March 1991 on the pair's winter territory and that it took the "widow" only 17 days to find another mate (an unbanded bird). The original unbanded pair could not be located in 1991 in WBNP, although a nest was found in CNA NY-1. Band colours of the banded bird in that pair could not be confirmed, but the bird appeared to be O-R/B. Observations at ANWR in winter 1991-1992 confirmed that this banded bird is now with the male of the original Nyarling pair (T. Stehn, personal communication).

6.4 *Alberta*

During radio-telemetry studies of northward-migrating Whooping Cranes in 1983, I noted potential summer crane habitat along a 60 km section of the cranes' migration path between the center of WBNP and the NWT-Alberta border. Aerial surveys there on 9–11 June 1990 resulted in the discovery of two new nests, an additional pair of unbanded birds and three single birds (a 2-yr-old, a 4-yr-old and an unbanded crane in adult plumage).

The area between new nest 31–90 (Figure 3) and the NWT-Alberta border and from that line east to Little Buffalo River contains suitable habitat for at least eight pairs of breeding Whooping Cranes. Additional wetlands scattered throughout the same area, individually perhaps too small to support a family group of cranes could provide suitable foraging habitat for nonbreeding birds.

Nest 32–90, near the NWT-Alberta border, was attended by a 1983 male (B/B-Yellow) and a 1985 female (Yellow-Red). In 1988 the male (with his first mate, later illegally shot in Texas) nested in an unknown area and then, with his new mate, was seen briefly in WBNP in 1989 but disappeared to summer in an unknown area. Most likely the two birds spent that summer in the vicinity of the 1990 nest site, an area not surveyed in 1988 or 1989. In 1991, the two birds nesting at 32–90 returned to the same area of the previous year, but they did not nest.

Nest 31–90, the southernmost nest, was 35 km south from the known breeding range. The nest was attended by a pair of colour-banded 3-yr-old cranes (White-YBY and Yellow-YBY). Sex of the birds is unknown but measurements taken during banding suggest Yellow-YBY was a male and White-YBY a female. I have only two previous records of 3-yr-old cranes (each mated with an older bird) successfully raising a chick. My expectation of this pair failing to produce a chick (also made probable by unfavourable habitat conditions in 1990) was realized when the pair abandoned its nest and the two eggs.

The two birds failed to return to their 1990 nest area in 1991. One of the birds apparently nested at nest 13–91 (CNA S-1) with an older male bird who lost his mate at ANWR in 1990/91 (T. Stehn, personal communication). The other bird, observed several times in 1991 near the Sass River-Highway 5 crossing, did not nest in 1991.

The discovery of two additional nests south of 60°N marks the first time that as many as three Whooping Crane nests have been found within the province of Alberta in one year.

6.5 *Nonbreeder area*

6.5.1 CNA SK-4

On 7 May 1987, while searching for a pair of Whooping Cranes seen on 2 May I found a bird on a nest on a small island in the northernmost part of the nonbreeder area. While the survey aircraft circled at about 500 m, the unbanded incubating crane left the nest and walked into the forest where it remained standing. This is unusual behaviour, suggesting a novice breeder (cranes often remain incubating or stand on the nest as the survey aircraft passes overhead). T. Stehn (personal communication) later indicated the bird's mate most likely was a 1979 crane (formerly BWB-Red which had lost both colour-bands but retained its metal band). That bird, the smallest one banded in 1979, lost her mate (a male) in North Dakota in fall 1984, failed to remate the following year but wintered in 1986 with a new mate and a chick after having nested in an unknown area.

BWB-Red's previous known nest site was a 1984 nest (nest 26–84, Figures 4, 6) located north of the 1987 nest. In 1988, the pair returned to the 1987 nest island and again produced two eggs (joined by an egg laid by a Sandhill Crane, *Grus canadensis*; Kuyt 1989). In 1989 and 1990, the birds nested 450 m NE of the original site. I am unsure whether these birds nested in 1991 in the same area (nest 4–91) or a short distance south (nest 27-91). There is some evidence to suggest a different pair usurped the resident pair's nest site in CNA SK-4. The size of CNA SK-4 occupied between 1987 and 1991 was about 2.4 km^2.

6.5.2 CNA SK-5

During an aerial survey on 13 May 1989 I found a bird in a small stand of bulrush, *Scirpus validus,* near the shore of a large lake in the northeast corner of the nonbreeder area. The bird was standing on a nest containing one egg. On 22 May I saw the bird rising well before the survey aircraft was near, behaviour indicative of a novice breeder. During the annual collection of eggs, we found that neither of the new pair's two eggs was viable, and a live egg from another nest was substituted. The cranes hatched the egg and raised the chick. My tentative identification of the colour-banded bird (1983 B/W-R/B) of this new breeding pair was confirmed by T. Stehn (personal communication) when the family group reached Welder Point near ANWR. The crane with the colour-band (likely a male) was banded as a juvenile in 1983 and its mate, carrying only a metal band, was of unknown age.

The cranes returned in 1990 to nest in the same stand of emergent vegetation where they nested in 1989. In 1991, Sandhill Cranes usurped the nest site, and the later-arriving Whooping Cranes nested on a small island in the center of the same lake. Both nests were destroyed about 20 May, apparently by a Black Bear, *Ursus americanus*. During its three consecutive breeding seasons the crane family used a small area (CNA SK-5) of about 2.0 km^2.

Discussion

The WBNP Whooping Crane breeding population increased from 17 pairs in 1982 to 32 pairs in 1987, and there were concomitant increases in numbers of juveniles produced annually and of surviving subadults. The maximum numbers of subadults (excluding juveniles) were 24 in 1968, 34 in 1980, 45 in 1987 and 60 in 1991 (45% of the total spring population). In view of these increases, with subadults "graduating" to the breeding segment and in the absence of major losses of breeding birds, and without serious, long-term breeding habitat degradation, it is not surprising to record an increase in the number of breeding pairs and the area occupied by them.

With the discovery of a nesting pair in the northeast Klewi marshes (nest 33–91), only a single crane colour-banded in 1985 or earlier remains unaccounted for. That bird has lost all colour-bands and is no longer identifiable from a distance. All of the surviving cranes banded in 1986 have been observed paired in WBNP or at ANWR or have already bred. At least six of the 15 colour-banded birds of the 1987 year-class have already bred and almost all of the remaining cranes in that year-class had paired and were expected to breed in 1992.

Although novice nesting pairs may initially nest some distance from running water (e.g. Sass and Klewi rivers, Preble Creek) there appears to be a tendency for them to move their nest sites closer to the more stable water regime of these streams in successive years. It is likely that this trend is more pronounced during dry years. The usurping of nest sites by other cranes in 1991, not noticed before, may also have indicated a relative paucity of nest sites during the dry spring of 1991. Water levels of nest ponds, measured during the annual collection of eggs, were lower in 1991 than during any of the previous 10 years.

Three composite nesting areas in isolated sites (Nyarling, Alberta, Lobstick) were considerably larger than those in areas of greater nest density. It remains to be seen if these composite nesting areas will decrease in size with increasing density of nesting birds.

The most meaningful data for size of composite nesting area are probably those for CNAs where pairs were identifiable. S-11, S-12, S-13, S-14, S-15, K-5, K-12, K-14, K-15, K-16, SK-2, SK-3 and SK-4 all contained one or two identifiable cranes and the mean size of these 13 areas was 4.1 km^2.

With minor exceptions, Whooping Crane breeding range extensions are occurring in a southward direction. Klewi River and Nyarling River cranes generally arrive and breed later than Sass River birds (Kuyt, unpublished data). If birds nested even farther north (e.g. nearer the large cold Great Slave Lake), the season would be shorter and this could be a barrier to successful raising of chicks. It is likely that with increasing population numbers further southward range extensions will occur.

Acknowledgments

I thank B. Johnson (formerly with Canadian Wildlife Service), J. P. Goossen and B. W. Johns (CWS) for their assistance in the field. Many charter pilots (in particular B. Bourque and G. Scott of Loon Air Ltd., Fort Smith, NWT) provided excellent flying service for over 20 years. Pilot J. W. Winship (USFWS) flew aerial surveys in 1990 and 1991. For the preparation of this paper, T. Stehn made available many useful observations of wintering cranes. Staff of WBNP for many years made important contributions in manpower, supplies and equipment. Two anonymous reviewers provided helpful comments on the manuscript. I thank all of these cooperators.

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Received 12 March 1992
Accepted 4 August 1993

Abundance and Summer Occupancy of Arctic Fox, *Alopex lagopus*, and Red Fox, *Vulpes vulpes*, Dens in the Northern Yukon Territory, 1984-1990

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Smits, Cor M. M., and Brian G. Slough. 1993. Abundance and summer occupancy of Arctic Fox, *Alopex lagopus*, and Red Fox, *Vulpes vulpes*, dens in the northern Yukon Territory, 1984-1990. Canadian Field-Naturalist 107(1): 13–18.

A total of 32 fox dens were known to exist on Herschel Island in 1990. Few dens were located before 1986. Dens located before 1986 were generally larger and, therefore, more likely to be natal than dens found in latter years. Thus a comparison of the proportion of natal fox dens between years was confounded. When proportions of natal dens are compared between years using dens sampled each year from 1986-1990 (n=32), proportions of natal Arctic Fox dens were substantially higher in 1988 (18.8%) and 1990 (18.8%) than in 1986 (6.3%), 1987 (6.3%), and in 1989 (3.1%). No substantial differences were apparent in proportions of natal Arctic Fox dens between all years during 1984-1990, comparing dens known in 1984 (n=14). On the Yukon Coastal Plain, 32 dens were identified during a preliminary survey in 1984, while an aerial stratified random block sampling census in 1987 yielded a total estimate of 50-63 dens (90% C.I.). One natal Arctic Fox den was found during each of 1985 and 1988, and one Red Fox natal den was observed in 1985, 1987, 1988, and 1989. There was no substantial difference in proportions of natal Arctic Fox, or natal Red Fox dens between years on the Yukon Coastal Plain. Herschel Island had one of the highest densities of Arctic Fox natal dens reported in the literature, whereas the Yukon Coastal Plain had one of the lowest densities.

Key Words: Arctic Fox, *Alopex lagopus*, Red Fox, *Vulpes vulpes*, den, productivity, Yukon Territory.

Arctic Foxes (*Alopex lagopus*) depend upon dens for rearing their young during spring and summer and use dens year-round for shelter (Macpherson 1969; Eberhardt et al. 1983). In the northern Yukon Territory, Arctic Foxes den on the Yukon Coastal Plain and on Herschel Island. Red Foxes (*Vulpes vulpes*) den in this area as well (Ruttan 1974; C.M.M.S., B.G.S., and R. H. Jessup, Yukon Department of Renewable Resources, unpublished data). The physical characteristics and terrain association of these den sites have been described to identify key Arctic Fox habitat and understand denning ecology (Smits et al. 1988; Smith et al. 1992). Prior to 1984 only cursory information on den distribution and occupancy in the Yukon Territory was available (Ruttan and Wooley 1974; Ruttan 1974). This study investigated the abundance and summer occupancy of fox dens in the northern Yukon Territory during 1984-1990 as baseline information for the management of Arctic Fox habitats and populations.

Study Area

The study area encompassed Herschel Island (101 km^2) and the Yukon Coastal Plain between the Babbage and Crow (Tulugaq) rivers to the east and the Canada/USA border to the west [2449 km^2] (Figure 1).

Herschel Island is composed of marine sediments that have been deformed and ice-thrusted into their present form (McKay 1959; Bouchard 1974). The sediments are predominantly fine-grained, with limited exposures of sand and gravel. Differential erosion has resulted in the development of coarse-textured ridges within a landscape of otherwise fine-grained materials. Most of the surface is rolling upland at elevations ranging from 60 - 180 m above sea level (Smits et al. 1988).

The Yukon Coastal Plain (Bostock 1970) is an eastward extension of the Arctic Coastal Plain (Wahrhaftig 1965) from Alaska. The plain encompasses an area of approximately 3700 km^2. It averages 20 km in width and slopes from a high point of 150 m above sea level northward to the Beaufort Sea. The surficial materials of the Yukon Coastal Plain originated from both glacial and non-glacial processes. Morainic, lacustrine, and fluvial deposits are most common. Active fluvial landforms (large deltas) predominate on the plain west of Herschel Island. East of Herschel Island, the plain consists of rolling moranic deposits interspersed with nearly flat areas of lacustrine material. Lakes and ponds of thermokarst origin dot the plain, and local relief rarely exceeds 30 m (Rampton 1982; Smits et al. 1988). The mean annual temperature at Komakuk is -12.1°C; the mean annual precipitation is 125 mm (Canadian Climate Program 1982).

Cottongrass tussocks (*Eriophorum vaginatum*), moss, ericaceous shrubs, and willows (*Salix* spp.) are the dominant vegetation on imperfectly drained upland sites. On well-drained sites Avens (*Dryas integrifolia*), vetch (*Astragalus* spp.) and Arctic Willow (*Salix arctica*) predominate (Wiken et al.

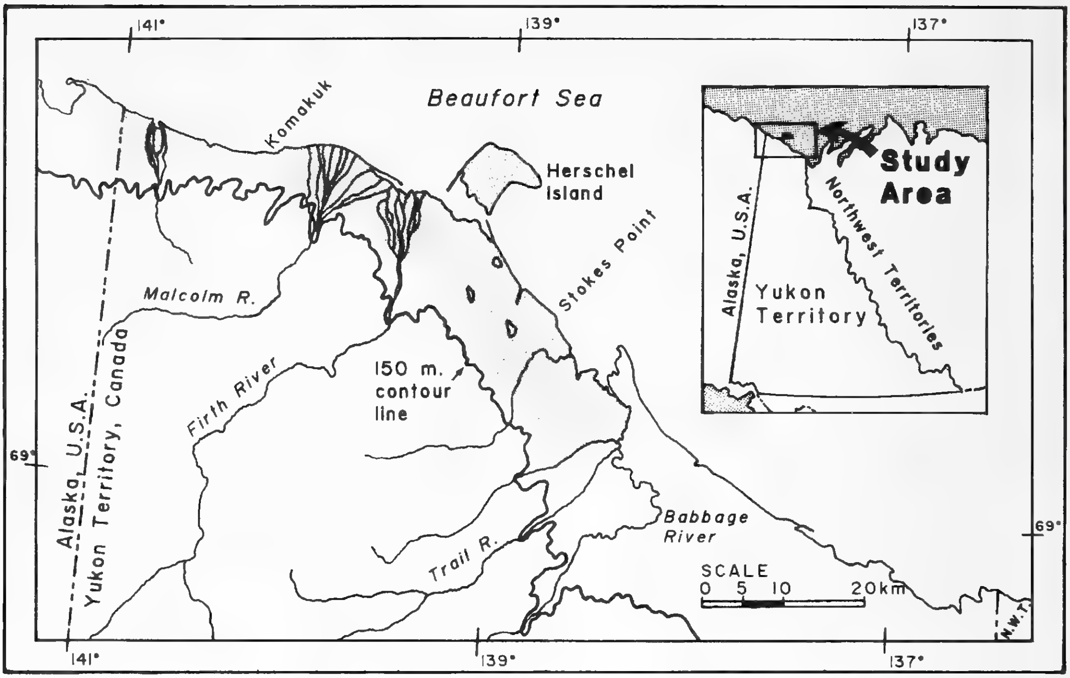

FIGURE 1. Location of the study area (shaded) in the northern Yukon Territory.

1981). Common small mammal species included Brown Lemming (*Lemmus sibiricus*), Varying Lemming (*Dicrostonyx groenlandicus*), Northern Bog Lemming (*Synaptomys borealis*), Tundra Vole (*Microtus oeconomus*), Northern Red-backed Vole (*Clethrionomys rutilus*), and Arctic Ground Squirrel (*Spermophilus parryii*, on Yukon Coastal Plain only). The area supports a large and varied nesting avifauna and is also important for migration, molting, and staging by several species (Salter et al. 1980; R. Ward and D. Mossop, Yukon Department of Renewable Resources, unpublished data). At least 50 bird species are summer residents of the study area, including Oldsquaw (*Clangula hyermalis*), Semi-palmated Sandpiper (*Calidris pusilla*), Lapland Longspur (*Calcarius lapponicus*), Baird's Sandpiper (*Calidris bairdii*), Arctic Tern (*Sterna paradisaea*), Northern Phalarope (*Lobipes lobatus*), Willow Ptarmigan (*Lagopus lagopus*), and American Golden Plover (*Pluvialis dominica*), all of which are abundant Microtine rodents and birds were the main summer food items of Arctic and Red foxes (Smits et al. 1989).

Methods

Dens were identified using a completed census (July 1984), incidental observations during monitoring flights (July 1985 and July 1986), an aerial stratified random block sampling census [Jolly 1969] (July 1987) and incidental observations (July 1985-1990). During aerial searches, den locations were plotted on 1:250 000 (Yukon Coastal Plain) or 1:50 000 (Herschel Island) topographical maps. Den searches were conducted from a Bell 206 Jet Ranger B helicopter by one or two observers. Each July during 1984-1990, all known dens were ground-checked for occupancy, with the exception of 1986 and 1990 when no dens were checked on the Yukon Coastal Plain. Occupancy status was determined by the presence of recent fox scats, hair, tracks, prey remains, and/or the presence of foxes. Dens were classified as natal if juvenile foxes were sighted, if juvenile tracks or faeces were present, or if characteristic juvenile barks were heard from within the den (Eberhardt et al. 1983). Red Fox and Arctic Fox dens were distinguished by sightings or hair identification at den entrances.

Differences in size (i.e., number of den entrances) of dens between years were evaluated using the TTEST procedure of SAS (SAS Institute Inc. 1985). Natal and non-natal dens were combined for Herschel Island and Yukon Coastal Plain to test for differences in size due to small sample size on the Yukon Coastal Plain.

Results

Herschel Island

The total number of dens identified on Herschel Island varied from 14-34 during 1984-1990 (Figure 2). Differences in the total number of dens between

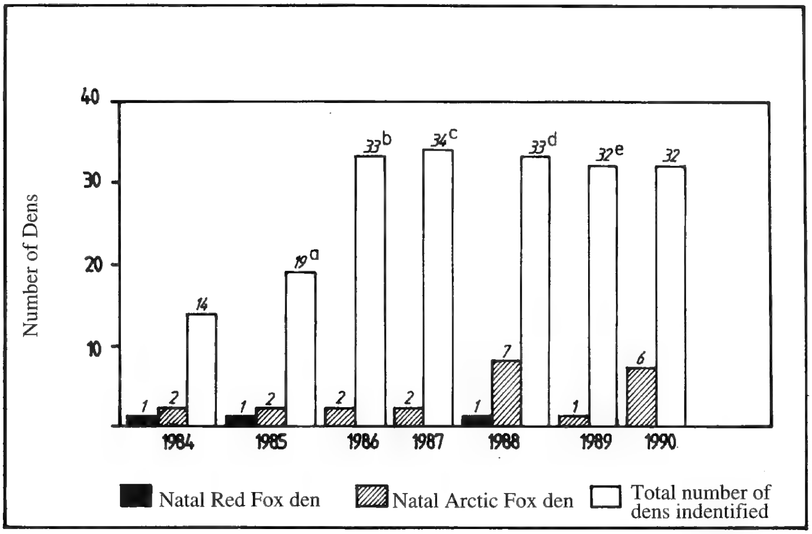

FIGURE 2. Breeding status and number of known fox dens on Herschel Island, 1984–1990: [a]additional dens found; [b]17 additional dens found while three known dens had collapsed since 1985; [c] one additional den found; [d], [e] one den collapsed each year.

years resulted from both the discovery of dens not previously found and from collapse of known dens. Dens detected in 1986 were significantly ($p = 0.0043$) smaller (number of den entrances) ($\bar{x} = 6.4 \pm 10.0$ [S.D.]) than dens located before 1986 ($\bar{x} = 20.8 \pm 13.4$). Non-natal dens (combined Herschel Island and Yukon Coastal Plain data) ($\bar{x} = 5.2 \pm 5.6$) were significantly ($p = 0.0001$) smaller than natal dens ($\bar{x} = 25.1 \pm 13.2$). The number of known natal Arctic Fox and Red Fox dens varied from 2-7, and from 0-1, respectively, during the study period (Figure 2). Substantial differences were apparent in the proportions of natal Arctic Fox dens between years when dens known in 1986 were compared ($n = 32$). These differences were less substantial when dens known in 1984 were compared ($n = 14$) (Table 1). Figure 3 shows the frequency with which known natal dens were used during the study period.

Yukon Coastal Plain

The total number of dens identified on the Yukon Coastal Plain increased from 32 in 1984 to 53 in 1989 (Figure 4). The mean number of entrances of dens identified in 1984 and 1985 ($\bar{x} = 18.2 \pm 8.7$) is significantly ($p = 0.0055$) greater than that of dens identified in 1987 ($\bar{x} = 9.2 \pm 9.6$). No substantial difference in proportions of natal dens between years for Arctic Fox or Red Fox was apparent on the Yukon Coastal Plain. This holds for both when dens

TABLE 1. Number of natal Arctic Fox dens located on Herschel Island, 1984–1990.

Year	Sub-Sample[1] (%)	Complete Sample[2](%)
1984	2(14.3)	
1985	2(14.3)	
1986	1(7.1)	2(6.3)
1987	2(14.3)	2(6.3)
1988	4(28.6)	6(18.8)
1989	1(7.1)	1(3.1)
1990	4(28.6)	6(18.8)

[1]Dens known in 1984 (for comparisons between 1984–1990).

[2]Dens known in 1986 (for comparisons between 1986–1990).

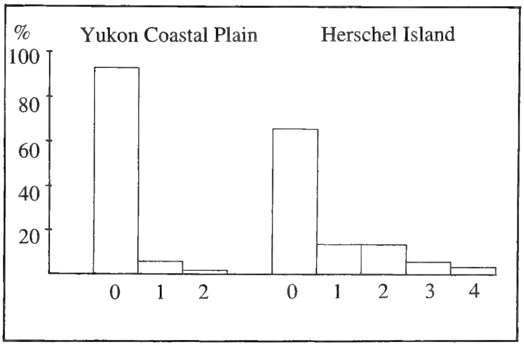

FIGURE 3. Frequency of natal den use per den. The number of years used was out of four years for the Yukon Coastal Plain and five years for Herschel Island.

Table 2. Crude density and percentage of natal dens reported for Arctic Fox den surveys.

Location	Natal Dens/ 100 km^2	%Natal Dens	Area (km^2)	Authority
USSR		31 - 74		Shibanoff 1951
Bol'shezemel'skaya tundra, USSR		12 - 100		Tchirkova 1951
Taimyr, USSR		6 - 100		Sdobnikov 1960
Bol'shezemel'skaya tundra, USSR		3		Skrobov 1961 (*in* Macpherson 1969)
Teshekpuk Lake area, Alaska		4		Chesemore 1969
Aberdeen Lake area, N.W.T.	0.33 - 1.38	12 - 50	4947	Macpherson 1969
Whole tundra zone, USSR		10 - 80		Bannikov 1970
Keewatin district, N.W.T.	0 - 1.74	0 - 43	518	Speller 1972
Northern Yukon Territory		4		Ruttan 1974
Prudhoe Bay, Alaska		25		Underwood 1975
Prudhoe Bay, Alaska		42		Fine 1980
Prudhoe Bay, Alaska	1.11 - 4.44	18 - 74	450	Eberhardt et al. 1983
Colville Delta, Alaska	0.12 - 1.35	6 - 55	1700	Eberhardt et al. 1983
Yukon-Kuskokwim Delta, Alaska	0 - 8.33	0 - 7	37	Anthony et al. 1985
Hardangervidda, Norway	0 - 1.65	0 - 3	182	Østbye et al. 1978
Herschel Island	0.99 - 6.93	6 - 21	101	This study
Yukon Coastal Plain	0 - 0.04	0 - 2	2449	This study
Svalbard	4.76	40	870	Prestrud 1992

known in 1984 were compared between years, and when dens known in 1987 (when many additional dens were located relative to 1984-1985) were compared between 1987, 1988, and 1989.

Discussion

Few dens of the larger size typical of natal dens were found during surveys after 1985 on both Herschel Island and the Yukon Coastal Plain, suggesting that few natal dens were missed during the later surveys. On Herschel Island two dens were used by the same Arctic Fox litter in 1988 (C.M.M.S, B.G.S., and A. Angerbjorn, University of Stockholm, unpublished data). Additional simultaneous use of dens by other litters may have occurred. In that case, fewer litters would have been present than suggested by the number of natal dens alone. However, with the exception of 1990, we consider this unlikely in view of the distance between natal dens (all > 2.7 km during 1984, 1985, 1986, 1987). Eberhardt et al. (1983) report an average distance between natal and successive Arctic Fox dens of 2.2 ± 0.7 km in northern Alaska. In 1990, simultaneous use of dens may have involved three dens 0.8-1.6 km apart. Hence, the number of Arctic Fox litters present in 1990 may have been four to six.

Herschel Island is the most important breeding area for Arctic Foxes in the Yukon Territory west of the Babbage and Crow rivers. The great differences in den density between Herschel Island and Yukon Coastal Plain is likely related to the difference in terrain between these areas. Arctic Foxes prefer well-drained soils, a prevalent terrain type on Herschel Island but much less common on the Yukon Coastal Plain (Smith et al. 1992). The limited available data do not support the occurence of a 3-4 year population cycle for both Herschel Island and Yukon Coastal Plain as reported for inland populations (Braestrup 1941; Elton 1942; Chitty 1950; Tchirkova 1951; Vibe 1967), nor of the magnitude of fluctuations reported by Tchirkova (1951), Sdobnikov (1960), or Bannikov (1970) in the coastal U.S.S.R. (Table 2). In inland Arctic Fox populations, the cycle closely follows changes in lemming populations and evidence has been presented that lemming abundance in the breeding season governs the survival of fox whelps (Macpherson 1969). Lemmings, primarily the Varying Lemming, were also the largest component in the summer diet of Arctic Foxes in northern Yukon during 1985 (Smits et al. 1989). However, coastal Arctic Foxes have access to a greater variety of food sources than inland Arctic Foxes (Braestrup 1941). As a result, coastal Arctic Foxes might not be regulated by lemming cycles to the same extent as inland Arctic Foxes. Alternatively, lemmings on the Yukon North Slope may not display a three to four-year population cycle. The annual harvest of Arctic Foxes on the Yukon North Slope has been extremely low since 1985 (K. Poole, N.W.T. Department of Renewable Resources, personal communication) and yearly variation in fox abundance was, therefore, undetectable in harvest statistics.

A low proportion of dens on Herschel Island and Yukon Coastal Plain are used for breeding, relative to other areas (Table 2). However, such a comparison may not be valid as it is not known in most cases if small dens (< 5 den entrances), unlikely to

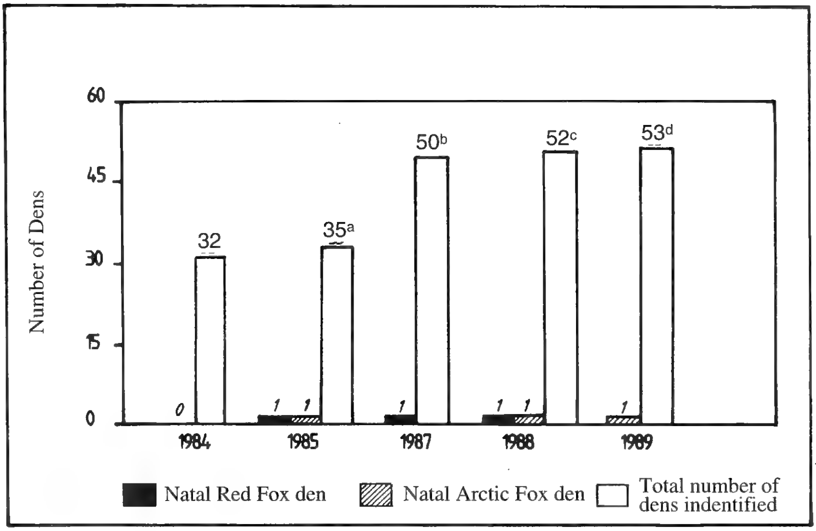

FIGURE 4. Breeding status and number of fox dens on Yukon Coastal Plain, 1984, 1985, 1987–1989. [a]three additional dens found; [b]50–63, 90% C.I., 50 natal dens were known, 15 of which were additional to those found in 1985; [c]two additional dens found in 1985; [d] one additional den found).

have been natal dens, were included in the sample of other studies. A more relevant comparison would involve the number of natal dens per unit area, which is also a more appropriate and direct index of habitat productivity. When this number is compared between areas (Table 2), Herschel Island is shown to possess one of the highest numbers of natal Arctic Fox dens per unit area, whereas the Yukon Coastal Plain possesses the lowest number reported. Similarly low proportions of natal dens were observed in the study area in 1972 (2 out of 50 identified dens, Ruttan 1974).

Many non-natal dens had been used by foxes in the recent past as evidenced by spoor of foxes at dens (i.e. scats, fur at den entrances). Such dens may have been occupied by pairs of foxes early in the breeding season whose litters subsequently failed (Macpherson 1969) or foxes may have used the dens for shelter from inclement weather at any time of year as has been reported by Eberhardt et al. (1983).

No Arctic Fox dens have been located on the Yukon Coastal Plain east of the Babbage and Crow Rivers despite systematic aerial surveys (Ruttan 1974; Ruttan and Wooley 1974; C.M.M.S. and R. H. Jessup, Yukon Department of Renewable Resources, unpublished data). However, the vegetation in that area is relatively dense and might obscure fox dens. There are no records of Arctic Foxes breeding in the Yukon Territory further inland than the Yukon Coastal Plain (D. Mossop, Yukon Department of Renewable Resources, and D. Russell, Canadian Wildlife Service, personal communication) although arctic tundra extends south to about 100 km from the Beaufort Sea. Information currently available, therefore, suggests that Herschel Island is the primary area producing Arctic Foxes in the Yukon Territory.

Acknowledgments

The study was funded by the Northern Oil and Gas Action Program (NOGAP)(1984 and 1985), the Yukon Wildlife Management Program of the Inuvialuit Final Agreement (IFA)(1987-1990), and the Yukon Department of Renewable Resources, with field support provided by Polar Continental Shelf Project (1987-1990). We thank the Canadian Parks Service for allowing us to work in Ivvavik National Park. Our gratitude is also expressed to A. Angerbjorn, H. Jessup, A. Baer, J. Snyder and M. Waterreus for their assistance in the aerial surveys and/or field. T. Rodger drafted the figures. D. Milne typed, while A. Baer and an anonymous reviewer critically read the manuscript.

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Received 6 April 1992
Accepted 23 August 1993

A Re-evaluation of the Numbers of Migrant Semipalmated Sandpipers, *Calidris pusilla,* in the Bay of Fundy during Fall Migration

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Mawhinney, Kimberley, Peter W. Hicklin, and J. Sherman Boates. 1993. A re-evaluation of the numbers of migrant Semipalmated Sandpipers, *Calidris pusilla*, in the Bay of Fundy during fall migration. Canadian Field-Naturalist 107(1): 19–23.

We improved on the methodology to quantify the numbers of shorebirds in large roosts in the Bay of Fundy during fall migration. A series of photographs was taken of a large roost of Semipalmated Sandpipers where a 1 m^2 quadrat had been placed. The number of sandpipers inside the quadrat was counted from photographs to provide a measure of roosting density (/m^2) in a 1) loose or 2) compact flock, which was extrapolated to the area of the roost (in m^2). Our findings represent a 37–67% increase in the density figures, and our recalculation of the total numbers of shorebirds in the Bay of Fundy, is 1 122 000 to 2 200 000, as opposed to the earlier estimate of 800 000 to 1 400 000 birds.

Key Words: Semipalmated Sandpiper, *Calidris pusilla*, roost, Bay of Fundy, migration.

The upper Bay of Fundy has been designated a Western Hemisphere Shorebird Reserve and a Ramsar site (Wetland of International Importance) because it is a critical link in the annual southward migration of Semipalmated Sandpipers, *Calidris pusilla*, and other shorebird species. It is the final stopover area where sandpipers replenish their fat reserves before a 3–4 day non-stop, 4000 km transoceanic flight to their South American wintering grounds (McNeil and Cadieux 1972; McNeil and Burton 1977; Williams et al. 1977; Morrison 1984). Individual birds remain 10–15 days to accommodate the necessary fat reserves (Hicklin 1987). The southward migration through Fundy begins in early July and extends to mid-November, with the main passage of birds occurring between 20 July and 20 August (Hicklin 1987).

Previous estimates of the numbers of shorebirds using the upper Bay of Fundy ranged from 800 000 to 1 400 000, of which 95% were Semipalmated Sandpipers (Hicklin 1987). Those estimates were based on aerial surveys and ground censuses conducted during high-tide periods at the main roost sites. Population numbers calculated from data obtained by ground censuses were based on estimates obtained by one of two methods:

(i) an observer counted 500–1000 birds individually within part of a roosting flock and multiplied this by the number of similar-sized areas in the entire roost to estimate the total number of birds, or

(ii) the area occupied by roosting birds (m^2) was multiplied by 60 birds /m^2 to provide an estimate of the number of birds in large roosting assemblages (Hicklin 1987).

The density of 60 birds/m^2 was obtained by counting the number of birds inside an area estimated by Hicklin (1987) as about 10.5 m^2, using a single photograph of roosting birds. Based on new photographs with a clearly marked 1 m^2 quadrat , among roosting birds (Hicklin 1987), we suggest that Hicklin's (1987) techniques underestimated the numbers of roosting Semipalmated Sandpipers in the Bay of Fundy.

This paper presents a more accurate methodology to quantify the numbers of birds in large roosts where counting of individual birds is impractical. Many "counts" obtained in such situations are more or less subjective estimates, which vary greatly among observers. Over time, fluctuations in shorebird numbers in the Bay of Fundy, and other areas where numbers of roosting birds are very large, would be impossible to monitor without a standardized accurate censusing procedure such as we describe here.

Methods

The study area was located at Evangeline Beach, Kings County, Nova Scotia (45°08'N, 64°22'W). On 30 July 1991, a fluorescent orange 1 m^2 quadrat of 0.5 cm plastic tubing was placed on the shoreline where shorebirds roosted at high tide (Figure 1). Photographs were taken of birds inside and around the quadrat, using a 100mm or 300mm telephoto lens on a 35mm camera, by an observer situated above the roost on a steep hillside approximately 5m from the quadrat. The numbers of shorebirds roosting inside the quadrat were determined by projecting the slides on a large sheet of paper where each bird could be marked off when counted. The number of marks per sheet gave the number of birds per m^2.

FIGURE 1. A typical roost of shorebirds (mainly Semipalmated Sandpipers) at Evangeline Beach, Nova Scotia, 30 July 1991, showing location of m^2 quadrat. Photo by J. Deal.

Traditional roosting sites along Evangeline Beach were identified, and distances between landmarks (e.g., property lines, flag poles, etc.) along the shoreline were measured. The roosts were typically square or rectangular (Figure 1), and we noted the landmarks along the edges of the roost. The area occupied by each roost was calculated in m^2 and multiplied by the density of the shorebirds per m^2, obtained from the photographs, to provide an estimate of the numbers of roosting birds.

Results

In six photographs examined, the mean number of shorebirds was 82/m^2 ± 6.3 S.E. (N=6), ranging from 57 (Figure 2) to a maximum of 101 birds/m^2 (Figure 2c). However, the avoidance of the conspicuously marked quadrat is evident in all three photographs (Figures 2, 3, 4, and personal observation) and the density of 57 birds/m^2 was unrepresentative of the main flock. The higher densities of the roost not impinging on the marked quadrat (Figures 3 and 4) suggest that 82 birds/m^2 was a minimum estimate of density (i.e., a loosely packed roost) whereas 100 birds/m^2 was more nearly representative of the roost as a whole (Figure 4; and personal observation). Hence, Hicklin's earlier (1987) estimate of 60 birds/m^2 was an underestimate. This new mean and maximum represents increases of 37–67% in the numbers of roosting birds per m^2 compared to those of Hicklin (1987). Using this method, the number of roosting birds in a single roost occupying 1299 m^2 at Evangeline Beach 30 July 1991 was estimated to be 131 200 shorebirds at 101 birds/m^2 (Figure 1).

Hicklin (1987) calculated the population of Semipalmated Sandpipers migrating through the upper Bay of Fundy by adding up the average peak numbers of adults and immatures for each roost site (including miscellaneous small sites) and multiplying this total by 1.25 and 2.00 to account for turnover. This resulted in a range within which population numbers of Semipalmated Sandpipers should fall in any given year.

We recalculated the range in population numbers of Semipalmated Sandpipers as described in Hicklin (1987: Table 5) by increasing his estimates of "average peak numbers" of adults and juveniles by 37–67% and accounting for turnover as described above. As a result, the recalculated peak numbers of Semipalmated Sandpipers, when averaged over all major roost sites, ranged from 797 000 to 976 000 (Table 1). By adding immatures and accounting for turnover, the numbers of Semipalmated Sandpipers staging in the Bay of Fundy during the southward migration were estimated at 1 122 000 to 2 200 000 (Table 1).

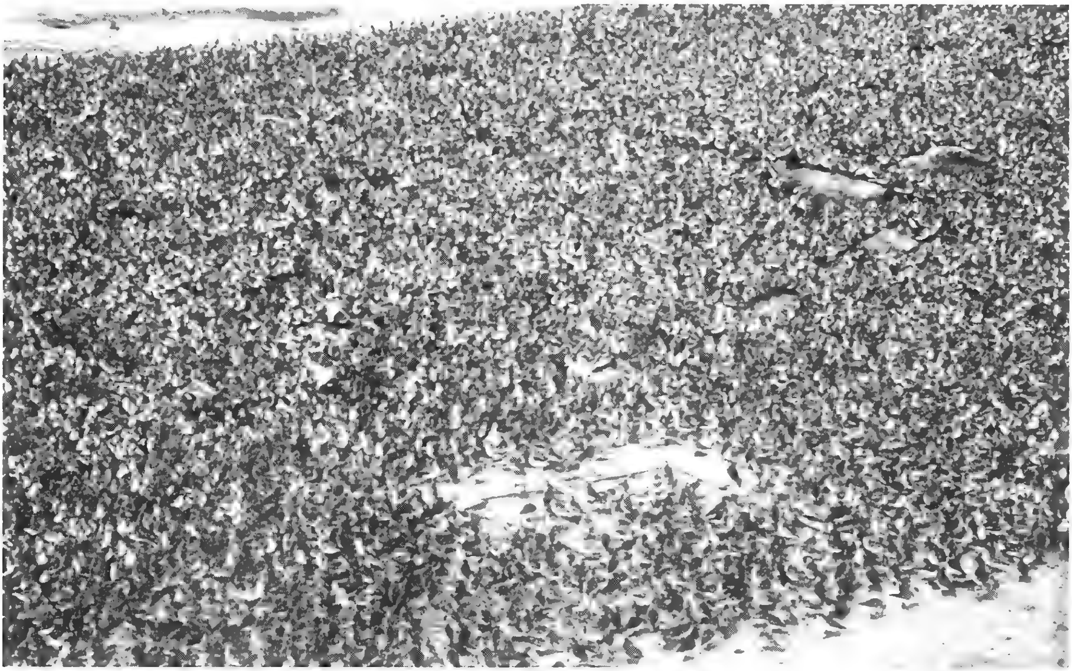

FIGURE 2. Semipalmated Sandpipers roosting in a 1 m^2 quadra: 57 birds/m^2. Photo by J. Deal.

FIGURE 3. Semipalmated Sandpipers roosting in a 1 m^2 quadra: 79 birds/m^2. Photo by J. Deal.

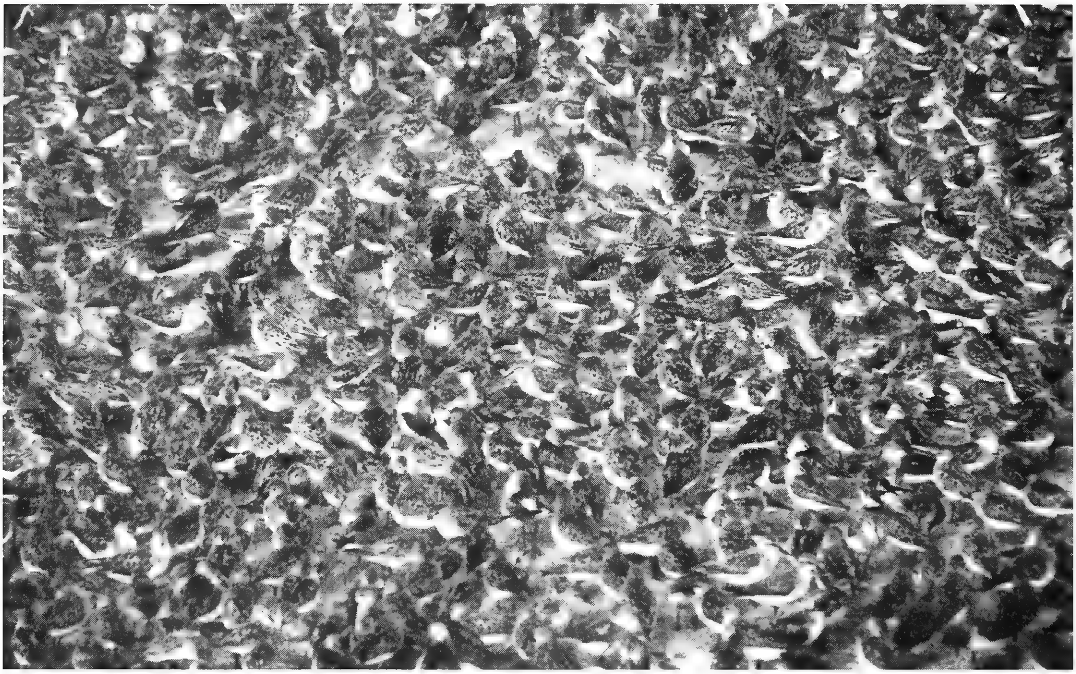

FIGURE 4. Semipalmated Sandpipers roosting in a 1 m^2 quadrat: 101 birds/m^2. Photo by J. Deal.

Discussion

Although species are not easily distinguished in large roosts of small calidrine sandpipers (Least, *Calidris minutilla*, Semipalmated, and White-rumped, *Calidris fuscicollis*, sandpipers, Sanderling, *Calidris alba*, and Semipalmated Plover, *Charadrius semipalmatus*), in the upper Bay of Fundy in late summer and fall, Semipalmated Sandpipers constitute 95% of the shorebirds in these roosts (Hicklin 1987). Our photographs indicated that densities of Semipalmated Sandpipers per m^2 ranged from 82 birds/m^2 in a loose flock, to 101 birds/m^2 in a compact flock. This represents densities which are 37-67% higher than those obtained by counting the number of birds inside a larger estimated area of 10.5m^2 (Hicklin 1987). Morrison and Ross (1989) estimated that the wintering population "of small shorebirds (mainly Semipalmated Sandpipers)" along the northern coast of South America was 2 000 000. Based on the present study, our estimates

TABLE 1: Recalculation of the population estimates of shorebirds in the upper Bay of Fundy during late summer and fall based on means of peak numbers 1974-1983, inclusive*, and where roosting densities range from 60 (Hicklin 1987) to 101 birds/m^2 (this study).

	Mean number of Semipalmated Sandpipers		
	60/m^2	82/m^2	101/m^2
Adults			
Evangeline Beach	31 000	41 333	51 667
Dorchester Cape	118 000	161 267	199 667
Mary's Point	161 667	220 945	269 445
Miscellaneous	273 220	373 401	455 367
Total Adults	583 887	796 946	976 146
+ Immatures (12.6%)	73 570	100 415	122 994
Total Adults and Immatures	657 457	897 361	1 099 140
Population Estimate	800 000- 1 400 000	1 122 000- 1 795 000	1 374 000- 2 200 000

* see Table 5 in Hicklin (1987).

of Semipalmated Sandpipers using the Bay of Fundy represent 50–95% of Morrison and Ross's (1989) estimated world total for this species.

The tendency to underestimate large flocks is especially prevalent with shorebirds and other birds that mass closely together on sand or water where the counting of individual birds is impossible (Arbib 1972). The reliability of estimating the number of birds in large flocks also varies widely among observers in relation to prior experience and training (Erwin 1982). The tendency to underestimate is common (Kaufman et al. 1949); and when numbers are especially large, the tendency to underestimate increases (Erwin 1982). With regards to conservation, estimating numbers accurately and consistently is especially important to monitoring species abundances over time. Using the simple method described in this paper would standardize the census techniques for Semipalmated Sandpipers in the Bay of Fundy. This same methodology can be applied to other species which congregate in large numbers in other regions.

Acknowledgments

We thank J. Deal for taking the photographs, H. Schoenfeld for assistance in the field, and S. Gilliland and R. D. Elliot for comments on the manuscript.

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Received 8 May 1992
Accepted 23 August 1993

Floristic composition, Phytogeography and Relationships of Prairies, Savannas and Sand Barrens along the Trent River, Eastern Ontario

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Catling, P. M., and V. R. Catling. 1993. Floristic composition, phytogeography and relationships of prairies, savannas and sand barrens along the Trent River, Eastern Ontario. Canadian Field-Naturalist 107(1): 24–45.

Fifteen remnants of natural vegetation of dry openings were grouped using Jaccard's coefficient and the unweighted pair group method and by principal coordinate analysis, revealing three major groups designated as limestone savanna, prairie, and sand barren. Analysis of presence, frequency and cover data from quadrats in 11 major associations gave the same result. Sites within the three major classes differed substantially in species presence, frequency and cover, and were not individually representative of the class. Each of the three vegetation classes had some unique species. The savannas, developing on fine textured soils shallowly overlying limestone bedrock, were dominated by shrubs including *Cornus racemosa*, *Symphoricarpos alba* and *Rhus aromatica*. The prairies were dominated by the prairie grasses *Andropogon gerardii*, *Schizachyrium scoparium* and *Sorghastrum nutans* and the shrubs *Prunus virginiana*, *Ceanothus herbaceus* and *Rhus aromatica*. Sand barrens occurred on soils with less organic matter than prairies and were dominated by *Carex siccata*, *Carex tonsa*, *Ceanothus americanus* and *Pteridium aquilinum*. Species present in all three major vegetation types included *Anemone cylindrica*, *Carex siccata*, *Carex pensylvanica*, *Poa compressa* and *Poa pratensis*. Approximately 40% of the prevalent species in Wisconsin prairie and savanna were present in equivalent vegetation types of the Trent valley, and numerous species present in the Trent sites were primarily western, some at their absolute eastern limit. There was also a well-defined southern floristic element. The sand barrens have less floristic affinity with the west. The western elements may have reached the area in early post-glacial times through migration eastward along a periglacial sidewalk or along the shores of post-glacial lakes or they may have moved eastward in a series of short dispersal steps between natural openings during the warmer and drier hypsithermal interval when open habitats were probably more widespread, or they may have been carried over great distances to the Trent valley by Indians. The limestone savanna was probably maintained by drought whereas a combination of drought and frequent fire were probably important in maintaining the prairies and sand barrens. Eight nationally and provincially rare species and numerous regionally rare species occur on the prairie sites, which are the easternmost in Canada. The limestone savannas and sand barrens are also rich in rare species, but to a lesser extent.

Key Words: Prairie, savanna, vegetation, Trent River, Ontario, Great Lakes region, phytogeography, rare species.

In southern Ontario, native vegetation of dry openings, including prairies, is of great interest in containing relatively large numbers of regionally, provincially, and nationally rare species. This type of vegetation has been largely destroyed in Ontario and elsewhere in North America, making the relicts additionally important in terms of protection of representative examples of a major natural ecosystem and maintenance of options for research.

Early survey records, diaries and historical studies, some cited by Alison (1976), Bakowsky (1988), Lumsden (1966) and Szeicz and MacDonald (1991), indicate widespread prairie and savanna over sandy soils in southwestern Ontario (Figure 1), and some of the prairies and savannas of this region are now documented (Bakowsky 1988; Langendoen and Maycock 1983; Faber-Langendoen 1984; Faber-Langendoen and Maycock 1987; Pratt 1979). Natural prairies in the central region of southern Ontario have also been documented (Reznicek 1980, 1983; Reznicek and Maycock 1983). There are historical records of an extensive prairie called the Rice Lake Plains even further northeast (Catling et al. 1992), and recent studies have shown that extensive prairie and savanna extended even further east to the northeastern limit of extensive sand prairie - sand savanna vegetation in the valley of the Trent River (Figures 1 and 2), but these easternmost sites have not yet been studied. Here we explore relationships among the dry natural openings along the Trent River so as to provide data for classification, and we document the floristic composition and discuss phytogeographic affinities. Specifically the purpose of the present work is to provide a more complete basis for future research concerning these dry openings and to provide the basic information necessary for a system of protected representative sites.

Methods

The study area, at the northeastern limit of extensive prairie and savanna vegetation in the Great Lakes region (Figure 1) extended along the Trent River from Rice Lake to the Bay of Quinte (Figure 2).

Aerial photographs and topographic maps were used to determine probable locations of natural openings, and all such localities were then surveyed. When assemblages of native species of open habitats were found, a list of all species present in the delineated prairie or savanna area was made. The sites (Table 1) ranged from a series of patches along road-

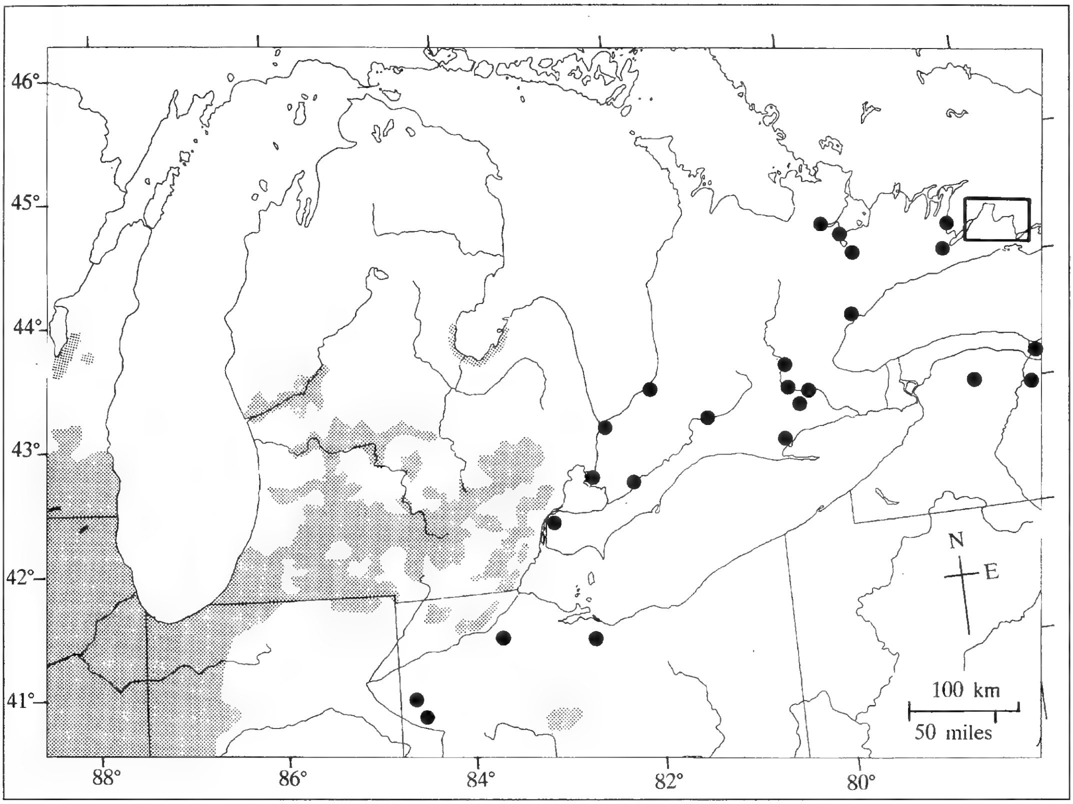

FIGURE 1. Location of the study area in the context of extensive sand prairie and associated savanna in the eastern Great Lakes region. Both shading and dots indicate areas of prairie and/or savanna. The study area is indicated by the rectangle in the upper right which corresponds to the area in Figure 2.

sides to larger areas of several acres. The size of prairie areas based on early survey descriptions and landscape features was also determined.

At 11 sites where there were few introduced species and little evidence of disturbance, we placed 10 to 15 m^2 quadrats along a transect, each quadrat

TABLE 1. Numbers, names and location (latitude, longitude and UTM grid reference) of sites studied.

Number	Name	N Latitude	W Longitude	UTM
1.	Glen Miller Savanna	44°09'30"	77°35'30"	31C/4 933923
2.	Batawa Savanna	44°10'20"	77°36'30"	31C/4 919937
3.	Game Club Prairie	44°13'20"	77°35'05"	31C/4 935995
4.	Ketcheson's Prairie	44°13'40"	77°35'11"	31C/4 935001
5.	New Overlook Prairie	44°14'00"	77°35'10"	31C/4 936003
6.	Overlook Prairie	44°13'50"	77°35'20"	31C/4 935494
7.	Plateau Prairie	44°13'30"	77°35'00"	31C/4 951999
8.	Sand Barren	44°15'10"	77°31'30"	31C/5 985027
9.	Sager Sand Barren	44°14'50"	77°32'40"	31C/4 970024
10.	Richardson's Prairie	44°14'14"	77°34'30"	31C/4 944010
11.	Sullivans Hill Prairie	44°14'40"	77°36'05"	31C/4 923024
12.	Stirling Sand Barren	44°16'00"	77°32'20"	31C/4 975045
13.	Healey Falls	44°23'00"	77°47'00"	31C/5 783175
			"	782171
			"	792160
14.	Hastings Prairie	44°18'05"	77°58'10"	31C/5 630096
15.	Hastings Savanna	44°17'50"	77°58'10"	31C/5 630092

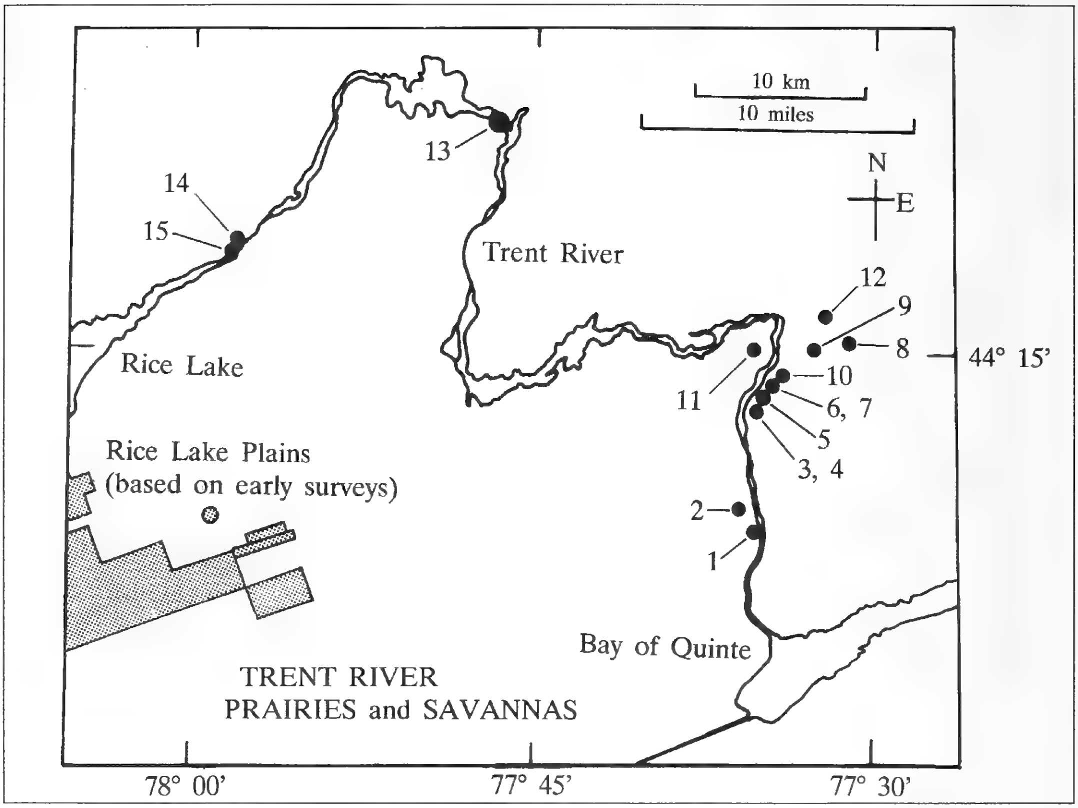

FIGURE 2. Location of remnants of prairie, savanna and sand barren at 15 sites along the Trent River. The numbers correspond to locations listed in Table 1.

being 3 m apart. If new species were still being added by the seventh quadrat, we used 15 quadrats instead of 10. Cover was estimated as one half of the surface area in dm^2 of each species in the quadrat. The cover and frequency of each species in each association was then expressed as a percentage (of total cover of all species and of the number of quadrats respectively).

The coefficients used and their appropriate application in ecological studies are discussed by Legendre and Legendre (1983) and Pielou (1984). All analyses were done with NTSYS-pc version 1.6 (Rolfe 1990). Relationships between sites were explored by clustering, using the unweighted pair group method with arithmetic averages (UPGMA), of Jaccard's, Russell and Rao, and Kulzynski coefficients derived from species presence/absence data. A principal coordinate analysis (PCO) was also done to complimentarily reduce the dimensionality of the data. A minimum spanning tree (MST) was superimposed on the PCO to help compensate for distortion. Relationships between major associations were explored with UPGMA clustering of Bray-Curtis distance and Canberra Metric coefficients derived from percent frequency and percent cover data.

The openings were evaluated in terms of phytogeography and floristic significance through reference to vegetation descriptions (Curtis 1959), distributions reported in standard floras (Fernald 1950; Gleason and Cronquist 1991) and published maps (e.g. Argus and White 1982, 1983; Argus and Keddy 1984; Pryer and Argus 1987), and other sources as noted in the text. Nomenclature generally follows Morton and Venn (1990). Specimen vouchers for this study are at the Agriculture Canada herbarium in Ottawa (DAO) with some duplicates at the University of Michigan (MICH).

Results

Relationships between sites and major vascular plant associations

Clustering of sites based on Jaccard's, Russell and Rao and Kulzynski coefficients separated sites 8, 9 and 12 from the remainder and made sites 1, 2, 13 and 15 also a discrete group (Figure 3 above). A reduction in the dimensionality of the data on to two axes using PCO revealed the same three groupings

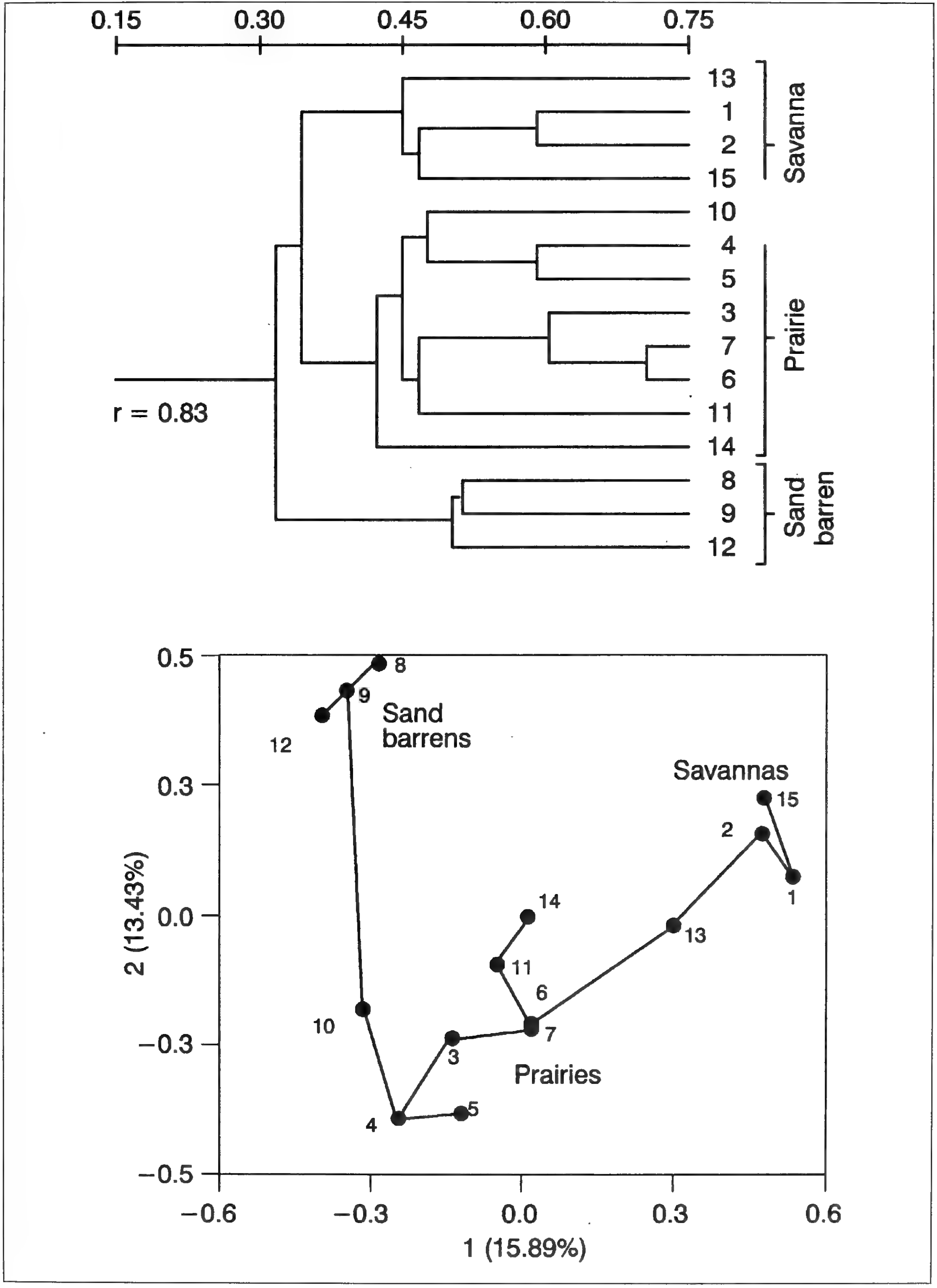

Figure 3. Relationships among 15 natural openings along the Trent River portrayed by a UPGMA clustering (above) and principal coordinate analysis with minimum spanning tree (below), both derived from a matrix of Jaccard's coefficients from species presence/absence data from species lists.

(Figure 3 below). The first and second axes accounted for 15.9 and 13.4% of the variation respectively with subsequent axes accounting for less than 9.3%. The first axis separates openings on deep sand and till at relatively high elevation (left-hand side) from those on finer textured Farmington loam soils (Gillespie et al. 1962), with pH 7.0 to 7.5 and derived from, and shallowly overlying, flat limestone (Trenton series) plains on lowlands adjacent to the river. We refer to the latter sites as savannas.

The term "savanna" has been applied loosely to prairies with trees. While a precise definition is probably not advantageous, we use the term in the approximate sense of Curtis (1959) where tree canopies cover less than 50% of the surface but tree density far exceeds one mature tree per acre (Figure 4a). The savanna identified here is not the kind of savanna related to prairies developing on deep sand and connecting sand prairies with sandy oak woods. This kind of savanna may well have existed along the Trent in association with the sand prairies, but no examples were found. The savannas identified here actually represent a connection between alvar and Bur Oak - Shagbark Hickory (*Quercus macrocarpa - Carya ovata*) woodland on shallow soil over limestone. To reflect this we refer to them as limestone savannas.

The openings on deep sand and till, mostly soils classified as Bondhead sandy loam (Gillespie et al. 1962), were once much more extensive and essentially treeless (Rankin 1832). The existing remnants are too small to be differentiated from savanna using the criteria applied by Curtis (1959), but they conform to prairie in being open areas, dominated by graminoid species (Figure 5a, b) of which more than, one half are grasses. This and the probable absence of trees on their larger precursors, as well as their composition (see below) justifies their designation as prairies. The fragments of undisturbed open plant communities at Healey Falls (site 15) have components of both prairie and savanna, explaining their intermediate position in Figure 2.

The second axis on the PCO diagram (Figure 3 below) separates sites with little organic material and relatively lower pH of 6.0 to 7.0 (above) from those with relatively more organic material and higher pH values of 7.5 to 8.0 (below). The former appear as a distinct cluster on the phenogram (Figure 3 above). These we refer to as "sand barrens" (Figure 5c). In all cases they occurred on Bondhead sandy loam or Tioga sandy loam (Gillespie et al. 1962).

A similar pattern of three groupings is evident in clustering based on species presence/absence data in major associations (Figure 6), where Jaccard's, Russell and Rao, and Kulzynski coefficients all gave a very similar result. All of the phenograms including different coefficients have cophenetic correlations exceeding 0.8 and are thus good representations. The PCO diagram with MST based on a matrix of Jaccard's coefficients clearly shows the three major groupings of associations: sand barrens, prairies and savannas.

The same three classes as resulting from analysis of presence/absence data for the 11 associations were also produced by analysis of percentage frequency data (Figure 7), although using the Bray-Curtis distance (Figure 7 above) the sand barrens were the most distinctive group, whereas the savannas were the most distinct group using the Canberra Metric (Figure 7 below). The Canberra Metric phenogram, with a cophenetic correlation of 0.88, is a slightly better representation.

The trend toward three groups was also evident, although less obvious, in the analysis of percentage cover data. In both the phenograms from clustering the Bray-Curtis distance and Canberra Metric, the sand barrens are distinct. The savannas are less distinct, being grouped with the prairies using the Bray-Curtis distance and being individually distinct using the Canberra Metric. The cophenetic correlations are 0.89 for the Canberra Metric phenogram and 0.81 for the Bray-Curtis distance phenogram, thus making them both good representations, but the former clearly the better fit to the original distance matrix.

To summarize these analyses, the dry natural openings along the Trent River can be classified into three distinct groups; sand barrens, prairies and limestone savannas. The very substantial differences in all characterististics, i.e., presence/absence, percentage frequency and percentage cover, between sites within each class indicate clearly the sites are not individually representative of the class. This means that it is necessary to protect more than one site in order to protect the class within the region, and that conclusions about the class should be based on consideration of more than one site. These three classes are slightly more distinctive in terms of species presence/absence than in terms of percentage frequency or percentage cover of species, evidently because of relatively greater within-class differences in the latter two characteristics. Despite substantial variation between sites within classes, class existence and site relationships are fairly consistent between characteristics and coefficients. For example sites 3 and 6 are most closely related to each other in all three characteristics and using different coefficients (Figures 3, 6, 7, 8). The similarities in results predominate over the differences, the most important differences being in the most distinctive class, i.e., sand barren or savanna, and in site relationships within these classes, i.e., site relationships within sand barren or savanna (Figures 3, 6, 7, 8).

Floristic composition

On the fifteen sites where remnants of native vegetation of dry openings occurred, a total of 171

FIGURE 4. A, Savanna at Glen Miller with herb-shrub layer dominated by *Carex pensylvanica* and *Symphoricarpos alba*. The trees are *Carya ovata*, *Quercus macrocarpa* and *Quercus muehlenbergii*. B, Sward of *Bouteloua curtipendula* with *Ranunculus fascicularis* on top of a limestone cliff above an old channel at Healey Falls. The trees are *Juniperus virginiana* and *Quercus macrocarpa*.

native species were recorded. Many of these were confined to one of the three major vegetation types: savanna, prairie and sand barren. However, a few species occurred in all, or almost all sites (Appendix Table 1). Included in this group were Long-fruited Anemone (*Anemone cylindrica*), Sedge (*Carex siccata*), Sedge (*Carex pensylvanica*), New Jersey Tea (*Ceanothus americanus*), Grey Dogwood (*Cornus racemosa*), Canada Blue Grass (*Poa compressa*) and Kentucky Blue Grass (*Poa pratensis*).

Cornus racemosa, *Carex siccata*, *Carex pensylvanica* and Snowberry (*Symphoricarpos albus*) (in order of descending cover values) were dominants on Hastings Savanna, while at Glen Miller Savanna (Figure 4a) *Symphoricarpos albus* comprised most of the cover, followed by Fragrant Sumac (*Rhus aromatica*), *Carex pensylvanica*, Northern Bedstraw (*Galium boreale*), Woodland Sunflower (*Helianthus divaricatus*) and *Cornus racemosa*. Although these sites had some dominants in common, they differed considerably in composition (Appendix Tables 2 and 3). *Carex pensylvanica, Cornus racemosa* and *Symphoricarpos albus* have their highest percentage frequency and percentage cover on the savannas (Appendix Tables 2 and 3). Species unique to the savannas include Grove Sandwort (*Arenaria lateriflora*), Large-leaved Aster (*Aster macrophyllus*), Cooper's Milk-vetch (*Astragalus neglectus)*, Canada Brome (*Bromus pubescens*), sedges (*Carex cephalophora*, *Carex rosea*, and *Carex umbellata*), Robin's-plantain (*Erigeron pulchellus*), *Galium boreale*, White Avens (*Geum canadense*), Round-lobed Hepatica (*Hepatica americana*), Bottle-brush Grass (*Hystrix patula*), Hairy Honeysuckle (*Lonicera hirsuta*), Horse Gentian (*Triosteum perfoliatum*) and Prickly Ash (*Zanthoxylum americanum*).

Different prairie sites were dominated by different species of the prairie grasses including Big Bluestem (*Andropogon gerardii*), Little Bluestem (*Schizachyrium scoparium*), Indian Grass (*Sorghastrum nutans*), Northern Dropseed (*Sporobolus heterolepis*) and Porcupine Grass (*Stipa spartea*), and/or the shrubs *Ceanothus americanus*, Choke Cherry (*Prunus virginiana*) and

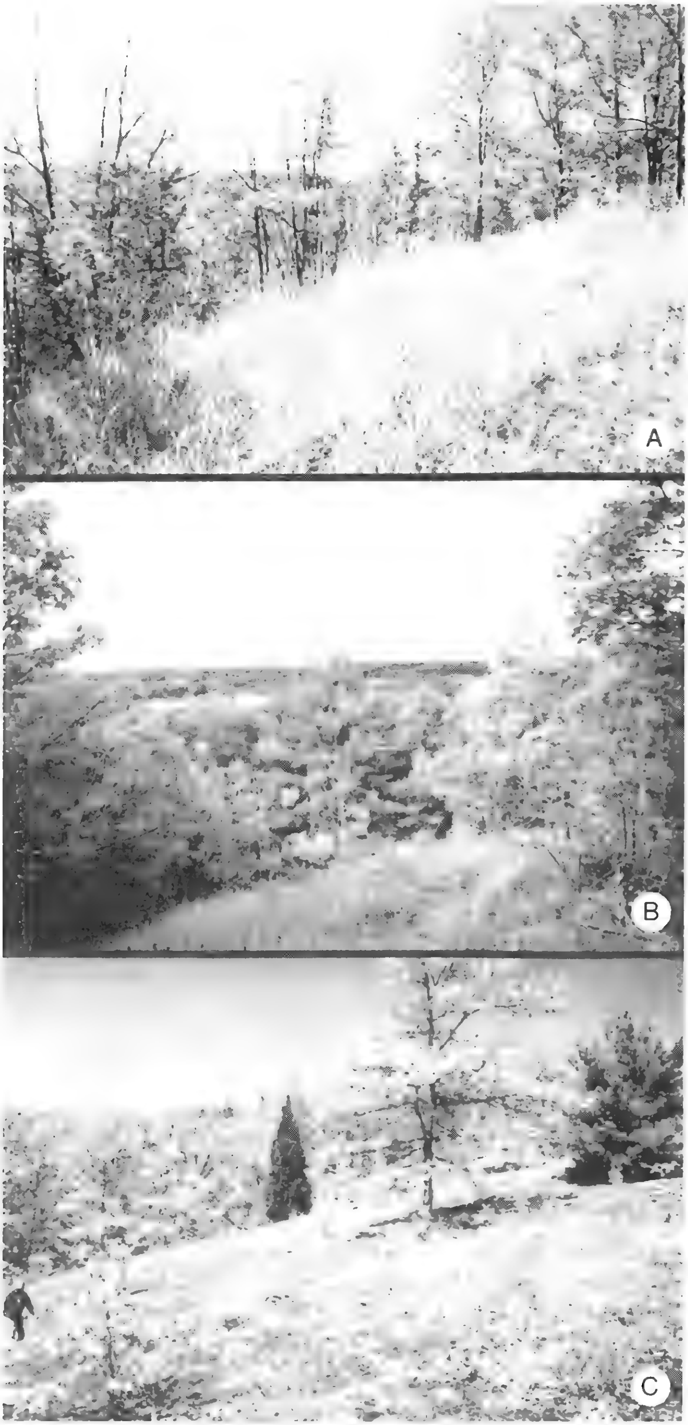

FIGURE 5. Prairies and a sand barren in the Oak Hills. A, Richardson's prairie dominated by *Andropogon gerardii*, surrounded by *Quercus velutina* and *Q. rubra*. B, New Overlook prairie with the Trent River in the background. The herb-shrub layer is dominated by *Andropogon gerardii* and *Sporobolus heterolepis*. The surrounding trees are *Pinus strobus*, *Quercus velutina* and *Populus grandidentata*. C, Sand barren domiated by *Carex tonsa*, *Ceanothus americanus* and *Pteridium aquilinum*. The trees are *Juniperus virginiana*, *Pinus strobus* and *Quercus velutina*.

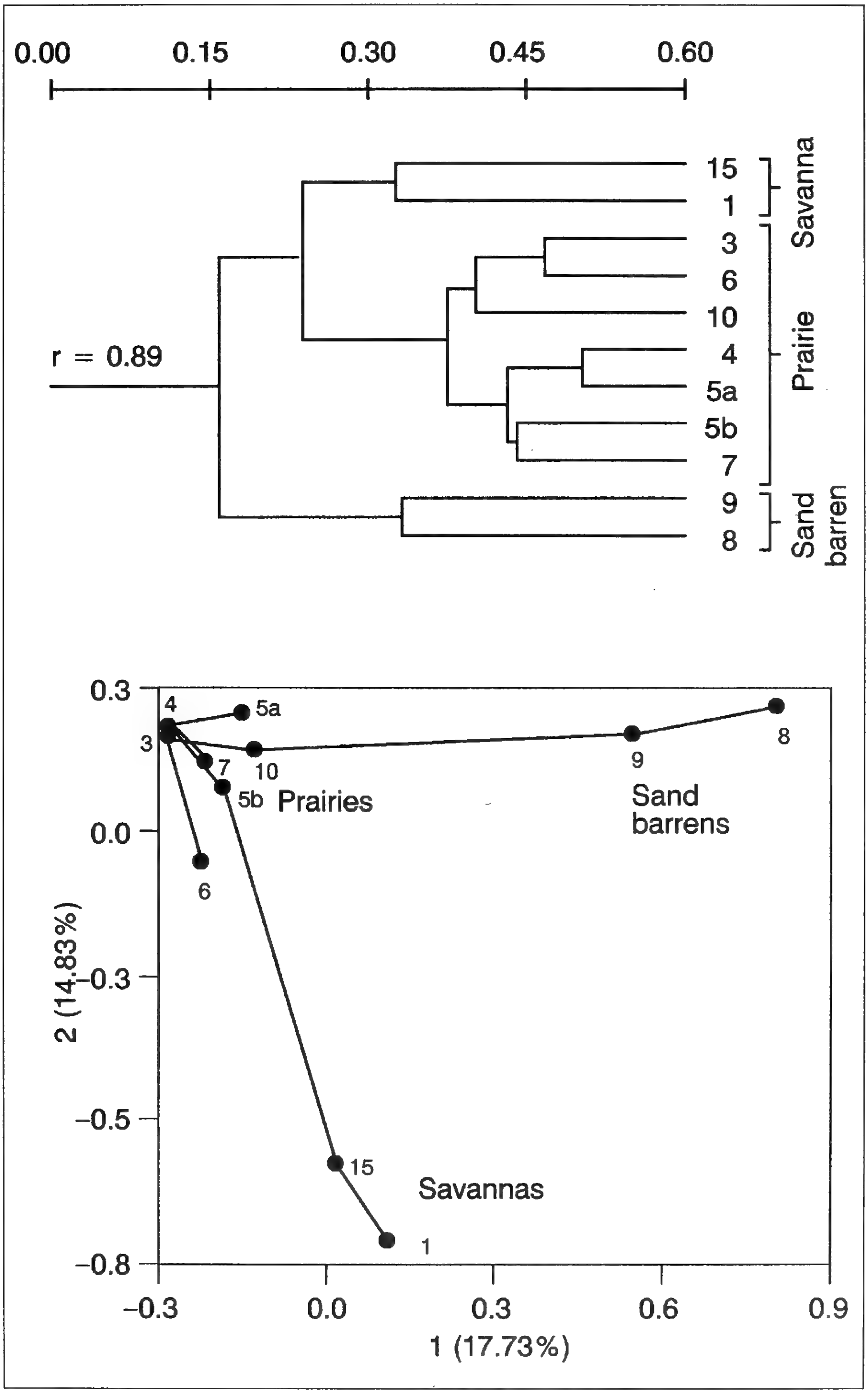

FIGURE 6. Relationships among 11 major associations in 10 natural openings along the Trent River portrayed by a UPGMA clustering (above) and principal coordinate analysis with minimum spanning tree (below), both derived from a matrix of Jaccard's coefficients from species presence/absence data from quadrats.

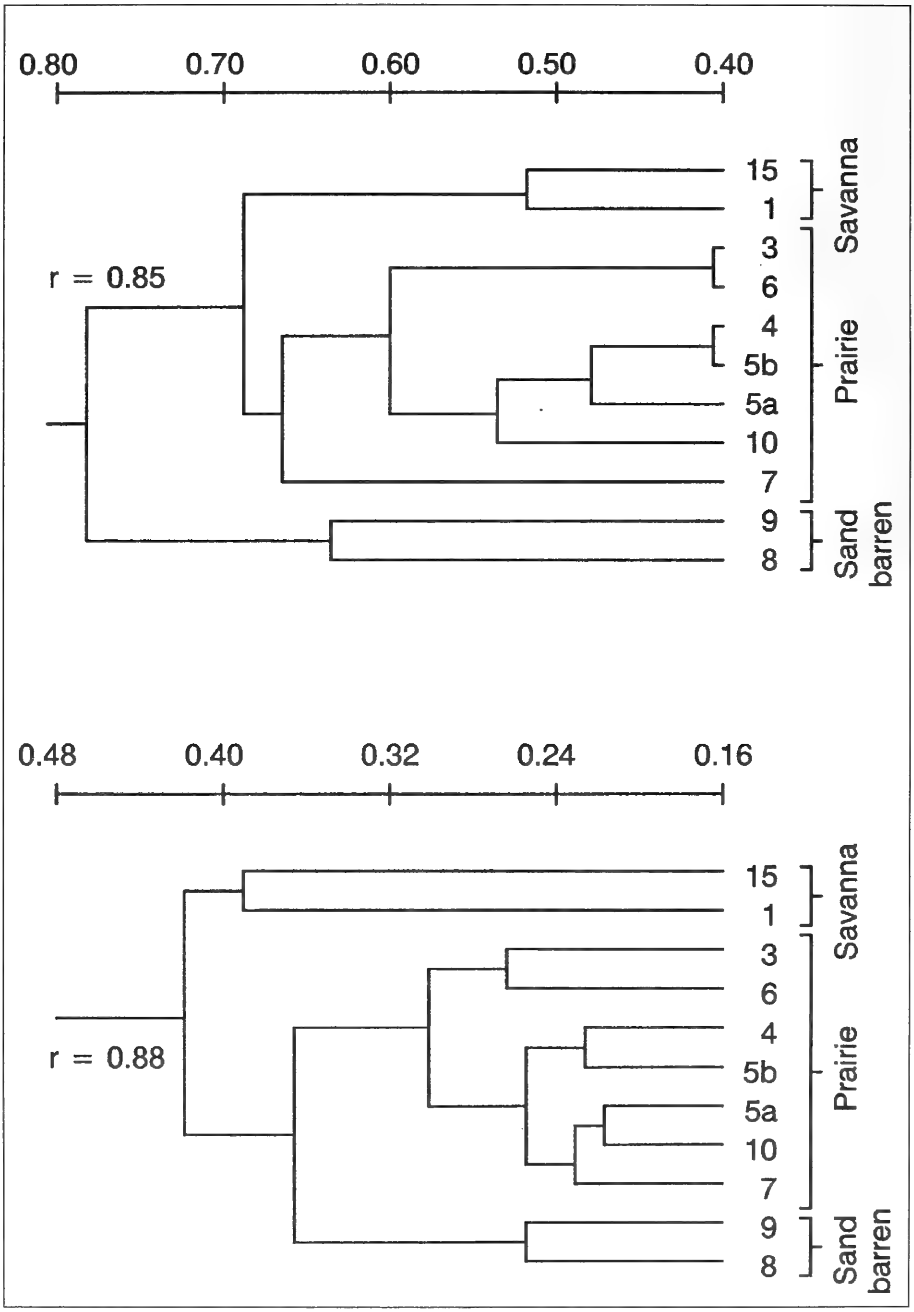

FIGURE 7. Relationships among 11 major associations in 10 natural openings along the Trent River portrayed by a UPGMA clustering derived from a matrix of Bray-Curtis distance coefficients (above) and Canberra Metric coefficients (below), both based on percentage frequency data.

Symphoricarpos albus. In addition to these dominants, species frequent in the prairie sites included *Anemone cylindrica*, Butterfly Milkweed (*Asclepias tuberosa*), Sky-blue Aster (*Aster oolentangiensis*), *Carex pensylvanica*, *Carex siccata*, Bittersweet (*Celastrus scandens*), Wild Bergamot (*Monarda fistulosa*), *Poa com-*

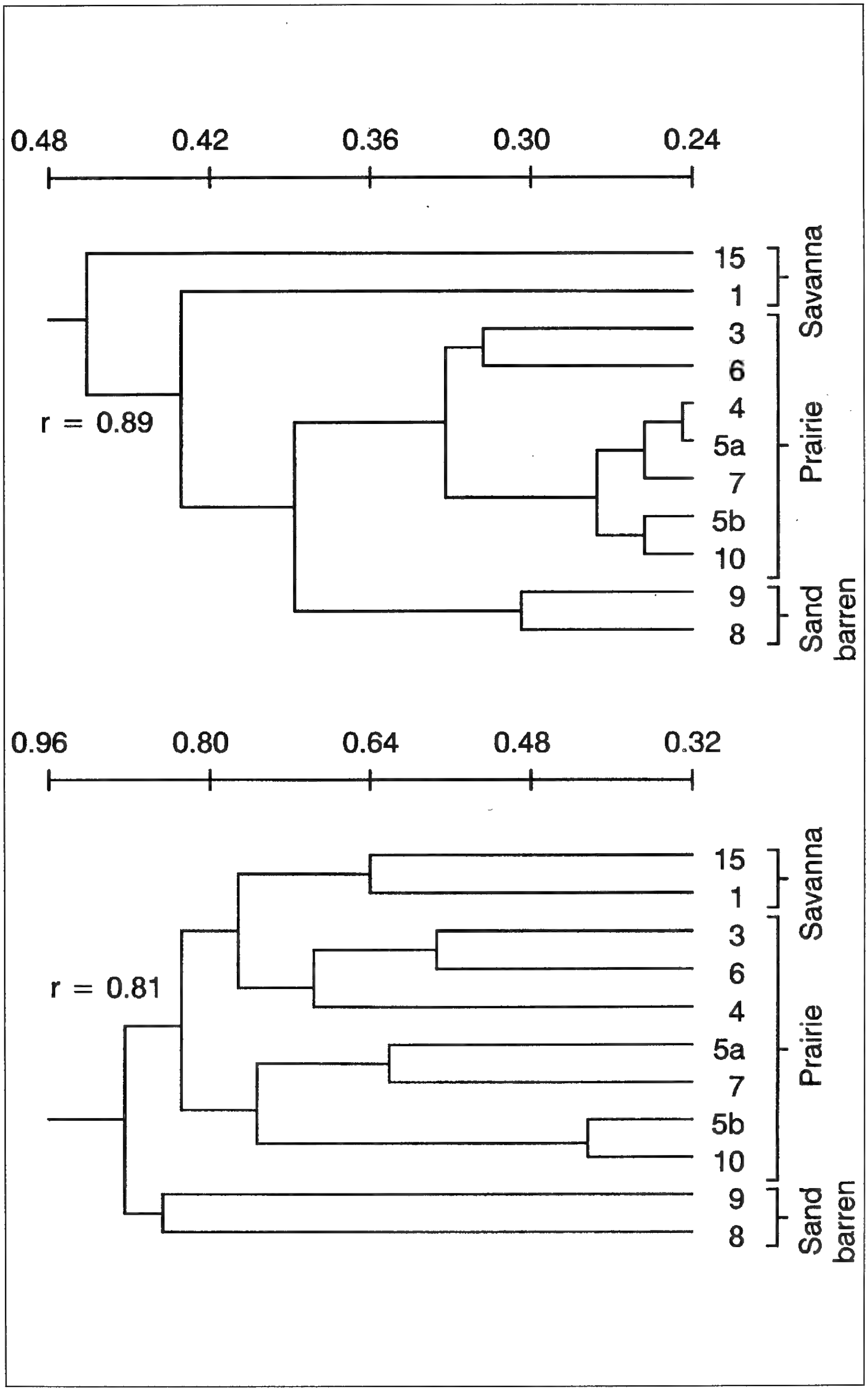

FIGURE 8. Relationships among 11 major associations in 10 natural openings along the Trent River portrayed by a UPGMA clustering derived from a matrix of Bray-Curtis distance coefficients (above) and Canberra Metric coefficients (below), both based on percentage cover data.

pressa, *Poa pratensis*, Poison Ivy (*Rhus radicans*), False Solomon's Seal (*Smilacina stellata*), Grey Goldenrod (*Solidago nemoralis*), and Heath Aster (*Virgulus ericoides*). Among the species confined to the prairie sites were Kalm's Brome (*Bromus kalmii*), sedges (*Carex muhlenbergii*, and *Carex richardsonii*), *Ceanothus herbaceus*, Dwarf Hackberry (*Celtis tenuifolia*), Prairie Smoke (*Geum triflorum*), Muhly Grass (*Muhlenbergia glomerata*), Prairie Buttercup (*Ranunculus rhomboideus*), Early Buttercup (*Ranunculus fascicularis*), Northern Dewberry (*Rubus flagellaris*), Hairy Goldenrod (*Solidago hispida*), *Sporobolus heterolepis* and *Stipa spartea*.

The separation between prairie and sand barren, although fairly clear in the present analyses, is less clear when blend zones and examples from elsewhere in Ontario are taken into account. Some dense stands of *Andropogon gerardii* grade into luxuriant *Carex siccata* (e.g., site 9) which then grades into a sparse cover with an increase of sedge (*Carex tonsa*), mosses, lichens and bare sand (e.g. site 8). Sometimes the dominance of species changes gradually with dominance of *Carex siccata* being replaced by dominance of either *Carex tonsa*, Panic Grasses (*Dichanthelium columbianum*, *Dichanthelium villosissimum* var. *praecocius*, *Panicum depauperatum*) or Poverty Oat Grass (*Danthonia spicata*), with little change in species frequency. The prairie and sand barren sites had many species in common that did not occur on the savanna sites including *Andropogon gerardii*, Nut Grass (*Cyperus lupulinus*), *Dichanthelium columbianum*, *Dichanthelium villosissimum* var. *praecocius*, Black Oak (*Quercus velutina*), *Schizachyrium scoparium*, *Sorghastrum nutans*, and Rock Spikemoss (*Selaginella rupestris*).

Dominants on the sand barren sites included Low Bindweed (*Calystegia spithamea*), *Carex siccata*, *Carex tonsa*, *Ceanothus americanus*, Panic Grass (*Dichanthelium depauperatum*), *Poa compressa*, and Bracken (*Pteridium aquilinum*). Bryophytes such as *Polytrichum peliferum*, and lichens such as *Cladina* spp. were also important in percentage cover. Species found only on the sand barrens included *Carex tonsa*, *Dichanthelium depauperatum*, Frostweed (*Helianthemum canadense*), and Mountain-rice (*Oryzopsis pungens*).

Since the sites were selected on the basis of native species dominance, the introductions are few and relatively unimportant. The most frequent introductions in the study sites were Common St. John's-wort (*Hypericum perforatum*), Toadflax (*Linaria vulgaris*), Tartarian Honeysuckle (*Lonicera tartarica*), Common Buckthorn (*Rhamnus cathartica*), and Sheep Sorrel (*Rumex acetosella*) (Appendix, Tables 2 and 3).

Discussion

Phytogeographic relationships of the vegetation

The natural openings along the Trent have much in common with similar vegetation types in the midwest where they were once very extensive. For example 33–42% (30 species) of the prevalent species of Wisconsin dry to mesic prairies, which covered two million acres in the southwestern portion of the state (Curtis 1959), are present in the Trent valley prairies. Included here are various dominant and/or frequent species of the Trent sites such as *Anemone cylindrica*, *Andropogon gerardii*, *Aster oolentangiensis*, *Ceanothus americanus*, *Geum triflorum*, Bush Clover (*Lespedeza capitata*), *Monarda fistulosa*, Prairie Cinquefoil (*Potentilla arguta*), *Solidago nemoralis*, *Sorghastrum nutans*, *Sporobolus heterolepis*, and *Stipa spartea*.

Likewise 40% of the prevalent species in Wisconsin oak opening savannas, which once occupied 5.5 million acres in that state, also occur in the Trent savannas. This includes dominant and/or frequent species of the Trent sites such as *Carex pensylvanica*, *Ceanothus americana*, *Cornus racemosa*, *Galium boreale* and *Monarda fistulosa*.

The Trent sand barrens include 10-28% of the prevalent species of Wisconsin sand barren and bracken grassland (respectively), including *Calystegia spithamea*, Slender Wheat Grass (*Elymus trachycaulus*), *Helianthemum canadense*, *Lespedeza capitata*, Rough-leaved Mountain-rice (*Oryzopsis asperifolia*), *Pteridium aquilinum*, *Selaginella rupestris* and *Solidago nemoralis*.

Thus natural openings along the Trent are evidently very similar to their once extensive, western counterparts and this is particularly true of the prairies and savannas. The estimated similarity would be even greater if all species, rather than just the prevalent Wisconsin species, were taken into account, but actual similarity then becomes more difficult to evaluate.

Not surprisingly, the Trent prairies have more in common with the closer pairies of the eastern Great Lakes region. Sixty-two percent (29 species) of the species of prairie affinity listed for prairies of the Lake Simcoe region (Reznicek 1983) also occur in the Trent Valley Prairies. Sixty-five percent (32 species) of the species of prairie and savanna affinity listed by Varga (1989) for the Humber Plains also occur in the Trent prairie sites.

Floristic affinity of the species

Not surprisingly, several of the species present in the Trent sites are widespread in midwestern and/or western North America, but rare northeastward. *Aster oolentangiensis*, *Dichanthelium villosissimum* var. *praecocius* (Reznicek 1984), Panic Grass (*Panicum perlongum*, Reznicek 1984) and *Ranunculus rhomboideus* are all at the eastern limits of their North American distribution in the Trent valley. These species are widespread in the west extending narrowly eastward in the Great Lakes region. Other species including Juneberry (*Amelanchier alnifolia* var. *compacta*), *Astragalus* *neglectus*, Side Oats Grama (*Bouteloua curtipendula*, Reznicek 1984), *Carex siccata*, *Carex richardsonii*, Narrow-leaved New Jersey Tea (*Ceanothus herbaceus*), Spike-rush (*Eleocharis compressa*), *Galium boreale*, White Prairie Gentian (*Gentiana flavida*, Rupert et al. 1987), *Geum triflorum*, Flax (*Linum sulcatum*), *Quercus macrocarpa*, *Ranunculus fascicularis* (Duncan 1980), Rough Dropseed (*Sporobolus asper*, Reznicek 1984), *Sporobolus heterolepis* (Reznicek 1984) and *Stipa spartea* (Reznicek 1984), have this primarily western pattern but extend further east, where they are nevertheless generally rare. There is clearly a well developed western element in the flora of the Trent natural openings.

The other major phytogeographic affinity is with the south. Species in this category often occur in the midwestern United States as well as to the south. Species such as *Celtis tenuifolia* (Wagner 1974; Little 1977), Rue-anemone (*Anemonella thalictroides*, Soper et al. 1963), Arrow-leaved Aster (*Aster urophyllus*), *Carya ovata* (Cody 1982), American Hazel (*Corylus americana*, Soper and Heimburger 1982), Chinquapin Oak (*Quercus muhlenbergii*, Fox and Soper 1954), and *Quercus velutina* (Fox and Soper 1954) are at their northern or northeastern limit. Other species including *Asclepias tuberosa*, *Ceanothus americanus* (Soper and Heimburger 1982), Rush (*Juncus secundus*, Brownell and Catling 1987), Red Cedar (*Juniperus virginiana*, Little 1971), *Lespedeza capitata* (Cody 1982), and Yellow Pimpernel (*Taenidia integerrima*, Cody 1982) are essentially southern or southern and midwestern reaching their northern limit in the Ottawa valley. A southern floristic element is well documented in the eastern Lake Ontario area (Soper 1954; Thaler and Plowright 1973; Cody 1982), and within this region the presence of southern elements along the Trent is not surprising given the openness of the sites and the south or west exposure of many of them, which would result in warmer than normal microclimate for the region.

Extent and maintenance of openings along the Trent

Open-grown and well-spaced oaks at various points along the river suggest natural openings but the shrub and herb layer is dominated by introduced European weeds such as *Rhamnus cathartica*, *Lonicera tatarica*, Smooth Brome (*Bromus inermis*) and Timothy (*Phleum pratense*). There are also numerous examples of *Juniperus virginiana* savanna but these invariably have an introduced herb layer and are evidently a succesional stage following abandonment of land previously used for grazing. It appears that destruction of native vegetation of limestone savanna by heavy grazing of livestock leads to colonization and replacement by weedy alien species. The extent of degraded limestone savanna suggests that savanna of the type described here on the basis of two well preserved remnants was once frequent, and perhaps even continuous along much of the Trent River. Although the limestone bedrock along the Trent is near or at the surface, it is generally covered with at least several inches of soil and the rock degrades contributing parent materials for a substrate that can support trees. This probably explains the absence of well developed alvar communities which are elsewhere in Ontario associated with *Quercus macrocarpa* savannas over limestone. The limestone savanna soils are wet in the spring because water is held up temporarily by the underlying rock and bound by the fine soil texture, but the limestone rock is porous and the water table is well below the rock surface in summer. Since the soils are shallow they dry readily. Dead trees (Figure 4a) on the limestone savannas studied attest to the effect of periodic drought, which has probably been the primary factor in their maintenance.

Prairie including both grasses, sedges and shrubs in various combinations was also probably frequent along the Trent. A few old open-grown *Quercus velutina* with large spreading branches may have developed in native prairie, but there is good evidence from the early survey records that large portions of the Oak Hills area (sites 3-12, excluding 11) were open in presettlement times, and this area may well have been the most extensive prairie along the lower portion of the Trent River. Although his descriptions are not very detailed, Rankin's survey notes of 1832 descibe 9 km^2 of the Oak Hills area as "level, barren, sandy plain" and "sandy plain with Oak bushes". The term "barren" probably referred to a lack of trees rather than the lack of any vegetation, and "plains" at that time certainly meant treeless areas. These were probably grass, sedge and shrub prairies with scrub oak (*Quercus alba* and *Q. velutina*). The extent to which the area was a sand barren or a prairie may never be known, but there is reason to suspect that both vegetation types were represented based on currently surviving remnants. Furthermore there is reason to suspect, on the basis of variability in currently surviving remnants, that the prairie was a mosaic of patches dominated by different species of grasses and shrubs, most of which nevertheless occurred over the entire area.

Rankin did not survey the entire Oak Hills area, but considering the extent of well-drained sandy soil continuous with the areas he described as "plains", it appears that the Oak Hills plains may have extended over an area of 30 km^2. A reasonable minimum would be the actual area of lots reported as "plains" which is 9 km^2. This was a relatively large area of probable sand prairie and sand savanna by Canadian standards, although it could be readily matched in many parts of New York State and southern New England (Thompson and Smith 1970). In presettlement times it was probably maintained by a combination of periodic drought and fires. Fires may have been relatively frequent for thousands of years as a consequence of both accidental and deliberate burning of vegetation by Indians who occupied well-known sites immediately below the Oak Hills on the Trent River (e.g., Richardsons Point). Extensive areas around Indian villages were burned and cleared of trees and shrubs (Day 1953), and a relationship exists between the occurrence of prairies in the eastern Great Lakes area and sites used continuously by Indians (e.g., Reznicek 1983). The rare plant species, including several western elements at or near to their eastern limit, are remnants of a prairie vegetation type that was probably once extensive along the Trent. With cessation of fire, much of the area that was not cultivated gradually returned to woodland where the prairie flora could not survive. Only in the driest sites where trees could not establish were the drier phases of the prairie maintained. On the edges of and within several of the surviving prairie remnants dead and dying trees are evident (Figures 5a, b). Cultivation and heavy grazing also destroyed the prairie landscape as did subsequent erosion and reforestation.

Origin of the Trent Prairies

Naturally one wonders how provincially rare plants, characteristic of western North America, could reach an isolated opening less than one quarter of an acre in extent. However, when one accepts that the small isolated openings are remnants of a once extensive prairie, the explanation is less of a problem. Although probably not continuous, these prairies and other southern Ontario prairies and savannas were separated from each other by distances of less than 50-100 miles, and those in the extreme southwest were separated by even shorter distances from a series in Michigan and Ohio continuous with the prairie peninsula and midwestern savanna belts (Nuzzo 1986; Transeau 1935). Prairies may have occupied most of the sandy sites along the Trent River and may have been nearly continuous along the valley slopes. The extensive Rice Lake Plains prairie existed approximately 25 km to the west of the Oak Hills and extended to the Trent River at the northwest end of Rice Lake (Catling et al. 1992). It is merely a series of short dispersal steps to spread seed by wind, mammals, or birds from the west to a "large target" prairie on the Trent River. Such dispersal through a series of patches of prairie vegetation could have taken place at various times, but particularly during the warmer and drier hypsithermal interval (Deevey and Flint 1957), when prairie patches would likely have reached their maximum extent. Prairie vegetation may also have spread along the shores of the Great Lakes during the hypsithermal interval (Reznicek 1983).

It is also quite possible that prairie vegetation was widespread along the receding shores of the early post-glacial precursors of the Great Lakes, just as it is currently on some dune systems along the present shores. Receding water levels 11 000–10 000 years B. P. (Dyke and Prest 1987) would have made extensive habitats available and some prairie flora may date to this early post-glacial period. Regardless of lakeshore dune habitats, there was undoubtedly a pathway of open habitat from the west in front of the receding glacier. This pathway may have varied in width and continuity during the full glacial period as a consequence of regional and temporal differences in movement of the ice and impoundment of water in front of the ice, but at least during the melting and recession it must have been a relatively broad "sidewalk" along which western flora could have expanded eastward (Marie-Victorin 1938; Schmidt 1938).

The valley of the Trent has been occupied by man for several thousand years (Kidd 1957) and it was undoubtedly an ancient Indian trail, an overland portion of which is shown on the on the Collins-Holland map of 1790 (Frost 1973). Numerous Indian sites, some 2000 years old, are scattered along its length, and regardless of its former turbulence, as emphasized by Frost (1973), it was undoubtedly travelled extensively. Some of the material recovered from Indian sites along the route originated thousands of miles to the west and midwest. Examples are freshwater pearls from the Mississippi and Obsidian from the foothills of the Rockies (Kidd 1957). It is not unreasonable to suspect that some plant species, including particularly those eaten (e.g., *Corylus americana*) or readily transported in furs (e.g., *Stipa spartea*) were dispersed by Indians who travelled these trading routes for thousands of years, importing and exporting trade materials over thousands of miles. Reznicek (1983) reported a very direct relationship between prairies and an Indian route in the central portion of southern Ontario, but he explained it largely on the basis of the Indians maintaining patches of a once more widespread prairie flora, rather than introducing it, although he also admitted the possibility of introduction of shrubs bearing edible fruit and seeds such as Western Sand Cherry (*Prunus besseyi*), *Amelanchier alnifolia* var. *compacta* and *Corylus americana*.

In some instances prairie vegetation occurs along railways and has clearly been introduced from regions to the west on trains (Catling and McKay 1974; Roberts et al. 1977), but this explanation of origin can only be applied with complete confidence to areas where a prairie flora was never known and where it is unlikely to have occurred. There are no railways near any of the prairie sites in the Oak Hills, but both of the savanna sites do have railways beside them. The savanna sites, however, are without remarkable western disjuncts, so introduction by railway does not seem to be an important consideration in the present case.

It is most probable that both short dispersal steps from the west, perhaps but not necessarily involving a glacial or early post-glacial "sidewalk", or over more continuous prairie in postgacial times, and dispersal by Indians along major trade routes, both contributed to the origin of the Trent prairies, but we may never know in what proportions. Clearly a substantial portion of the flora is eastern and this even includes many of the dominant species. Thus a large portion of the flora of the natural openings probably originated to the south and east, and thus the vegetation may be as much of an eastern phenomenon as a western one, the very clear western floristic affinity notwithstanding. Extensive prairies and savannas existed on the sandy soils of New York State and southern New England in presettlement times (Day 1953; Thompson and Smith 1970).

Floristic significance

The natural openings along the Trent contain nine provincially rare species, all found in the prairies except *Juncus secundus* which occurred on one savanna. The provincial rarities are all plants with western or midwestern affinity, except for the southern and midwestern *Celtis tenuifolia* and *Juncus secundus*. Thirty-two regionally rare plants occur on these sites, and many other plants have restricted distributions in Ontario, but are not rare in the region, which is one of exceptional richness (D. G. Cuddy. 1991. Vascular plants of eastern Ontario. Draft report, Ontario Ministry of Natural Resources, Eastern Region, Kemptville, Ontario).

The valley of the Trent River evidently contained the easternmost prairie in Canada and it was probably extensive along the valley and only 25 km east of an even more extensive prairie that once existed to north of the central portion of Lake Ontario and south of Rice Lake; i.e., the Rice Lake Plains (Catling et al. 1992). Some species with western prairie affinity extend further east but only as patches at Indian sites and along fluctuating rivershores, never as part of an extensive or once extensive prairie association. The undisturbed remnants of the Trent prairies are exceptional in the primarily forested region of eastern North America and are of special interest in being the eastern limit of several plant species characteristic of the midwestern and western North American prairies. The limestone savannas and sand barrens are also of great interest, both being of generally resticted occurrence, but more widespread in the eastern North America. These kinds of vegetation of dry natural openings have been largely destroyed in Ontario and elsewhere in North America, making the relicts an important and final opportunity for the protection of representative examples of a formerly extensive natural ecosystem. Apart from their significance to botanical and ecological sciences, these remnants provide important options for research in other fields, such as climatic history, effects of climatic change and soil development.

Acknowledgments

S. M. McKay-Kuja, D. G. Cuddy and J. Norris assisted with field work. J. and B. Ketcheson very kindly assisted in accessing an opening on their properties, and other landowners kindly permitted access. P. Y. Wong and R. Ireland, both of the Canadian Museum of Nature, identified lichens and mosses respectively. R. Bayer of the University of Alberta identified *Antennaria* collections. A. A. Reznicek of the University of Michigan identified material of *Carex* section *Ovales*. J. B. Phipps of the University of Western Ontario identified *Crataegus* collections. H. E. Ballard, Jr., of the University of Wisconsin kindly identified *Viola* collections.

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Received 23 March 1992
Accepted 18 August 1993

APPENDIX TABLE 1. Native species present in 15 sites along the Trent River, southeastern Ontario. Site numbers indicating presence follow the names. C = nationally rare based on Argus and Pryer (1990). P = provincially rare based on Argus and Keddy 1984, Pryer and Argus 1987. R = regionally rare based on D. G. Cuddy (1991. Vascular plants of eastern Ontario. Draft report. Ontario Ministry of Natural Resources, Eastern Region, Kemptville, Ontario). 1 = *C. macrosperma* or *C. succulenta*. 2 = *C. chrysocarpa* or *C. irrasa*. Historical records of *Castilleja coccinea* (Macoun's catalogue) and *Polygala polygama* (Dawson papers), both from the Oak Hills area, cannot be identified with a particular site.

	Achillea millefolium ssp. *lanulosa* 1, 2, 3, 4, 5, 6, 7, 12, 13, 14
	Allium canadense 15
	Ambrosia artemesiifolia 12, 15
	Amelanchier alnifolia var. *compacta* 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13
	Amelanchier arborea ssp. *laevis* 5, 8
R	*Amelanchier spicata* var. *spicata* 1, 3, 5, 6, 7, 10
	Andropogon gerardii 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
	Anemone cylindrica 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Anemone virginiana 3
R	*Anemonella thalictroides* 11
	Antennaria howellii var. *petaloidea* 1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Antennaria parlinii var. *fallax* 1, 2, 3, 6, 7, 9, 10, 11, 12, 13, 15
	Apocynum androsaemifolium 1, 2, 3, 5, 6, 7, 9, 10, 13, 14, 15,
	Aquilegia canadensis 1, 2, 3, 6, 7, 8, 10, 13, 15
	Arabis divaricarpa 6
	Arabis glabra 15
	Arabis hirsuta 6
	Arctostaphylos uva-ursi 7, 10, 12
	Arenaria lateriflora 15
	Artemesia campestris 8, 9, 12
	Asclepias syriaca 8, 9, 12
R	*Asclepias tuberosa* 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Aster cordifolius 1, 15
	Aster macrophyllus 1
	Aster novae-angliae 1, 7, 13
R	*Aster oolentangiensis* 3, 4, 5, 6, 7, 9, 10, 11, 12, 14
	Aster urophyllus 1, 6, 7, 15
R	*Astragalus neglectus* 15
	Betula papyrifera 12
	Bromus kalmii 4, 5, 6, 13
R	*Bromus pubescens* 6
CPR	*Bouteloua curtipendula* 1
R	*Calystegia spithamea* 1, 2, 8, 9, 12
	Campanula rotundifolia 1, 2, 3, 5, 6, 7, 10, 12, 13, 15
	Carex backii 2, 8, 13
	Carex cephalophora 1, 15
	Carex eburnea 13
	Carex lanuginosa 13
	Carex molesta 6, 12, 14, 15
	Carex muhlenbergii 3, 5, 14
	Carex pensylvanica 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Carex richardsonii 2, 3, 4, 5, 6, 7, 12, 13, 14
	Carex rosea 1, 15
R	*Carex siccata* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
R	*Carex tonsa* 8, 12
	Carex umbellata 15
	Carya ovata 1, 2, 3, 6, 11
R	*Castilleja coccinea*
	Ceanothus americanus 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
R	*Ceanothus herbaceus* 5, 7, 8, 10
	Celastrus scandens 1, 2, 3, 4, 5, 7, 15
CPR	*Celtis tenuifolia* 3, 4, 5
	Cerastium arvense 6, 13, 15
	Clinopodium vulgare 15
	Comandra umbellata 1, 2, 6, 7, 8, 9, 11, 13, 14, 15
	Cornus racemosa 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15
	Cornus rugosa 3, 6, 10, 14, 15

	Corylus americana 3, 4, 5, 6, 8, 10, 15
	Crataegus sp. a[1] 4
	Crataegus sp. b[2] 14
	Crataegus sp. 3, 15
	Cyperus lupulinus 3, 9, 10, 11, 12
	Danthonia spicata 1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Deschampsia flexuosa 3
	Desmodium canadense 3, 7, 13, 15
R	*Dichanthelium columbianum* 8, 9, 12
R	*Dichanthelium depauperatum* 2
	Dichanthelium implicatum 2, 8, 13
	Dichanthelium linearifolium 9, 12,
PR	*Dichanthelium perlongum* 8, 9
CPR	*Dichanthelium villosissimum* var. *praecocius* 3, 4, 6, 7, 12
	Diervilla lonicera 13
	Eleocharis compressa 2
	Elymus canadensis 3
	Elymus trachycaulus var. *unilaterale* 1, 2, 3, 6, 7, 9, 11, 13, 14, 15
	Equisetum hyemale 3, 7, 8, 12
R	*Erigeron pulchellus* 1, 15
	Fragaria virginiana 1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15
	Fraxinus americana 1, 5
	Galium boreale 1, 2, 13, 15
	Galium circaezans 3, 4, 15
CPR	*Gentiana flavida* 13
	Geranium maculatum 1
	Geum canadense 1, 15
	Geum triflorum 3, 6, 7, 11
R	*Helianthemum bicknellii* 9, 10, 11, 12
R	*Helianthemum canadense* 3, 8, 9, 10
	Helianthus divaricatus 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Helianthus strumosus 1, 3, 4, 5, 6, 7, 10, 13
	Hepatica americana 1, 15
R	*Hierchloe odorata* 15
	Hystrix patula 1, 2, 15
	Juncus dudleyi 15
CPR	*Juncus secundus* 2
	Juniperus communis 1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13
	Juniperus virginiana 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15
	Lactuca canadensis 3
R	*Lechea intermedia* 8, 9, 12
R	*Lespedeza capitata* 3, 6, 7, 8, 9, 10, 12
	Lilium philadelphicum 1, 2, 3, 4, 5, 6, 7, 13
R	*Linum sulcatum* 3, 8, 11, 12
	Lonicera dioica 1, 2, 13, 15
	Lonicera hirsuta 1, 2, 15
	Maianthemum canadense var. *interius* 3, 10
	Minuartia michauxii 3, 4, 5, 6, 7, 10, 11, 13
	Monarda fistulosa 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15
	Muhlenbergia glomerata 6, 7, 13
	Oryzopsis asperifolia 1, 2, 8
R	*Oryzopsis pungens* 8
	Panicum philadelphicum 2, 13, 15
R	*Panicum xanthophysum* 5
	Penstemon hirsutus 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 13, 14, 15
	Pinus strobus 2, 3, 4, 5, 8, 9, 10, 12, 14
	Poa compressa 1, 2, 3, 4, 5, 6, 7, 8, 9 10, 11, 12, 13, 14, 15
	Poa pratensis 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
R	*Polygala polygama*
	Polygala senega 1, 3, 5, 6, 7, 9, 10, 11, 13, 15
	Populus grandidentata 3, 4, 5, 8, 11, 12
	Populus tremuloides 4, 8
	Potentilla arguta 3, 6, 7, 9, 10, 11, 12, 13, 14, 15
	Potentilla canadensis 13

	Potentilla recta 2, 3, 6, 7, 8, 9, 11, 12, 13, 14, 15
	Potentilla simplex 4, 13
	Prunella vulgaris 1, 7
	Prunus pensylvanica 3, 8, 9
	Prunus virginiana 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Pteridium aquilinum 3, 4, 8, 9, 10, 11, 12, 15
	Quercus alba 1, 2, 3, 7, 11, 15
	Quercus macrocarpa 1, 2, 6, 7, 13, 14, 15
	Quercus muehlenbergii 1, 5
	Quercus rubra 1, 2, 5, 6, 7, 11
R	*Quercus velutina* 3, 4, 5, 8, 9, 10, 12
	Ranunculus fascicularis 3, 4, 5, 6, 7, 10, 11, 13
R	*Ranunculus rhomboideus* 3, 5
	Rhus aromatica 1, 2, 3, 4, 5, 6, 7, 11, 13, 14, 15
	Rhus radicans 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
	Rhus typhina 2, 4, 5, 7, 8, 9, 10, 13
	Ribes sp. 15
	Rosa acicularis 11
	Rosa blanda 1, 2, 3, 6, 7, 8, 9, 13, 14, 15
R	*Rubus flagellaris* 3, 4, 5
	Salix humilis 10
	Sanicula marilandica 1, 15
	Saxifraga virginiensis 3, 7, 11, 12, 13
	Schizachne purpurascens 2, 5, 6, 8, 12, 13, 15
R	*Schizachyrium scoparium* 3, 4, 5, 6, 7, 9, 10, 12
	Scutellaria parvula 2, 13, 15
	Selaginella rupestris 3, 6, 8, 9, 12
	Shepherdia canadense 1, 3, 7, 11, 13
	Smilacina racemosa 1, 2, 15
	Smilacina stellata 3, 4, 5, 6, 7, 8, 10, 11, 13, 14, 15
	Smilax herbacea 3, 7
	Solidago canadensis 1, 10, 13
R	*Solidago hispida* 5, 6, 7
	Solidago juncea 1, 2, 3, 10, 12, 13, 14, 15
	Solidago nemoralis 1, 2, 3, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15
R	*Sorghastrum nutans* 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
CPR	*Sporobolus asper* 13
PR	*Sporobolus heterolepis* 5, 13
PR	*Stipa spartea* 3
	Symphoricarpos albus 1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15
R	*Taenidia integerrima* 1, 2, 3, 6, 7, 15
	Thuja occidentalis 3
	Trichostema brachiata 13, 15
	Triosteum perfoliatum 1
	Vaccinium angustifolium 7, 8, 11, 12
	Viburnum rafinesquianum 1, 2, 3, 6, 7, 8, 13, 15
R	*Viola adunca* 3, 7, 10, 11, 12
R	*Viola affinis* 2, 8, 9, 10, 12
R	*Viola fimbriatula* 10
	Viola sp. 15
	Virgulus ericoides 3, 6, 7, 10, 14, 15
	Vitis riparia 3, 7, 9, 10, 13
	Zanthoxylum americanum 1, 7, 13, 15

APPENDIX TABLE 2. Percentage frequency of species of vascular plants, bryophytes and lichens in 11 major associations in 10 Trent valley sites. * = lichens, + = mosses. All of the *Amelanchier alnifolia* except a few sterile plants were clearly referable to var. *compacta*. The *Cladina* spp. included *cristatella*, *pyxidata*, *pocillum*, *phyllophora* and *chlorophylla*. [1] ssp. *petaloidea*. [2] ssp. *fallax*. [3] var. *praecocius*. [4] var. *spicata*.

	SITE NUMBER										
Site Number	15	1	3	4	5a	5b	7	10	9	8	6
Savanna	———	———									———
Prairie			———	———	———	———	———	———			
Sand Barren									———	———	
SPECIES	15	1	3	4	5a	5b	7	10	9	8	6
Achillea millefolium	–	13	–	10	–	–	–	–	–	–	–
Ambrosia artemesiifolia	–	–	–	–	–	–	–	–	–	–	10
Amelanchier alnifolia	–	–	–	60	20	80	–	–	–	–	10
Amelanchier spicata[4]	–	–	–	–	–	10	–	–	–	–	–
Andropogon gerardii	–	–	–	70	100	70	–	100	20	–	–
Anemone cylindrica	33	7	30	10	20	20	70	30	40	–	70
Antennaria howellii[1]	7	–	–	–	–	–	–	–	–	–	20
Antennaria parlinii[2]	–	13	10	10	–	–	–	20	–	–	10
Apocynum androsaemifolium	–	7	–	–	–	–	–	10	–	–	–
Aquilegia canadensis	–	7	–	–	–	–	–	–	–	–	–
Asclepias syriaca	–	–	–	–	–	–	–	–	13	–	–
Asclepias tuberosa	–	–	–	40	20	10	10	10	33	20	–
Aster cordifolius	7	7	–	–	–	–	–	–	–	–	–
Aster macrophyllus	–	20	–	–	–	–	–	–	–	–	–
Aster novae-angliae	–	10	–	–	–	–	–	–	–	–	–
Aster oolentangiensis	–	–	40	20	–	10	40	100	–	–	70
Aster urophyllus	–	60	–	–	–	–	–	–	–	–	10
Astragalus neglectus	13	–	–	–	–	–	–	–	–	–	–
Bromus kalmii	–	–	–	10	–	–	–	–	–	–	–
Bromus pubescens	–	27	–	–	–	–	–	–	–	–	–
Calystegia spithamea	–	–	–	–	–	–	–	–	40	27	–
Campanula rotundifolia	7	–	10	–	–	20	–	10	–	–	20
Carex cephalophora	13	7	–	–	–	–	–	–	–	–	–
Carex pensylvanica	60	82	40	30	40	100	30	50	13	10	90
Carex richardsonii	–	–	70	80	–	–	–	–	–	–	20
Carex rosea	7	–	–	–	–	–	–	–	–	–	–
Carex siccata	87	73	80	90	50	90	10	60	100	50	70
Carex tonsa	–	–	–	–	–	–	–	–	–	90	–
Ceanothus americanus	33	–	–	50	–	50	–	–	7	30	–
Ceanothus herbaceus	–	–	–	–	–	20	90	–	–	–	–
Celastrus scandens	13	–	10	10	10	20	50	–	–	–	–
Clinopodium vulgare	13	–	–	–	–	–	–	–	–	–	–
Comandra umbellata	–	40	–	–	–	20	–	–	–	–	30
Cornus racemosa	93	13	–	10	–	–	40	–	–	–	–
Crataegus spp.	13	–	–	–	–	–	–	–	–	–	–
Cyperus lupulinus	–	–	–	–	–	–	–	–	7	20	–
Danthonia spicata	20	–	–	–	–	–	–	–	13	–	60
Desmodium canadense	–	–	–	10	–	–	–	–	–	–	–
Dichanthelium columbianum	–	–	–	–	–	–	–	–	7	30	–
Dichanthelium depauperatum	–	–	–	–	–	–	–	–	–	100	–
Dichanthelium perlongum	–	–	–	–	–	–	–	–	13	–	–
Dichanthelium villosissimum[3]	–	–	30	–	–	–	–	–	–	–	60
Elymus trachycaulus	7	7	–	–	–	–	–	–	7	–	–
Epipactis helleborine	13	–	–	–	–	–	–	–	–	–	–
Equisetum hyemale	–	–	40	–	–	–	–	–	–	–	–
Erigeron pulchellus	–	7	–	–	–	–	–	–	–	–	–
Fragaria virginiana	33	–	10	20	–	10	10	–	–	–	90
Fraxinus americana	–	–	–	–	–	10	–	–	–	–	–
Galium boreale	53	40	–	–	–	–	–	–	–	–	–
Geum triflorum	–	–	–	–	–	–	30	–	–	–	70
Helianthemum bicknellii	–	–	–	–	–	–	–	10	13	–	–
Helianthemum canadense	–	–	–	–	–	–	–	–	–	40	–
Helianthus divaricatus	7	80	20	60	60	90	10	10	–	–	–

Helianthus strumosus	–	7	–	10	–	–	–	–	–	–	–
Hepatica americana	7	7	–	–	–	–	–	–	–	–	–
Hieracium piloselloides	7	–	–	–	–	–	–	–	27	20	–
Hypericum perforatum	40	–	30	–	–	–	20	10	–	10	10
Hystrix patula	13	60	–	–	–	–	–	–	–	–	–
Juniperus virginiana	–	13	10	–	–	–	–	–	7	–	10
Lechea intermedia	–	–	–	–	–	–	–	–	–	10	–
Lespedeza capitata	–	–	–	–	–	–	–	10	33	–	30
Lilium philadelphicum	–	–	20	–	10	–	–	–	–	–	–
Linaria vulgaris	27	20	–	–	–	–	–	–	–	–	–
Linum sulcatum	–	–	–	–	–	–	–	–	–	10	–
Lithospermum officinale	7	–	–	–	–	–	–	–	–	–	–
Lonicera dioica	7	–	–	–	–	–	–	–	–	–	–
Medicago lupulina	20	7	–	–	–	–	–	20	–	–	–
Melilotus alba	7	–	–	–	–	–	–	10	–	–	–
Minuartia michauxii	–	–	10	30	30	–	–	–	–	–	–
Monarda fistulosa	60	–	50	50	–	40	20	30	7	–	70
Oryzopsis asperifolia	–	7	–	–	–	–	–	–	–	–	–
Penstemon hirsutus	7	–	–	10	10	–	10	–	–	–	–
Pinus strobus	–	–	–	–	–	–	–	–	7	–	–
Poa compressa	40	20	80	10	60	10	90	20	60	60	70
Poa pratensis	40	87	20	70	30	30	10	40	27	–	20
Polygala senega	13	7	–	–	10	–	–	–	–	–	20
Populus grandidentata	–	–	–	–	20	–	–	–	–	–	–
Potentilla arguta	13	–	–	–	–	–	70	20	–	–	30
Potentilla recta	–	–	–	–	–	–	–	–	–	–	50
Prunus virginiana	20	–	100	50	60	100	10	–	–	–	100
Pteridium aquilinum	–	–	10	20	–	–	–	–	–	80	–
Quercus macrocarpa	–	–	–	–	–	–	10	–	–	–	–
Quercus velutina	–	–	–	–	–	–	–	–	20	20	–
Ranunculus fascicularis	–	–	40	20	20	–	–	–	–	–	40
Ranunculus rhomboideus	–	–	10	–	–	–	–	–	–	–	–
Rhus aromatica	20	40	–	10	10	30	–	–	–	–	20
Rhus radicans	7	–	80	10	30	50	30	60	–	–	70
Rhus typhina	–	–	–	–	20	–	–	–	27	–	–
Ribes sp.	7	–	–	–	–	–	–	–	–	–	–
Rosa acicularis	–	–	10	–	–	–	–	–	–	–	–
Rosa blanda	7	–	–	–	–	10	–	–	40	–	–
Rumex acetosella	–	–	–	–	–	–	–	–	–	20	–
Schizachne purpurascens	7	–	–	–	–	10	–	–	–	–	–
Schizachyrium scoparium	–	–	100	50	–	–	–	–	–	–	60
Selaginella rupestris	–	–	–	–	–	–	–	–	7	30	–
Silene vulgaris	7	–	–	–	–	–	–	–	–	–	–
Smilacina racemosa	7	20	–	–	–	–	–	–	–	–	–
Smilacina stellata	–	–	70	10	10	–	–	10	–	–	–
Solidago canadensis	–	–	10	–	–	–	–	10	–	–	–
Solidago juncea	7	–	–	–	–	–	30	–	–	–	–
Solidago nemoralis	–	–	60	–	20	–	40	–	40	30	50
Sorghastrum nutans	–	–	10	70	10	50	100	20	7	–	10
Sporobolus heterolepis		–	–	–	20	–	–	–	–	–	–
Stipa spartea	–	–	70	–	–	–	–	–	–	–	–
Symphoricarpos albus	87	87	50	–	–	10	–	10	–	–	50
Taenidia integerrima	27	27	–	–	–	–	–	–	–	–	–
Viburnum rafinesquianum	20	–	–	–	–	–	–	–	–	–	–
Viola adunca	–	–	–	–	–	–	–	–	–	–	10
Viola sp.	7	–	–	–	–	–	–	–	–	–	–
Virgulus ericoides	–	7	10	70	–	–	80	30	–	–	30
Vitis riparia	–	–	10	–	–	–	–	40	–	–	–
Zanthoxylum americanum	13	–	–	–	–	–	–	–	–	–	–
**Cladina rangiferina*	–	–	–	–	–	–	–	–	–	20	–
**Cladina* spp.	–	–	–	–	–	–	–	–	–	20	–
+*Polytrichum peliferum*	–	–	–	–	–	–	–	–	–	50	–
+*Ceratodon purpureus*	–	–	–	–	–	–	–	–	–	20	–
+*Thuidium abietinum*	–	–	–	–	–	–	–	–	–	–	40

APPENDIX TABLE 3. Percentage cover of vascular plants, mosses and bryophytes in 11 major associations at 10 sites along the Trent River. * = bryophytes, + = mosses. For additional information, see caption for Appendix Table 2.

	SITE NUMBER										
Site Number	15	1	3	4	5a	5b	7	10	9	8	6
Savanna	———	———									
Prairie			———	———	———	———	———	———			———
Sand Barren									———	———	
SPECIES	15	1	3	4	5a	5b	7	10	9	8	6
Achillea millefolium	–	0.2	–	0.2	–	–	–	–	–	–	–
Ambrosia artemesiifolia	–	–	–	–	–	–	–	–	–	–	0.1
Amelanchier alnifolia	–	–	–	3.8	0.6	5.5	–	–	–	–	0.7
Amelanchier spicata[4]	–	–	–	–	–	0.2	–	–	–	–	–
Andropogon gerardii	–	–	–	17.7	46.8	0.9	–	70.4	4.4	–	–
Anemone cylindrica	0.7	0.1	0.4	0.2	0.3	0.1	1.1	0.3	1.3	–	1.4
Antennaria howellii[1]	0.1	–	–	–	–	–	–	–	–	–	4.3
Antennaria parlinii[2]	–	0.4	0.2	1.0	–	–	–	0.7	–	–	0.1
Apocynum androsaemifolium	–	0.2	–	–	–	–	–	0.2	–	–	–
Aquilegia canadensis	–	0.1	–	–	–	–	–	–	–	–	–
Asclepias syriaca	–	–	–	–	–	–	–	–	0.3	–	–
Asclepias tuberosa	–	–	–	0.6	0.9	0.2	1.0	0.1	1.1	2.3	–
Aster cordifolius	0.1	0.1	–	–	–	–	–	–	–	–	–
Aster macrophyllus	–	1.2	–	–	–	–	–	–	–	–	–
Aster novae-angliae	–	0.2	–	–	–	–	–	–	–	–	–
Aster oolentangiensis	–	–	1.0	0.3	–	1.3	0.8	3.9	–	–	1.7
Aster urophyllus	–	1.7	–	–	–	–	–	–	–	–	0.4
Astragalus neglectus	3.0	–	–	–	–	–	–	–	–	–	–
Bromus kalmii	–	–	–	0.3	–	–	–	–	–	–	–
Bromus pubescens	–	0.5	–	–	–	–	–	–	–	–	–
Calystegia spithamea	–	–	–	–	–	–	–	–	9.3	2.7	–
Campanula rotundifolia	0.1	–	0.2	–	–	0.1	–	0.3	–	–	0.3
Carex cephalophora	0.3	0.1	–	–	–	–	–	–	–	–	–
Carex pensylvanica	11.2	13.4	0.2	0.5	2.1	6.6	0.5	2.4	1.7	0.2	9.8
Carex richardsonii	–	–	1.7	4.4	–	–	–	–	–	–	3.4
Carex rosea	0.1	–	–	–	–	–	–	–	–	–	–
Carex siccata	20.8	3.9	4.1	11.0	1.0	4.4	0.9	1.9	62.0	4.1	7.7
Carex tonsa	–	–	–	–	–	–	–	–	–	17.2	–
Ceanothus americanus	3.0	–	–	4.1	–	4.4	–	–	1.0	17.0	–
Ceanothus herbaceus	–	–	–	–	–	0.1	40.0	–	–	–	–
Celastrus scandens	0.3	–	0.6	0.2	0.5	0.4	3.0	–	–	–	–
Clinopodium vulgare	0.3	–	–	–	–	–	–	–	–	–	–
Comandra umbellata	–	0.9	–	–	–	0.3	–	–	–	–	0.3
Cornus racemosa	33.0	5.7	–	0.8	–	–	2.2	–	–	–	–
Crataegus spp.	0.1	–	–	–	–	–	–	–	–	–	–
Cyperus lupulinus	–	–	–	–	–	–	–	–	0.1	0.5	–
Danthonia spicata	0.4	–	–	–	–	–	–	–	0.8	–	1.4
Desmodium canadense	–	–	–	1.3	–	–	–	–	–	–	–
Dichanthelium columbianum	–	–	–	–	–	–	–	–	0.4	0.9	–
Dichanthelium depauperatum	–	–	–	–	–	–	–	–	–	6.3	–
Dichanthelium perlongum	–	–	–	–	–	–	–	–	0.4	–	–
Dichanthelium villosissimum[3]	–	–	0.6	–	–	–	–	–	–	–	3.6
Elymus trachycaulus	0.1	0.1	–	–	–	–	–	–	0.1	–	–
Epipactis helleborine	0.1	–	–	–	–	–	–	–	–	–	–
Equisetum hyemale	–	–	0.1	–	–	–	–	–	–	–	–
Erigeron pulchellus	–	5.2	–	–	–	–	–	–	–	–	–
Fragaria virginiana	0.4	–	0.2	0.5	–	0.1	0.1	–	–	–	3.2
Fraxinus americana	–	–	–	–	–	0.2	–	–	–	–	–
Galium boreale	2.7	8.4	–	–	–	–	–	–	–	–	–
Geum triflorum	–	–	–	–	–	–	1.0	–	–	–	4.7
Helianthemum bicknellii	–	–	–	–	–	–	–	0.1	0.2	–	–
Helianthemum canadense	–	–	–	–	–	–	–	–	–	4.5	–
Helianthus divaricatus	0.4	8.2	3.2	6.8	13.5	10.4	5.7	4.3	–	–	–
Helianthus strumosus	–	0.5	–	0.3	–	–	–	–	–	–	–
Hepatica americana	0.1	0.1	–	–	–	–	–	–	–	–	–

Hieracium piloselloides	0.1	–	–	–	–	–	–	–	0.5	0.2	–
Hypericum perforatum	0.3	–	0.1	–	–	–	0.1	0.1	–	0.1	0.1
Hystrix patula	0.1	1.4	–	–	–	–	–	–	–	–	–
Juniperus virginiana	–	0.6	0.2	–	–	–	–	–	0.1	–	0.3
Lechea intermedia	–	–	–	–	–	–	–	–	–	0.2	–
Lespedeza capitata	–	–	–	–	–	–	–	0.1	2.1	–	0.7
Lilium philadelphicum	–	–	0.6	–	–	–	–	–	–	–	–
Linaria vulgaris	0.1	0.3	–	–	–	–	–	–	–	–	–
Linum sulcatum	–	–	–	–	–	–	–	–	–	0.2	–
Lithospermum officinale	0.1	–	–	–	–	–	–	–	–	–	–
Lonicera dioica	0.1	–	–	–	–	–	–	–	–	–	–
Medicago lupulina	0.7	0.1	–	–	–	–	–	0.1	–	–	–
Melilotus alba	0.1	–	–	–	–	–	–	0.1	–	–	–
Minuartia michauxii	–	–	0.2	0.5	0.5	–	–	–	–	–	–
Monarda fistulosa	2.3	–	2.8	0.8	–	1.1	1.0	0.7	0.8	–	4.4
Oryzopsis asperifolia	–	0.2	–	–	–	–	–	–	–	–	–
Penstemon hirsutus	0.3	–	–	0.2	0.2	–	0.3	–	–	–	–
Pinus strobus	–	–	–	–	–	–	–	–	1.0	–	–
Poa compressa	1.1	0.1	1.7	0.2	1.4	0.3	5.4	1.2	3.4	6.6	1.1
Poa pratensis	0.7	3.4	0.4	1.9	0.3	0.9	0.2	1.1	1.9	–	0.2
Polygala senega	0.3	1.8	–	–	0.3	–	–	–	–	–	0.3
Populus grandidentata	–	–	–	–	0.8	–	–	–	–	–	–
Potentilla arguta	0.6	–	–	–	–	–	3.3	1.0	–	–	0.6
Potentilla recta	–	–	–	–	–	–	–	–	–	–	0.6
Prunus virginiana	0.3	–	6.4	7.2	7.5	49.0	1.1	–	–	–	22.4
Pteridium aquilinum	–	–	0.6	1.1	–	–	–	–	–	19.9	–
Quercus macrocarpa	–	–	–	–	–	–	1.1	–	–	–	–
Quercus velutina	–	–	–	–	–	–	–	–	0.5	3.9	–
Ranunculus fascicularis	–	–	0.7	0.3	0.3	–	–	–	–	–	0.5
Ranunculus rhomboideus	–	–	0.1	–	–	–	–	–	–	–	–
Rhus aromatica	0.9	14.2	–	1.1	0.2	10.9	–	–	–	–	0.8
Rhus radicans	0.1	–	8.9	0.2	0.6	1.6	1.0	4.7	–	–	1.5
Rhus typhina	–	–	–	–	0.9	–	–	–	1.3	–	–
Ribes cynosbati	0.5	–	–	–	–	–	–	–	–	–	–
Rosa acicularis	–	–	0.2	–	–	–	–	–	–	–	–
Rosa blanda	0.1	–	–	–	–	0.3	–	–	0.8	–	–
Rumex acetosella	–	–	–	–	–	–	–	–	–	0.5	–
Schizachne purpurascens	0.1	–	–	–	–	0.1	–	–	–	–	–
Schizachyrium scoparium	–	–	38.6	6.2	–	–	–	–	–	–	15.6
Selaginella rupestris	–	–	–	–	–	–	–	–	0.1	1.8	–
Silene vulgaris	0.1	–	–	–	–	–	–	–	–	–	–
Smilacina racemosa	0.3	0.6	–	–	–	–	–	–	–	–	–
Smilacina stellata	–	–	3.1	0.2	0.2	–	–	0.4	–	–	–
Solidago canadensis	–	–	0.2	–	–	–	–	0.7	–	–	–
Solidago juncea	0.1	–	–	–	–	–	0.5	–	–	–	–
Solidago nemoralis	–	–	2.4	–	0.3	–	0.9	–	4.0	1.1	1.5
Sorghastrum nutans	–	–	0.7	24.5	0.3	2.2	24.5	1.5	0.1	–	0.1
Sporobolus heterolepis	–	–	–	–	17.2	–	–	–	–	–	–
Stipa spartea	–	–	9.1	–	–	–	–	–	–	–	–
Symphoricarpos albus	6.9	26.0	9.9	–	–	0.8	–	2.1	–	–	4.0
Taenidia integerrima	4.9	1.5	–	–	–	–	–	–	–	–	–
Viburnum rafinesquianum	0.4	–	–	–	–	–	–	–	–	–	–
Viola adunca	–	–	–	–	–	–	–	–	–	–	0.1
Viola sp.	0.1	–	–	–	–	–	–	–	–	–	–
Virgulus ericoides	–	0.1	0.3	1.6	–	–	4.6	0.7	–	–	0.6
Vitis riparia	–	–	0.4	–	–	–	–	0.4	–	–	–
Zanthoxylum americanum	0.4	–	–	–	–	–	–	–	–	–	–
**Cladina rangiferina*	–	–	–	–	–	–	–	–	–	0.9	–
**Cladina* spp.	–	–	–	–	–	–	–	–	–	0.9	–
+*Polytrichum peliferum*	–	–	–	–	–	–	–	–	–	7.2	–
+*Ceratodon purpureus*	–	–	–	–	–	–	–	–	–	0.7	–
+*Thuidium abietinum*	–	–	–	–	–	–	–	–	–	–	1.4

Ring-billed Gull, *Larus delawarensis*, Status and Movements in the Maritime Provinces of Canada

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Erskine, Anthony J. 1993. Ring-billed Gull, *Larus delawarensis,* status and movements in the Maritime Provinces of Canada. Canadian Field-Naturalist 107(1): 46–52.

Few Ring-billed Gulls *Larus delawarensis* are present in Canada's Maritime Provinces in summer, except at nesting colonies, or in winter. In spring and fall, most concentrations occur in areas where few or none breed at present, the largest numbers being along Northumberland Strait and in the lower St. John River valley. The distribution and numbers found in spring and fall may be plausibly derived from Ring-billed Gull stocks breeding in the Maritimes, and their increases over the last 30 years parallel in timing and scale those in the breeding population. Transients from Newfoundland, Labrador, and eastern Quebec are hypothesized to migrate mainly by way of the St. Lawrence river and estuary, rather than passing through the Maritimes. Recoveries of banded Ring-billed Gulls support this hypothesis for the Newfoundland stock, but leave open whether the Maritimes gulls stemmed originally from the Gulf North Shore or from the Great Lakes/St. Lawrence River stocks.

Key Words: Ring-billed Gull, *Larus delawarensis*, Maritime Provinces, seasonal distribution, numerical changes, movements.

The Ring-billed Gull, *Larus delawarensis*, became common and widespread in the Maritime Provinces (New Brunswick, Nova Scotia, Prince Edward Island) only within the last 35 years. Before that, Squires (1952) and Tufts (1962) termed it an uncommon transient here, only occasionally appearing in larger numbers in autumn, with a few stragglers into early winter, and Palmer (1949) gave a similar status for Maine. The species' vast increase in the Great Lakes region in 1950-1980 was well-documented (Ludwig 1974; Southern 1974; Blokpoel 1977; Blokpoel and McKeating 1978; Scharf et al. 1978; Weseloh et al. 1986). Ring-billed Gulls nested on the North Shore of the Gulf of St. Lawrence by Audubon's time (Todd 1963) and on the island of Newfoundland before 1940 (Peters and Burleigh 1951), but they never were abundant in those areas. Their more recent spread, as breeding birds, through the Province of Quebec was summarized by Mousseau (1984). Ring-billed Gulls were first detected breeding in the Maritimes in 1965, and increased to some 1700 pairs in 10 coastal colonies by 1983 (Lock 1988), plus a few nesting inland. Their occurrence away from these colonies, and the movements implied thereby, are the subjects of this paper (Figure 1 shows colony locations).

Sources, and problems with the data

I first encountered Ring-billed Gulls in the Maritimes in 1957, when they were scarce at all seasons. My observations, with others filed at the New Brunswick Museum or summarized in *Nova Scotia Birds* (formerly *Nova Scotia Bird Society Newsletter*), provided the basis of this account. I also examined recoveries of Ring-billed Gulls banded in Canada east of Ontario, obtained through the Bird-Banding Office of the Canadian Wildlife Service, Environment Canada.

In 1957, I knew the Ring-billed Gull from birding in Ontario, where the species had recently become common, and in 1960-1968 I made efforts to pick it out and record its numbers in the Maritimes during routine coastal waterfowl counts. After my return here in 1977, my surveys were less frequent and less systematic, but I detected more birds with less coverage, which strengthened the evidence for an increase although it would have complicated documentation of a decline.

Many other observations were made opportunistically by many different people. Coverage was poorly or not standardized between surveys in most areas. Because the gulls may use different areas on different times, the absence of gulls from an area on a survey may only reflect local movements. Few observers routinely recorded numbers of gulls of the more common species in the field, so Ring-billed Gull reports were mostly in round numbers summarizing a day's observations. Hardly anyone reported numbers of the different age-classes of these gulls, except in trivial numbers. Most bird-watchers now recognize that Ring-billed Gulls are expectable in the Maritimes, and many identify the species each year; however, many Ring-billed Gulls here, especially in flocks at a distance, were, and still are, ignored as "just gulls" - which in the Maritimes in the past has meant Herring Gulls if not qualified in some way.

The scarcity of earlier records thus may mean that:
a) no observers were active in an area;
b) the observers did not record gulls;

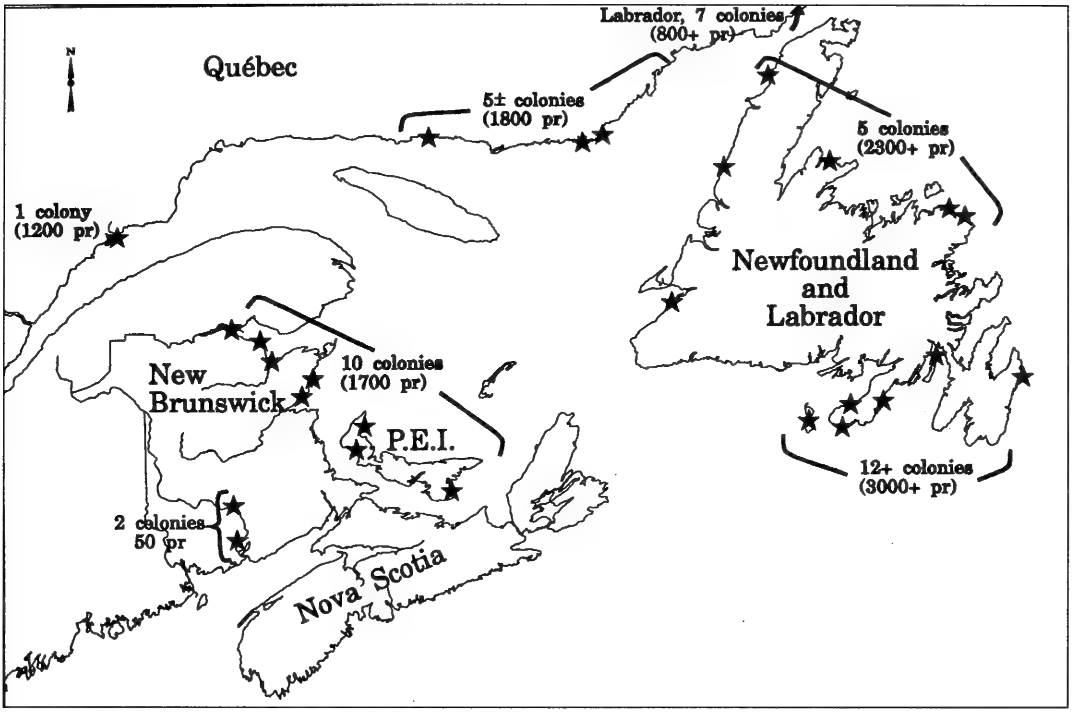

FIGURE 1. Breeding distribution (stars) of Ring-billed Gulls in Atlantic coastal regions of Canada, after Lock (1988), Mousseau (1984), Erskine (personal observations).

c) the observers did not distinguish most Ring billed from Herring Gulls; or
d) Ring-billed Gulls really were scarce there.

Apparent increases sometimes meant only that an observer had learned to recognize the species. More systematic counts of gulls would have been preferable, but the available data provided useful perspective if one made allowance for their weaknesses.

Results

(1) Winter

Only a few hundred Ring-billed Gulls over-wintered in the Maritimes. The Christmas Bird Counts (CBC; Table 1; Figure 2) showed the early winter situation. Counts of >50 of these gulls were made most often at Cape Tormentine, New Brunswick (in 8 years) and in the Halifax, Nova Scotia, CBCs (18 and 8 years, respectively). Exceptionally high counts (ca. 1000) were noted at Wolfville, Nova Scotia, in 1990-1991, when Halifax area counts also were at record levels. Fewer than 20 of the 50+ CBCs (many published locally rather than in *American Birds*) recorded these gulls regularly, counts active earlier showing increases starting in the 1970s. The one exception with fewer gulls recently, Moncton, had major habitat alteration caused by causeway construction starting around 1970. Most of the Ring-billed Gulls seen on CBCs moved away soon afterwards, when ice cover increased.

After early January, up to 100 birds wintered regularly in the Halifax-Dartmouth metropolitan area. Elsewhere, Ring-billed Gulls usually occurred in very small numbers (5 birds or less; Table 1), and not in every year. Most records were from towns in southern Nova Scotia, where the birds fed on human wastes, often at sewage outlets and waterfowl feeding areas, seldom competing at garbage dumps with the larger gulls (personal observations). Most Ring-billed Gulls in the east winter much farther south, especially in Florida (Southern 1974).

(2) Spring

First arrivals appeared, in areas where no birds wintered, from mid-March to early April (Table 2), depending on when waters and marshes became free of ice. Peak counts, which rarely exceeded 300 birds, were mostly in the second and third weeks of April. Many gulls seen in May and early June were probably non-breeders, as laying began in late May (Maritimes Nest Records Scheme). The sightings gave no direct clues as to the routes followed or the birds' destinations, as the progression of arrival dates from southwest to northeast paralleled the schedule on which areas became ice-free. The birds that breed in the Maritimes presumably move directly from these early staging areas to the colonies, to lay in late May. The few seen east of Halifax in spring might have been enroute to Newfoundland colonies (see Figure 1), but the late dates of most high counts there (Table 1) suggested they were non-breeders. The paucity of records from Cape Breton in all periods partly reflected the few observers there.

The largest spring numbers were in areas that were icebound in winter, around the head of Chignecto Bay, and especially along Northumberland Strait. The mud-flats (scoured by winter ice) do not provide good feeding in spring for shorebirds (Hicklin et al. 1980) and likely not for Ring-billed Gulls also, and agricultural lands are also unattractive then (seldom tilled before mid-May; personal observations), in contrast to feeding opportunities in those habitats in fall. Most Ring-billed Gulls in late April were in estuaries and along shores away from settlements, apparently relying on spring fish runs.

(3) Summer

There were too few reports away from known colonies in June and early July to warrant tabulation. Small groups, mostly of subadults (yearling and 2-year-olds; personal observations), occurred along most coasts where agricultural lands adjoin flat shores, particularly in Northumberland Strait and the Gulf of St. Lawrence. The young birds fledged in mid-July, and started to disperse from the colonies soon afterwards.

(4) Autumn

The August to November period showed no obvious break, in occurrence or numbers, while the birds engaged in post-breeding dispersal, staging, and fall migration. Ring-billed Gulls were more abundant and widespread during these months than at other seasons (Table 3), but the records did not reveal any period then during which numbers were consistently higher than at other times. As in spring, there were no records of visible migration, but the birds were more generally common along Northumberland Strait and the St. John River than elsewhere. Flocks of 50-200 were common on nearby fields, especially when birds followed the plough.

Fall numbers evidently increased since the 1960s, as most peak monthly counts (Table 3) were made after 1975. My counts since 1977 along Northumberland Strait far exceeded those I made in the same areas in the 1960s (Table 4), and Ring-billed Gulls now are regular visitors around Cumberland Basin and Shepody Bay where none were noted earlier (Table 5).

(5) Evidence from banded birds

Some 67 recoveries from Ring-billed Gulls banded at one site in southeast Newfoundland in 1953-1959 included only two, both indirect (i.e. not in the banding year), in the Maritimes and a third on the Maine coast. About 59 recoveries from bandings, mostly in 1924-1943, at five sites on the Gulf North Shore

TABLE 1. Ring-billed Gulls (RbGu) in winter in the Maritime Provinces, from Christmas Bird Counts (CBC) and other data. CBCs with Ring-billed Gulls on five or fewer counts overall were ignored.

Area	CBC began	1st RbGu on CBC	Mean RbGu's on CBC 1960s	1970s	1980s	Later in winter
Prince Edward Island						
Hillsborough	1971	1979	n.d	0.9	2.4	none
P.E.I. National Park	1971	1979	n.d	0.3	4.9	none
New Brunswick (from NE to SW)						
Cape Tormentine	1961	1961	10.2	39.1	44.0	once, 1
Sackville	1960	1973	0	3.3	0.9	none
Moncton	1961	1961	8.4	0.3	0.8	none
Riverside-Albert	1967	1968	n.d.	3.5	1.1	none
Fundy National Park	1965	1976	0	1.2	1.3	none
Saint John	1957	1961	3.8	17.1	8.9	usual, 1-5
Eastport (Maine) — Campobello	1967	1967	n.d	5.5	20.0	none
Nova Scotia (from SW to NE)						
Yarmouth	1967	1973	n.d	12.0	16.7	often, 1-5
Pubnico	1978	1979	n.d	n.d	6.6	occasional, 1-5
Broad Cove	1970	1973	n.d	0.7	2.9	none
Halifax West	1955	1955	4.4	25.9	44.1	usual, 5-20
Halifax East	1955	1955	28.7	77.1	150.2	usual, 15-35
Wolfville	1921	1976	0	0.9	35.0	some, 1-5
Economy*	1971	1978	n.d	0.1	6.3	once, 1

Key: CBC = Christmas Bird Count; for locations, see Figure 2; n.d. = no data, *or* CBC data only for <5 years in decade.
*Not shown in Figure 2; all other localities are included there.

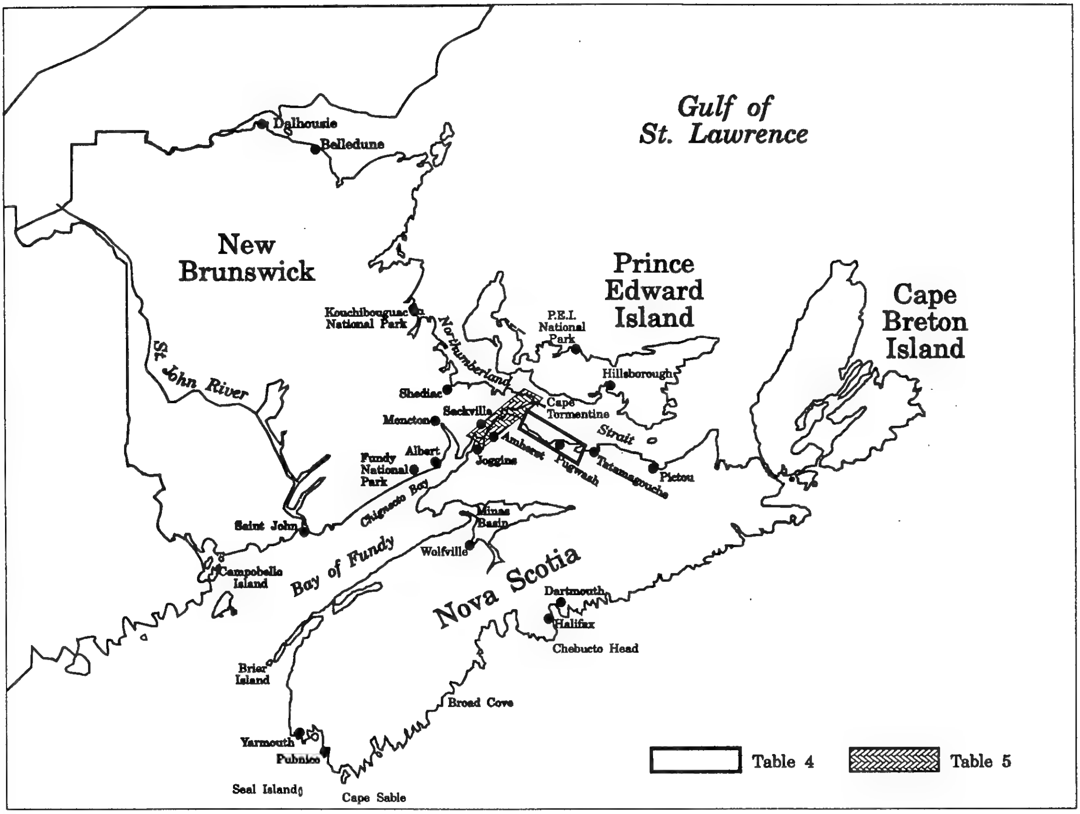

FIGURE 2. Locations where Ring-billed Gulls reported in Tables 1–5 were sighted, Maritime Provinces.

(Harrington to Baie Comeau) included direct recoveries (i.e., in the banding year) along the St. Lawrence River (4) and around the southern Gulf of St. Lawrence (6). Among several hundred recoveries from gulls banded near Montreal, only five direct and four indirect recoveries were in the Maritimes and none in Maine, although first-autumn recoveries blanketed all the St. Lawrence valley and estuary east to Baie Comeau. The almost total absence of recoveries (from any source) in Nova Scotia (1), the south coast of New Brunswick (0), and in Maine east of 70°W (2) suggested that birds from Newfoundland did not pass through the Maritimes. Some, but perhaps only a small proportion, of those from the North Shore moved through the Maritimes. Only a minor trickle came here from the much larger stocks around Montreal and farther west, but so many more gulls breed there that even a trickle might have provided equal or greater numbers of immigrants than might be expected from the Gulf North Shore colonies.

Discussion

(1) Changes in numbers

Ring-billed Gull numbers along Northumberland Strait in spring (personal observations) and fall (Table 4) more than doubled between the 1960s and 1980s. They also occurred regularly in fall since 1980 around the upper Bay of Fundy where none were seen in the earlier period (Table 5). No other areas had comparable data covering the fall migration back through the 1960s, but the CBCs (Table 1) also showed that Ring-billed Gulls had increased where known earlier, and occurred in early winter since 1975 in many areas where they were formerly absent. Most of the monthly high counts in fall (Table 3) were also in the 1980s or late 1970s.

These increases took place over the same period in which the establishment and growth of the Ring-billed Gull breeding population in the Maritimes was occurring (compare Lock 1988). The numbers encountered across the Maritimes in spring and fall may all plausibly be derived from the Maritimes colonies alone. The local breeding Ring-billed Gulls, with their offspring and surviving subadults, should total at least 5000 birds in fall; these birds all move away from the colonies, and most leave the region then. Alternatively, the sightings in the Maritimes might include mostly transients from other breeding areas, but diverse evidence suggests that this is not the case.

TABLE 2. Occurrence of Ring-billed Gulls in spring in the Maritime Provinces.

Area	First arrivals[a]	Peak Dates[b]	Peak Counts
SW New Brunswick, including Saint John	17 March	8-27 April	35–300
SW Nova Scotia	17 March	19 March-10 April	30–100
Halifax area, Nova Scotia	27 March	8 April	40
Minas Basin, Nova Scotia	2 April	13-16 April	25
SE New Brunswick	24 March	4 April-2 May	100–300
N shore Nova Scotia	24 March	3-21 April	100–500
Prince Edward Island	30 March	3-7 April	30-many
NE New Brunswick	6 April[c]	16 May[d]	300
Cape Breton Island, Nova Scotia	12 April	17 April-7 May[d]	45–50
St. John River, New Brunswick	15 April	18 April-11 May[d]	85-many

[a] Excluding single birds

[b] Range in different years

[c] One record on 19 March at a breeding site was omitted.

[d] These late flocks may not (all) be migrants.

Lock (1988) noted an increase in breeding Ring-billed Gulls on the island of Newfoundland, but growth there started in the 1950s before any bred in the Maritimes. The breeding population along the North Shore of the Gulf of St. Lawrence neither increased nor decreased appreciably (Chapdelaine and Brousseau 1984) in recent decades when spring and fall staging birds in the Maritimes were increasing. As breeding stocks existed on both the North Shore and Newfoundland in the 1940s and 1950s,

TABLE 3. Ring-billed Gulls in late summer and autumn in the Maritime Provinces.

Area	Peak counts in month[a] August	September	October	November	December[b]
NE New Brunswick (N of Kouchibouguac National Park)	175/62	many/67	200/61		
Prince Edward Island	200/79		200/81	300/81	
SE New Brunswick — Strait (Kouchibouguac National Park South)	59/74	83/78	160/66	250/73	25/66
SE New Brunswick — Bay (Fundy National Park East)	150/87	250/89	200/71	200/87	30/74
North Nova Scotia — Bay (Joggins north)	80/81	100/84	30/89		
North Nova Scotia — Strait (W of Pictou)	500/78	404/83	500/78	700/79	400/77
Eastern Nova Scotia and Cape Breton Island		[no fall counts >12 reported]			
Minas Basin and Channel, Nova Scotia		30/87	177/87		
Halifax Co., Nova Scotia	150/83	160/87	100/83	60/85	20/84
Sambro Head to Cape Sable, Nova Scotia		42/88			
Yarmouth Co. & Seal Island, Nova Scotia	40/86	43/85	300/85	350/83	200/76
Cape Split to Brier Island, Nova Scotia	[no fall counts >8 reported]				
Saint John Co., New Brunswick	200/72	150/71	500/61	150/70	
SW New Brunswick			many/81		
St. John River, New Brunswick (Keswick-Jemseg)			— 150-300/80s[c] —		

[a] Expressed as maximum number / year in which maximum noted; counts of <25 birds were ignored.

[b] Excluding Christmas Bird Counts.

[c] Similar numbers at several sites suggested movements within the area.

TABLE 4. Changes in Ring-billed Gull numbers on comparable survey areas in northern Nova Scotia.

Areas surveyed in 1960s (those also in 1980s in italics)	Numbers of gulls (and dates surveyed)	
	1960-1968	1978-1989
AmSh, *Nort*, *Lind*, PoPh, Mala, *Bayh*	155 (highest count; (28 October 1965)	*380* (2 November 1981)
AmSh, *Lind*, PoHo	95 (22 October 1968)	*181* (19 October 1986)
Lind, PoPh, *Bayh*	59 (8 October 1960)	*190* (19 October 1984)

Key to areas (W to E): Amherst Shore, Northport, Linden, Port Howe, Port Philip, Malagash, Bayhead.

long before Ring-billed Gulls were being seen commonly in the Maritimes, the migration routes of those stocks then presumably bypassed this area. Those migration routes would have had to change if birds of those stocks were to appear in the Maritimes in larger numbers after 1965. Migration routes of birds sometimes do change (e.g., Brant *Branta bernicla*; Erskine 1988), but that is unusual. It seems more plausible that those northern Ring-billed Gull stocks always migrated by way of the St. Lawrence estuary and valley. That is a longer and less direct route to and from southeast Newfoundland than along the outer coasts of Nova Scotia, where an offshore route is unlikely, as the species is seldom seen out at sea (Brown 1986). The lack of recoveries in Nova Scotia of gulls banded in Newfoundland argues strongly against their passage through that province. Moreover, the numbers seen in Nova Scotia at all seasons are far fewer than the ca. 10 000 birds comprising the southeast Newfoundland stock in autumn, and it may be questioned whether feeding opportunities for so many more Ring-billed Gulls exist in coastal Nova Scotia.

Several thousand Ring-billed Gulls breed along the upper St. Lawrence estuary, near Montmagny and Baie Comeau, and tens of thousands more pairs breed near Montreal (Mousseau 1984). Although up to 300–500 Ring-billed Gulls were noted in northern New Brunswick in the 1960s, shortly before the first breeding occurred here, numbers greater than those of recent New Brunswick breeding stocks have never been seen moving around or across that province in spring and fall. The St. Lawrence estuary birds presumably retrace the route they followed when they colonized that area over the last 30 years: along the St. Lawrence River, and via the Hudson and Richelieu Rivers to the Atlantic coast in fall, and the reverse in spring. Agriculture in the St. Lawrence lowlands is much more extensive and productive than in the Maritimes and northern New England (Warkentin 1968), so staging areas along the St. Lawrence probably can support much larger numbers of Ring-billed Gulls, including the Newfoundland and North Shore stocks as well as those which breed there.

(2) Projections for the future

Ring-billed Gulls were fairly common in northern New Brunswick, especially in spring, in the early 1960s, just before breeding was first detected there in 1965 (P.A. Pearce, unpublished data). No comparable observations were made before the species' spread to Prince Edward Island in the 1970s. Given its apparent preference for coasts with fields nearby, and the recent appearance of two small colonies on islands in the St. John River (P. A. Pearce, personal

TABLE 5. Changes in fall Ring-billed Gull numbers in regularly visited areas in New Brunswick - Nova Scotia border area (August - early December not including Christmas Bird Counts).

Area (all New Brunswick except as shown)	Number of fall dates with Ring-billed Gulls (maximum number of birds)	
	1960-1968	1978-1987
Grande Anse	0	13 (maximum 50+)
Sackville	2 (both 1)	52 (maximum 60)
Aulac, N.B.— Fort Lawrence, N.S.	0	7 (maximum 20)
Amherst-Amherst Point, N.S.	0	8 (maximum 100+)
Tidnish, N.S.	2 (4 & 3)	3 (maximum 40)
Baie Verte	6 (maximum 100+)	8 (maximum 110)
Port Elgin	0	5 (maximum 15)
Murray Corner	3 (maximum 10)	4 (maximum 50+)
Cape Jourimain	1 (30)	14 (maximum 50+)

communication), new colonies might be predicted to appear next along Northumberland Strait between Shediac, New Brunswick, and Tatamagouche, Nova Scotia. However, this stretch of coast has very few islands, and the larger gull species already occupy the one coastal industrial site at Pugwash, Nova Scotia, which resembles existing Ring-billed Gull nesting areas at Dalhousie and Belledune (New Brunswick). A further increase in colonies in northeastern New Brunswick and on Prince Edward Island thus seems more likely than occupation of areas in Nova Scotia or southern New Brunswick that lack secure nesting sites.

Although Ring-billed Gull numbers in the Great Lakes basin and in the St. Lawrence valley increased enormously between 1950 and 1980, they levelled off in some areas (e.g., Blokpoel and McKeating 1978) because the birds had occupied all suitable nesting areas, whether or not they exceeded the local food supply. Both food and nest-site limitations apply also in the Maritimes, where feeding opportunities in agricultural and urban areas are much more restricted than farther west. The colonies founded here in 1981-1983 were no farther east or south than those found earlier, so the Maritimes population may also be nearing a saturation level.

Acknowledgments

Dick Brown and Tony Lock commented on earlier drafts. David Christie and Peter Pearce provided additional unpublished New Brunswick occurrences. Tony Gaston suggested using band recoveries to explore the origin of the Maritimes breeding stock. An anonymous referee provided a number of helpful comments on the submitted manuscript. Dan Busby drafted the maps by computer. I thank them all, as well as all the other people whose observations were used in assembling this summary.

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Received 19 June 1992
Accepted 20 July 1993

Foraging Behaviour of the Tiger Beetle *Cicindela denikei* Brown (Coleoptera: Cicindelidae)

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Kaulbars, Michael M., and Richard Freitag. 1993. Foraging behaviour of the tiger beetle *Cicindela denikei* Brown (Coleoptera: Cicindelidae). Canadian Field-Naturalist 107(1): 53–58.

Adults of *Cicindela denikei* Brown are ambush predators that change their ambush sites frequently. Prey encounters modify the foraging behaviour of adult *C. denikei* such that they remain in the vicinity of the encounter, indicating a degree of memory, which confirm findings for *C. hybrida* Linnaeus by Swiecimski (1957). Adults forage in open areas mainly in the proximity of lush, mixed vegetation where arthropod prey density and diversity likely are greatest within the habitat of *C. denikei*. For more than 80% of the time it changes an ambush site the adult moves a distance roughly equal to or less than its field of vision effecting a systematic and thorough coverage of the foraging area. Prey attack, capture and consumption by *C. denikei* adults are similar to those recorded for its closest relatives, *C. sexguttata* Fabricius and *C. patruela* Dejean.

Key Words: Tiger beetle, *Cicindela denikei,* prey encounters, foraging behaviour.

Tiger beetles forage in unobstructed places within a variety of terrestrial habitats. Field observations indicate that foraging behaviour differs among cicindelid species groups which are adapted to particular environments. Adults of the *Cicindela sexguttata* Fabricius species group (*C. sexguttata*, *C. patruela* Dejean, and *C. denikei* Brown) are normally restricted to forest habitats and forage mainly on paths, little used roads, and clearings (Easton 1909; Larochelle 1972; Glaser 1976). Adults of *C. sexguttata* have been seen foraging in unusual situations such as on lily pads (Lawton 1974) and fallen logs (Shelford 1907; A.B. Clark, personal communication), and on the trunks of standing trees (M. M. Kaulbars, unpublished). Adults of *C. patruela* forage along dirt trails and open areas within their habitat (Boyd 1978; A. B. Clark, personal communication).

Incidental notes on cicindelid predation such as those above are commonly published as part of general behavioural research. More in-depth research of the adult foraging process has focused on later stages including prey encounter, prey selection, and capture (Swiecimski 1957; Wilson 1978) in the context of predation theories. Descriptive studies of earlier phases of cicindelid foraging behaviour however have been curiously neglected for most species groups. This study was conducted principally to quantify early foraging behaviour of *C. denikei* in order to establish diagnostic measurable characteristics of the foraging process for ecological and taxonomic purposes of comparative analysis among species of the *C. sexguttata* group, and among species groups of *Cicindela*.

Study Area

The principal study site was 54 km east of Kenora, Ontario, on gas pipeline road #50-2+15.71 which intersects Highway 17. This site was chosen because it had the largest known colony of *C. denikei*. The road was a seldom used sand and gravel track cleared on both sides. The surrounding area is boreal forest, predominantly Jack Pine (*Pinus banksiana* Lamb) and birch (*Betula* spp.), with some willow (*Salix* spp.) and poplar (*Populus* spp.) in the moister low lying areas. Ground vegetation in the cleared area is a mixture of grasses and various opportunists such as daisy (*Chrysanthemum leucanthemum* L.), Milfoil (*Achillea millefolium* L.) and raspberry (*Rubus idaeus* L.). The soil is a silty sand with much exposed bedrock.

Methods

The beetles were observed with binoculars from a 2 m high embankment 4 m from the pipeline road. Accurate observations of the beetles on the road could be made for 10 m in either direction. Observations were dictated into a portable tape recorder. The tapes were transcribed and timed in the laboratory. Behaviours noted were as follows:

Pause:	The beetle does not move or change orientation for a full second or more.
Run/Stop:	Adult tiger beetles usually move about in short dashes, here termed a "run/stop". In *C. denikei* the runs cover 10 to 15 cm averaging about 13 cm. The stops are brief and not noted as pauses.
Orient:	The beetle changes the direction that it is facing or moving. The beetle frequently orients itself such that it faces parallel or perpendicular to the long axis of the road. The direction that a beetle faces is classed as being (i) "away", facing away from the observer towards the far side of the road, (ii) "towards", towards the

observer's side of the road (iii) "right", facing down the road to the observer's right, or (iv) "left", the opposite of "right". All facings of the beetle are classed into one of the above four categories. All changes in orientation are noted except those occurring during a "move" (see below).

Run: The "run" differs from the run/stop in that the beetle does not pause during the course of the run. The beetle moves approximately 20 cm/sec although the speed varies considerably.

Move: The "move" consists of crawling slowly over the ground, covering 1-6 cm/sec. This often occurs after a beetle strikes at prey, misses, and then tries to find it. The "move" also occurs when a beetle moves through dense vegetation and cannot run. The "move" includes many short pauses and changes in facing, all of which cannot be accurately recorded. Only the initial and final facing are noted for orientation.

Other recorded behaviours are encountering conspecific, grappling with conspecific, mating, attempts to capture prey, prey handling, prey consumption, and flying. Whenever possible, the position of the beetle relative to certain reference points was noted, ie., vegetation on the sides of and in the middle of the road, numbered markers, and certain conspicuous rocks and plants. Twenty-six adult beetles were observed.

Results and Discussion

Foraging. Adults of *C. denikei* forage in open areas. They can be found on paths, old roads, cleared and burned areas, and on the many large pieces of exposed bedrock that exist throughout the habitat. If an adult strikes at a prey and misses, it will then probe the substrate and sample objects in the immediate environment in search of the prey. Otherwise, they were not seen to exhibit scavenging behaviour, which is a non-directed wandering through the habitat while sampling live and dead animal matter, a characteristic described by Swiecimski (1957) and observed in various unrelated species of *Cicindela* (Mitchell 1902; Rogers 1974; Wilson 1978). Adults of *C. denikei* obtain food by direct attack on mobile prey.

Figure 1 shows the frequency of different pauses for 26 adult *C. denikei* observed for 469 minutes, of which 94.7% of their foraging time was spent immobile. Rather than choose a single foraging site however, the beetles moved from spot to spot, pausing in each from several seconds to several minutes. There is some indication that individuals have preferences for pause duration, but it is not statistically significant.

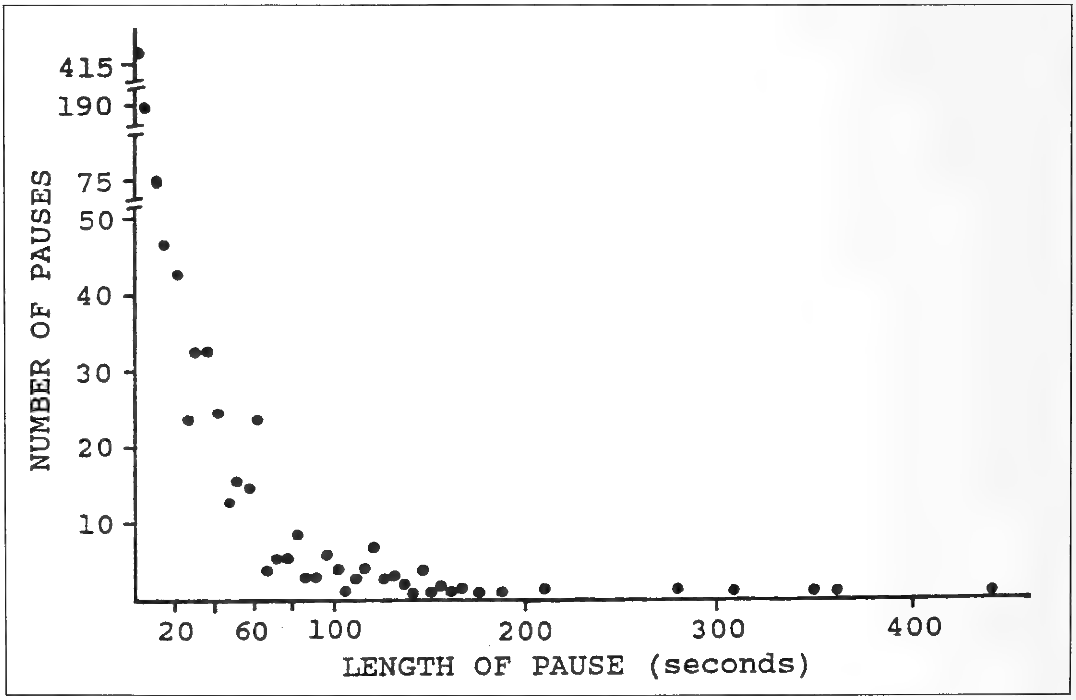

FIGURE 1. Number of pauses by foraging *C. denikei* plotted as a function of pause duration.

About 40% of all pauses are very short, from one to five seconds. As the beetle moves, it makes many short pauses, presumably in search of prey. The other 60% of the pauses range from six seconds to over seven minutes. The average pause duration is 23 seconds. If short pauses are not considered, the average pause duration is 38.4 seconds, which suggests that the beetle is an ambush predator, one that exhibits many long pauses (Swiecimski 1957) and frequently changes its ambush site. This behaviour is similar to that of *C. patruela* Dejean, a close relative of *C. denikei* (Boyd 1978; A.B. Clark, personal communication).

The mean duration of pauses prior to a prey encounter and after a prey encounter were compared with the use of a Mann Whitney U Test (Table 1). At least four, and as many as 10 pauses per encounter, five before and five after, were compared. It was not possible to use 10 pauses in all cases because of subsequent encounters with prey or conspecifics, which further modified the behaviour, or because the beetle left the study area before pausing five times. Analysis of 22 prey encounters by 14 beetles shows that there is a significant difference between the average pause length prior to the encounter and after the encounter. In addition the beetle modifies its behaviour in the vicinity of an encounter with prey. For example following an encounter, the beetle pauses more frequently (Figure 2). Swiecimski (1957) found that tiger beetles also remember the size and shape of prey and alter their behaviour accordingly.

TABLE 1. Analysis of effect of prey encounter on pause duration by adults of *C. denikei*. Group 1 is the pause duration prior to the prey encounter. Group 2 is the pause duration after the prey encounter. The difference in the means is significant at the 95% and 99% confidence levels.

	$\bar{x}$ (sec)	S.D.	n (pauses)
Group 1	13.7	19.42	127
Group 2	31.8	48.80	127
	U= 6159	Z=-3.265	P= 0.0011

Many tiger beetle prey escape by becoming immobile (Willis 1967; Wilson 1978). By remaining in the vicinity of an encounter, the beetle increases the probability that it will encounter the same prey again. A common food item of tiger beetles is ants (Willis 1967). Hence the foraging pattern of the beetle is such that it will be successful at locating and exploiting ant colonies. By moving frequently, the beetle will eventually move into the vicinity of a colony. If it encounters an ant, it will tend to remain in the area; the more prey it encounters, the longer it will remain in the area. Thus the foraging strategy of

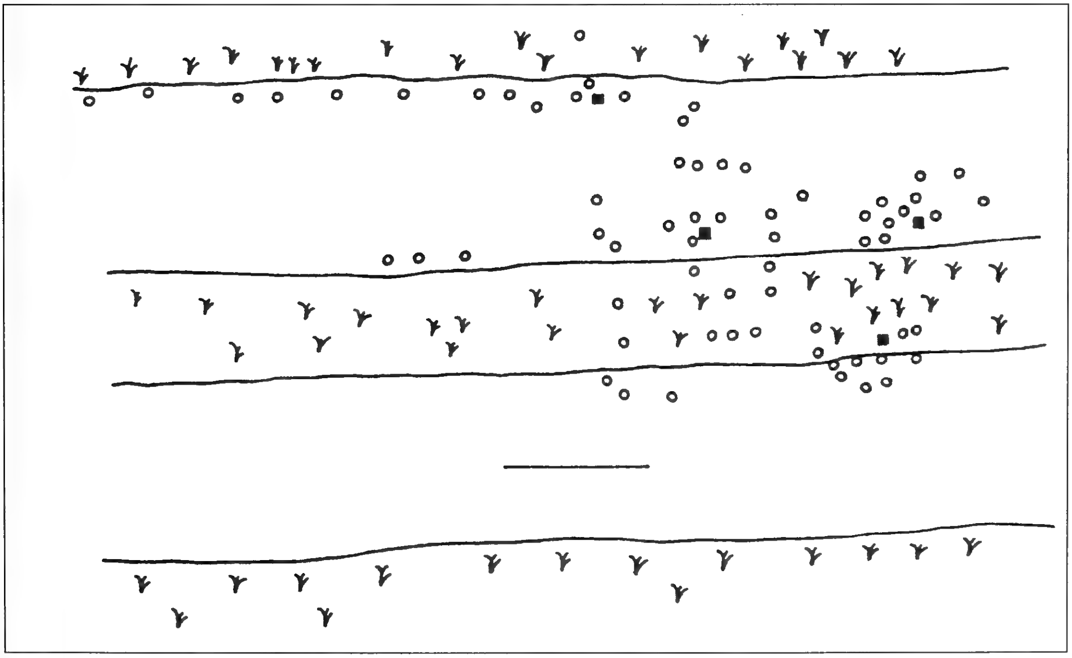

FIGURE 2. Foraging microhabitat of *C. denikei* and activity of a foraging adult. Movement of the beetle is roughly a connection of the circles. Legend: open circles, pauses of greater than five seconds duration; closed squares, prey encounters. Vegetation is indicated on sides of road tracks. Scale bar = 1 m.

the beetle will result in locating prey concentrations and remaining in the area of the concentration.

Figure 2 shows the location of long pauses by a single *C. denikei* adult as it forages along the road. As indicated, the beetle tends to move and pause close to the interface between the road and the vegetation. This behaviour is typical of all of the observed beetles. Because other tiger beetles with similar eyes have 360° vision (Kuster 1979; Kuster and Evans 1980), one would expect these beetles to pause and forage in the middle of the track where there are fewer obstructions to vision. By remaining near the interface, the beetle reduces its effective visual field, but it is probably compensated by an increased rate of prey encounter.

The road where the beetle forages is homogenous and resource-poor, thus arthropod density and diversity is low. In the vegetation where there are more resources, arthropod densities and diversity are higher, and generally highest in lush, mixed vegetation. If the beetles prey on arthropods that "spill over" from the surrounding vegetation, one would expect them to preferentially forage near the vegetation.

Table 2 shows the linear density of the beetles along the road expressed as a function of the adjacent vegetation. The linear density is highest where the vegetation is lush and mixed, and correlates with the density of adjacent vegetation. Where the road itself is overgrown, there are few beetles; they do not forage within the vegetation itself. Hence the higher density of beetles near lush vegetation is probably a result of the beetles tending to remain where they encounter more prey, and possibly for protection from terrestrial visual predators, though the latter has not yet been quantitatively demonstrated.

Foraging behaviour by adults of *C. denikei* was also analyzed using behaviour sequence matrices. Table 3 shows absolute frequency of various behaviours in the study. The "run/stop" is the most common type of movement. The number of "moves" and "runs" is misleading, however, as most of them are associated with prey and conspecific encounters. They are not as frequent during foraging.

From Table 4, it is possible to calculate the frequency of the distance a beetle moves when it changes the ambush site. The probability of a run/stop being followed by a pause is 0.425; thus for 42.5% of the events the beetle moves about 13 cm before pausing again. The beetles probably detect small to medium prey from 8 to 15 cm away, which has been observed in other species (Moore 1906; Balduf 1925; Willis 1967). Hence for 42.5% of the events, the beetle moves a distance roughly equal to the radius of its visual field. The beetle moves a distance equal to or less than the diameter of its visual field about 82% of the time that it changes the ambush site, so that the new site usually borders on, or includes, part of the old site. While foraging, therefore the beetle tends to cover an area systematically and thoroughly.

The probability that an "orient" will be followed by some type of movement is 0.75. Because the beetle has a visual field of 360°, the orient is probably used to point the body in the desired direction of travel. However, 22% of the "orients" are followed by "pause". The "orient", is usually 90° which probably serves to change the field of the beetle's stereoscopic vision which covers about 50% of the whole visual field (Kuster and Evans 1980).

Almost 25% of all movement is followed by an "orient", indicating frequent changes in direction of travel. Rather than move down the road consistently in one direction, the beetle follows the vegetation interface on one side of the road, crosses to the middle and follows the interface there. Beetles frequently forage on one track of the road and then move into the vegetation. If they find a suitable foraging area, such

TABLE 2. Linear density of tiger beetles per meter of road expressed as a function of the vegetation beside the road. The data base was 92 beetles over 420 meters of road.

Adjacent Vegetation	Beetles Per Meter of Road
Absent	0.062
Sparse	0.171
Intermediate	0.263
Lush	0.354
Lush (mixed)	0.380
Lush (grasses only)	0.267
Road overgrown, Intermediate	0.092

TABLE 3. Behaviour sequence matrix for *Cicindela denikei* showing absolute frequencies.

				FOLLOWS		
P						
R		Pause	Run/Stop	Orient	Move	Run
E	Pause		424	229	37	31
C	Run/Stop	553	545	143	16	43
E	Orient	94	288	10	17	16
D	Move	45	9	19		1
E	Run	33	28	25	5	34
S		725	1294	425	75	125

TABLE 4. Behaviour sequence matrix for *Cicindela denikei* showing relative frequencies calculated to show probability of other behaviours following a given behaviour.

	FOLLOWS				
PRECEDES	Pause	Run/Stop	Orient	Move	Run
Pause		58.8	31.8	5.1	4.3–100%
Run/Stop	42.5	42	11	1.2	3.3–100%
Orient	22	67.8	2.4	4	3.8–100%
Move	60.8	12.2	25.6		1.4–100%
Run	26.4	22.4	20	4	27.2–100%

as the other track of the road, they forage there. If they do not find a foraging site after moving 50 to 100 cm, they usually return to the road. While in the vegetation, the beetles move quickly with few pauses.

Prey Capture and Feeding. The foraging area is a circle that extends to the limit of the beetle's vision. The radius of the circle has been estimated as 10 to 13 cm for *C. purpurea* Olivier, 8 to 13 cm for *C. repanda* Dejean (Moore 1906) and 25 cm for *C. hybrida* (Swiecimski 1957). The beetles are mainly dependent on movement by the prey for detection (Swiecimski 1957; Willis 1967; Wilson 1978) and their attacks on prey have been observed as four distinct behavioural stages by Swiecimski (1957): (i) preparation; (ii) attack; (iii) capture; and (iv) consumption.

In preparation for attack, the beetle faces the prey and elevates the front of the body, possibly to centre the prey in its stereoscopic visual field. The pursuit and attack on the prey is made with short dashes characteristic of tiger beetle movement. Capture of the prey occurs when the prey is grasped with the beetle's mandibles. Wilson (1978) studied success rates of attacks by tiger beetles and found that they are successful about 50% of the time, that success depended on the type of prey, and that the beetles had a high success rate with ants (Formicidae) and low success with flies (Diptera). Detailed descriptions of the beetles' consumption of prey, including articulation of the mouth parts, can be found in Balduf (1925), Evans (1965), and Willis (1967). A.B. Clark (personal communication) studied handling time and consumption time in adult *C. patruela* and found that they average 0.48 and 3.3 min respectively.

The radius of the effective visual field of adult *C. denikei* varies with the size of the prey. On a flat surface without obstructions, large prey, about the same size as the beetle, were seen at a distance of roughly one meter. Small prey, 5 mm or less, are seen at a distance of 10 to 15 cm. As with other tiger beetles adults of *C. denikei* appear to perceive prey mainly by its movement.

Table 5 lists the frequency of certain events experienced by observed adults of *C. denikei*. Unfortunately, the definition of prey encounters and success rates are not comparable to those of Wilson (1978). In this context, prey encounter is defined as an attempted attack on a prey item, whether it is in striking range or not. The median time between captures of 78 min is comparable to 94.2 min for Arizona grassland species (Pearson and Stemberger 1980). Table 6 lists capture success rate by prey type. As with adults of *C. sexguttata* and *C. patruela*

TABLE 5. Frequency of events during foraging by adults of *Cicindela denikei*.

Event	Number	Median Time Between Events
Prey Encounter	40	12 min.
Prey Capture	6	78 ··
Conspecific Encounter	18	26 ··
Mating	3	156 ··

TABLE 6. Number of capture attempts and successful captures of various prey by adults of *Cicindela denikei*. Identifications of prey are tentative as none of them were recovered for identification.

Prey Type	Number of Attempts	Number of Captures
Diptera	13	0
Formicidae	6	3
Sphecidae (?)	5	0
Ichneumonoidea (?)	2	1
Unknown	14	2

Table 7. Amount of time spent by adults of *Cicindela denikei* in handling and consuming captured prey.

Handling Time in Seconds	Consumption Time in Seconds
35	287
28	250
7	120
13	344
30	126
10	flew w/prey
$\bar{x} = 20.5$	$\bar{x} = 225$

(Wilson 1978), adults of *C. denikei* are most successful in attacks on ants (Formicidae) and least successful with flies (Diptera). Prey capture and consumption by adults of *C. denikei* occurs as described for other tiger beetles (Balduf 1925; Swiecimski 1957; Evans 1965). Table 7 lists the handling and consumption time for prey captures witnessed. The respective means of 20.5 (N=6) and 225 (N=5) seconds are comparable to those for *C. patruela*, 30 and 200 seconds (A.B. Clark, personal communication).

Prey Types. Reviews of the prey that *Cicindela* have been observed to capture are in Willis (1967) and Larochelle (1974, 1977). Adults of *Cicindela* might be described as general predators, although "indiscriminant predators" would be a better description. Willis (1967: 195) stated that "*Cicindela* eat nearly any arthropod that they can subdue and which occurs in their microhabitat", although Wilson (1978) observed *C. repanda* refuse to attack insects that were easily captured by *C. sexguttata* and *C. patruela*. Observations of *C. denikei* allies it to its sister species in this respect. Table 6 lists the observed prey items that adult *C. denikei* captured or attempted to capture. Given the opportunity, adults will attack any arthropods near them which places them in a more generalist feeding category.

Associated Cicindela. At the pipeline road collecting site specimens of *C. denikei* were collected with *C. longilabris* Say, *C. tranquebarica* Herbst, *C. repanda* Dejean, *C. duodecimguttata* Dejean, and *C. limbalis* Klug. Adults of *C. repanda* and *C. duodecimguttata* were collected near a low-lying swampy area where *C. denikei* adults were not common. Adults of both *C. longilabris* and *C. limbalis* were more numerous about 500 m down the road where the vegetation was thicker and the soil moist. The foraging behaviour of adult *C. denikei* in the presence of other cicindelid species was not recorded, though its importance to understanding foraging patterns is duly recognized.

Acknowledgments

Special thanks to J. Pineda for typing the manuscript, B.L. Barnes for technical assistance and A.D. Macdonald for confirmation of plant names. We thank A.B. Clark of the Kellogg Biological Station, University of Michigan for sharing the results of her studies on predation by *Cicindela patruela*. Financial support was provided by NSERC grant A-4888 to R. Freitag, and by an Ontario Graduate Scholarship awarded to M. Kaulbars.

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Received 18 August 1992
Accepted 20 August 1993

Evidence of Long-term Survival and Reproduction by Translocated River Otters, *Lutra canadensis*

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Serfass, Thomas L., Robert P. Brooks, and Larry M. Rymon. 1993. Evidence of long-term survival and reproduction by translocated River Otters, *Lutra canadensis*. Canadian Field-Naturalist 107(1): 59–63.

During 1982-1984, we reintroduced 26 River Otters (*Lutra canadensis*) into Pine and Kettle Creek drainages in northcentral Pennsylvania. Results of initial radio-tracking studies indicated that habitats at reintroduction sites could support otter populations. To demonstrate long-term survival, we conducted surveys for otter scats along Pine and Kettle Creeks during September-December 1990 and April 1991, respectively. Otter scats were frequently encountered along both streams during surveys, demonstrating that otters have remained at release areas approximately six to eight years. Evidence gathered from otters accidentally caught by trappers at reintroduction areas demonstrated that six of nine otters trapped at Pine Creek and two of four at Kettle Creek had been reproduced by the respective reintroduced populations.

Key Words: River Otter, *Lutra canadensis*, Pennsylvania,reintroduction, survey, survival, reproduction.

Historical records indicate that River Otters (*Lutra canadensis*) once inhabited every major watershed in Pennsylvania (Rhoads 1903). As a result of unregulated trapping and habitat loss during the 1800s and early 1900s the state's otter population declined and became limited to northeastern Pennsylvania (Eveland 1978; Kirkland and Serfass 1989). At present, otters are classified as a species "At Risk" in Pennsylvania (Kirkland and Krim 1990) and have received complete legal protection since 1952. In 1982, we initiated The Pennsylvania River Otter Reintroduction Project to restore otters to portions of the their historic range in Pennsylvania.

During 1982-1984, we translocated 26 otters from Pennsylvania, Louisiana, New York, and Michigan into Kettle and Pine Creek drainages in northcentral Pennsylvania (Table 1). Results of radio-tracking studies conducted on otters initially released at reintroduction sites indicated that these drainages provide habitat suitable to sustain otter populations (Serfass and Rymon 1985). However, evidence of long-term survival and reproduction was necessary before we could consider the otter reintroduction project successful and confidently expand reintroduction efforts elsewhere in Pennsylvania.

During the 1980's, at least 14 States in the U.S. and one Canadian Province were involved with River Otter reintroduction projects (Polechla 1990; Ralls 1990). Although several of these projects monitored reintroduced otters by radio-tracking, only a few have provided documentation of post-release survival of otters (Erickson and McCullough 1985; Serfass and Rymon 1985) and none have demonstrated long-term survival or direct evidence of reproduction by translocated otter populations. In this paper, we document evidence indicating that reintroduced otters have established reproducing populations in northcentral Pennsylvania.

Study Areas

Pine and Kettle Creeks are located in the Allegheny High Plateau Section of the Appalachian Plateau Physiographic Province of northcentral Pennsylvania (Guilday 1985). Both streams flow southward through steep, narrow valleys to the West Branch of the Susquehanna River. The region's rugged topography supports low aquatic habitat diversity and suitable otter habitat is limited to narrow riverine corridors through valley floors.

Pine Creek is the largest tributary to the West Branch of the Susquehanna River, draining about 2500 km^2 in Potter, Tioga, and Lycoming counties. Kettle Creek is a smaller drainage (about 630 km^2) situated in the adjacent valley west of Pine Creek in Potter and Clinton counties. Large portions of each drainage are forested and occur on public land administered by the Pennsylvania Bureau of Forestry. Fishing, hunting, and trapping are popular in the region, attracting sportsmen from throughout the state. Canoeing and rafting are common activities along Pine Creek during spring.

Water quality is generally high throughout Kettle and Pine Creek drainages and each support healthy invertebrate and fish populations. Crayfish, an important otter prey item in Pennsylvania (Serfass et al. 1990), are numerous throughout both drainages. Both streams are designated "approved trout waters" and are stocked each spring by the Pennsylvania Fish and Boat Commission. Seasonal survival of trout is poor in Pine Creek because of warm water tempera-

TABLE 1. Summary of River Otter translocations along Kettle and Pine Creeks during 1982-1984.

Reintroduction Site	Release Period	Source	Number Released	Sex (M:F)
Kettle Creek	Nov-Dec 1982	Pennsylvania	4	(2:2)
Pine Creek	May 1983-July 1984	Lousiana	17	(9:8)
		Pennsylvania	3	(1:2)
		Michigan	1	(1:0)
		New York	1	(0:1)

tures during summer months; however, many tributaries support native Brook Trout (*Salvelinus fontinalis*). Smallmouth Bass (*Micropterus dolomieui*) is the predominant gamefish in Pine Creek. Kettle Creek supports a holdover stocked trout population and native Brook Trout and Brown Trout (*Salmo trutta*) occur in headwaters and tributaries.

Pine Creek's shoreline is rocky and steeply sloped with few undercut banks or backwater areas. The flow of Pine Creek is relatively straight and characterized by intermittent stretches of riffles and slow moving pools. In contrast, stream meanders, backwater areas, and riparian cover are abundant along Kettle Creek.

Methods

To determine presence of otters, we conducted surveys for otter scats along Pine and Kettle Creeks during September-December 1990 and April 1991, respectively. To maximize opportunities to find otter scats, we selected survey periods to coincide with periods of peak otter scat marking (determined during preliminary evaluations of otter scat marking habits) and survey routes to include stream sections occupied by otters during previous surveys and radio-tracking. The Pine Creek survey comprised 77 km of shoreline along a 50 km stream section. Kettle Creek was surveyed throughout both shorelines along three 3.4 km stream sections that respectively encompassed upper, middle, and lower stream reaches.

We gathered evidence from otters incidentally trapped during trapping seasons for legal furbearers to determine reproduction. Since initiating the River Otter reintroduction project in northcentral Pennsylvania, we have solicited cooperation from trappers through public information programs and news releases timed to precede fall trapping seasons. These public information campaigns were designed to encourage trappers to report trapped and released otters. Trappers also were reminded that otters killed in traps must be surrendered to Pennsylvania Game Commission personnel.

Otter carcasses received by the Pennsylvania Game Commission were provided to us for examination. To determine if otters were members of the founding population, each carcass was examined for ear-tags and x-rayed to determine presence of transmitters surgically implanted in the abdomen of 14 founders. Reproductive condition of females was evaluated by examining reproductive tracts for blastocysts and embryos (Payne 1982). Age and reproductive class were determined for each otter not identified as a founder. Juveniles were identified from older age classes by examining radiographs of epiphyses at distal ends of radii and ulnae (Larson and Taber 1980). Baculum size was used to classify males as juveniles, yearlings, and adults (Friley 1949). To verify age classification, canines from all otters examined were extracted and sent to a commercial laboratory (Matson's Laboratory, Milltown, Montana) for age determination by cementum annuli analysis (Larson and Taber 1980; Stephenson 1977). Occurrence of immature otters and those born since initiation of the otter reintroduction were judged as evidence of reproduction by founding otters.

Results

Scat Surveys

Otter scats were encountered frequently while surveying Pine and Kettle Creeks, demonstrating that otters have remained at these sites for at least 6.5 and 8 years, respectively. During surveys of Pine Creek, we counted 808 otter scats from 46 locations (range = 1-150 scats/location). Otter scats occurred at 2 of 3 survey locations (middle and upper stream reaches) along Kettle Creek where we identified 104 scats from 11 locations (range = 1-22 scats/location) and 33 scats from 9 locations (range = 1-12 scats/location), respectively.

Reproduction

Since initiating otter reintroduction efforts, we have confirmed reports of four otters (two founders and two juveniles) trapped and released along Kettle Creek and examined carcasses of nine otters killed in traps along Pine Creek (Table 2). Review of trapping incidents and examination of otter carcasses indicated that otter reproduction has occurred at both reintroduction sites. The first evidence that reintroduced otters had reproduced was obtained in October 1984

TABLE 2. Summary of River Otters killed in Pine Creek reintroduction area during trapping seasons since 1987.

Otter Number	Sex	Est. Age (yrs)[a]	Capture Date	Capture Location	Target Species	Trap Type	Release Date[b]
1-87[c]	F	4	Feb 87	Marsh Cr	Beaver	330 Conibear	–
2-87	F	<1	Dec 87	Pine Cr	Beaver	leghold	N.A.
M26[d]	M	>4	Feb-Mar 88	Pine Cr	–	–	16 May 84
1-88	F	3	29 Dec 88	Crooked Cr	Beaver	leghold	N.A.
1-89	F	<1	11 Nov 89	Pine Cr	Raccoon	leghold	N.A.
1-90	F	1	Feb 90	Marsh Cr	Beaver	leghold	N.A.
F23	F	>6	Feb 90	Marsh Cr	Beaver	220 Conibear	12 Jan 84

[a] Ages determined by cementum annuli analysis

[b] Applies to founding otters

[c] Presumed founder, but no ear-tags

[d] Decomposed carcass recovered near Pine Creek; presumed accidentally trapped and discarded by trapper

when the skinned carcasses of two illegally trapped juvenile males were found by a fisherman along Pine Creek. These otters are thought to have been conceived by female (F16) (Serfass and Rymon 1985) prior to her translocation from northeastern Pennsylvania. Consequently, we did not consider these births evidence that the entire reproductive process had been completed by reintroduced otters.

The first indication that mating and parturition had occurred was obtained during January 1985 when two otters were accidentally caught in #3 leg-hold traps (14 cm jaw spread) set by a beaver trapper along Kettle Creek. The otters apparently were traveling together when captured and were presumed to be siblings. The trapper photographed the otters prior to releasing them from his traps and reported that they were not ear-tagged and were of similar size (approximately 4.5 kg). From a photo of one of the otters where the trap was visible, we extrapolated an estimated total length of <90 cm by computing a ratio of trap size to total length. Comparison of this total length to measurements of otters sorted by age class in Idaho (Melquist 1983), Ontario (Stephenson 1977), and Pennsylvania (Serfass 1984) indicated that an otter in this size range is very likely a juvenile. We judged the otters to be juveniles based on review of the photographic record and the trapper's description of their size and behavior. Furbearer biologists (Greg Linscombe and Noel Kinler, Louisiana Department of Wildlife and Fisheries and Mark Brown, New York State Department of Environmental Conservation; personal communications) reviewed the photographs and supported our conclusion that they were of juvenile otters.

Since 1987 we have recovered and examined seven otters killed by trappers along Pine Creek of which four were judged to have been reproduced by the translocated population (Table 2). Among otters considered born at Pine Creek, 2 (2-87,1-89; Table 2) were clearly identified as juveniles by presence of open epiphyses (Larson and Tabor 1980). Ages determined by cementum annuli analysis verified classification of these otters as juveniles and demonstrated that otters 1-88 and 1-90 (Table 2) were born since initiation of the reintroduction project. Although ear-tags were missing from the three remaining otters, two were confirmed as original releases by presence of transmitters. These otters were identified as M26 and F23 (Serfass and Rymon 1985) and had survived along Pine Creek for approximately four and six years, respectively. Both otters were in good condition when trapped and had gained weight since their releases (approximately 3 kg and 1 kg, respectively). The remaining otter (1-87; Table 2) was believed to have been an original release (non-transmittered) that also did not retain ear-tags. Blastocysts or embryos were not detected during examination of reproductive tracts from three otters classified as adult females (Table 2).

Otters have succeeded in colonizing Marsh Creek, the largest tributary of Pine Creek. Marsh Creek, a deep, slow gradient stream with abundant riparian cover, appears to provide important otter habitat in Pine Creek drainage. Otters were known to use Marsh Creek during radio-tracking (Serfass and Rymon 1985). Their continued use of Marsh Creek is evidenced by an abundance of otter scats and three otters killed there during trapping seasons (Table 2). Otters are also succeeding in expanding their range to Crooked Creek which shares common headwaters with Marsh Creek. As a result, Marsh Creek provides a corridor by which dispersing otters can enter Crooked Creek. This appears to be the case with female otter 1-88 which was trapped on Crooked Creek 29 December 1988.

Discussion

Based on evidence of long-term survival and reproduction, otter restoration efforts in northcentral Pennsylvania appear to have been successful. We are confident that an expanding, self-sustained otter population has been established along Pine Creek. Otters have extended their range beyond areas occupied during initial radio-tracking (Serfass and Rymon 1985) and now occupy at least 95 km of Pine Creek (Serfass et al. 1987). Evidence of otters expanding beyond Pine Creek to major tributaries and adjacent drainages is demonstrated by their occurrence on Marsh and Crooked Creeks. We suspect otters dispersing from Pine Creek have supplemented the Kettle Creek population. Although only four otters were released along Kettle Creek, otter scats were common in two of three survey routes along this stream.

Minimizing losses of otters due to accidental capture by trappers may present the biggest challenge to maintaining reintroduced populations in low-diversity aquatic habitats such as those encountered in northcentral Pennsylvania. At present, trapping does not appear to have seriously limited the reintroduced otter populations. However, concern resulting from loss of three females during the 1989-1990 trapping season (Table 2) has prompted the Pennsylvania Game Commission to implement special trapping regulations along Pine Creek to provide additional protection to otters.

Release of 22 otters (11M, 11F) appears to have been sufficient for establishing a self-sustaining population along Pine Creek. However, because otters have low reproductive rates (Liers 1958), maintain low population densities (Melquist and Hornocker 1983), and are limited to semi-aquatic habitats, we consider small otter populations particularly vulnerable to extirpation through stochastic processes (i.e., change in sex ratios, poor reproductive years, and loss of genetic diversity) (Shaffer 1981). To maximize opportunities to maintain otter populations, we recommend concomitant otter releases in adjacent drainages. Such a release strategy provides for depleted populations to be supplemented by dispersing otters and promotes maintenance of genetic diversity through gene flow between populations. This release strategy appears to have been beneficial in maintaining otters along Kettle Creek and will be promoted during planning for future otter releases in Pennsylvania.

Louisiana otters adapted well to environmental conditions in Pennsylvania and were important during initial phases of the project when mechanisms were not in place to obtain adequate numbers of otters from other areas. However, because of concern over potential differences among regional genotypes we prefer to obtain otters from less distant populations. Since concluding reintroductions on Pine Creek, we have released an additional 54 otters at three subsequent reintroduction sites in northcentral and western Pennsylvania (Serfass et al. 1993). Among these otters, all were obtained from northern populations and 51 came from northeastern Pennsylvania and surrounding states (Serfass et al. 1993). Based on preliminary studies, these reintroductions also appear to have succeeded in establishing otter populations.

Acknowledgments

Funds and support for this project were provided by the Pennsylvania Game Commission and Pennsylvania Wild Resource Conservation Fund (nongame tax-checkoff). We thank C. Dubrock, J. Hassinger, A. Hayden, and D. Sheffer of the Pennsylvania Game Commission and F. Felbaum of the Pennsylvania Wild Resource Conservation Fund for their ongoing cooperation and support of River Otter recovery efforts in Pennsylvania. We are grateful to T. Swimley, T. Stecko, D. Krupa, and B. Plowman for their participation in surveys.

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Received 1 September 1992
Accepted 15 July 1993

Observations on Sympatric Tundra, *Cygnus columbianus*, and Trumpeter Swans, *C. buccinator*, in North-central Alaska, 1989–1991

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An aerial census of summering swans in Alaska's north-central interior in 1989 showed 25 Tundra (*Cygnus columbianus*) and 35 Trumpeter Swans (*C. buccinator*) on a sympatric nesting range. Four of six Tundra Swan nests were in the Kanuti River drainage, and four of seven Trumpeter Swan nests were in the Kanuti-Chalatna Creek drainage. Tundra Swan nest lakes averaged 169 ± 7% (CV) m elevation, and Trumpeter Swan, 181 ± 10% m. Combined densities of nests for both species was 1 nest/625 km^2 of suitable habitat. Most Tundra Swan nest lakes occurred in meadow, whereas Trumpeter Swans favored forest. Six of eleven and six of sixteen Tundra and Trumpeter pairs had clutches averaging 4.7 ± 10.1% and 4.0 ± 15.8% eggs, respectively. Recruitment at fledging was 20% for Tundras and 6–11% for Trumpeters. The present population and available habitat favors the marginal expansion of Trumpeter Swans, though in late years, it is not likely all young would fledge by freeze-up.

Key Words: Tundra Swan, *Cygnus columbianus*, Trumpeter Swan, *Cygnus buccinator*, Interior Alaska.

There is a need for information on status, habitat requirements and production of native swans in North America because of the different conditions to which each is subjected. Aerial surveys of Tundra (*Cygnus columbianus*) and Trumpeter Swans (*Cygnus buccinator*) in Alaskan breeding grounds have contributed significantly to our knowledge on populations and productivity (*see* Hansen et al. 1971; Lensink 1973; Wilk 1988; Conant et al. 1991). Each species occupies mainly separate breeding ranges delimited by the treeline (Conant et al. 1991). Hence, species identification during aerial surveys have been assigned largely according to distribution (Conant et al. 1991).

In the Koyukuk River drainage of west central Alaska, tundra and forest ecosystems overlap. In this broad ecotone, both species were observed in very low densities in summer (R. M. Oates, personal communication, 1987; Loranger and Lons 1988). This overlap makes aerial censusing difficult, and raises questions about the interaction of these species. In 1989, I conducted a baseline census of the swan population in the overlap zone, north of the Yukon River and east of the Koyukuk River, to determine the numbers and distribution of each species in the Kanuti National Wildlife Refuge (KNWR), along with nesting habitat and production data. I include additional observations from 1990 and 1991.

Study Area

The KNWR encompasses 6500 km^2 and straddles the Arctic Circle (Figure 1). About 3750 km^2 (58%) of the refuge consists of lowlands with ponds and marshes. The lowlands are surrounded by foothills and mountains separating the area from other populations of swans. Sixty percent of the area is forested with spruce (*Picea glauca* and *P. mariana*), White Birch (*Betula papyrifera*), Quaking Aspen (*Populus tremuloides*) and Balsam Poplar (*P. balsamifera*). Dwarf shrub and graminoid tussock peatland characterizes much of the lowland (Talbot et al. 1985). A mosaic of these two broad habitats characterizes the breeding area. The study area also included the largest lake in the region (approximately 8.3 × 5.8 km at largest axes) — Todatonten, three km west of the refuge (Figure 1), which is included in all references to the KNWR.

Methods

Phenology Overflights: Four overflights of the refuge were carried out between 27 April and 26 May 1989 to estimate snow and ice cover in spring break-up and to document the arrival of migratory waterfowl. I estimated percentage ice and snow cover from systematic samples on ≥ 50 lakes and ≥ 20 pre-determined 2 × 4 km ground plots in the lowlands during each flight.

Nesting Census and Follow-up: I conducted a census of all potential swan nesting areas between 9 and 13 June 1989 in a Bell 206B Jet Ranger III helicopter, and revisited nests located in 1989 on 14–15 June 1990 and 13 June 1991. The survey altitude was 90–210 m above ground level, at ground speeds of 50–150 km/h. Having observed both species of swans in the wild for years, I distinguished them confidently based upon differences in body size, neck and body posture; bill shape, color and size

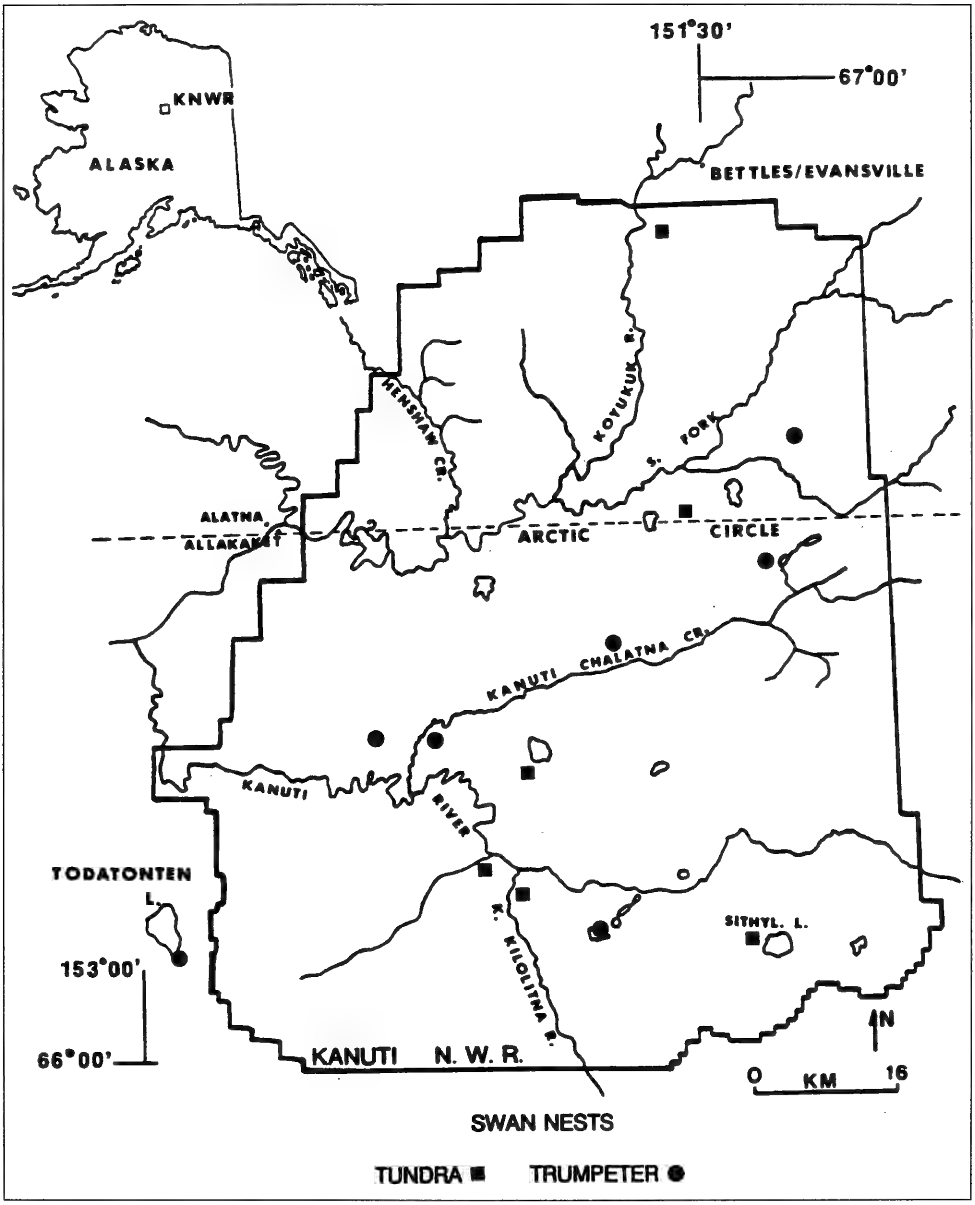

FIGURE 1. The study area and distribution of swan nests recorded in June 1989.

(Jordan 1988); and nest territory defense behavior (raised wings, highly aggressive and tenacious in Trumpeter Swans, personal observation). I determined clutch size by a quick lateral approach and departure from each nest. We landed on three occasions to verify species previously identified from the helicopter and the aerial observations were confirmed by the ground observations in all cases.

All KNWR wetlands that appeared to be suitable for swans were searched in 1989, including adjacent terrestrial habitat. All observations of swans were marked on 1:63 360 (1 cm = 0.634 km) topographic quadrangle maps.

The fate of each nesting pair or family group was monitored during scheduled and incidental overflights in 1989, and occasionally in 1990 and 1991. When a nest was judged unsuccessful (no young produced), or all cygnets in a brood were lost, I ended monitoring of the associated pairs, except in 1989 when I conducted an overall reconnaissance on

12 of the 13 nests on 24 August. The final overflight of the area was carried out 11 October 1989.

A great wildfire occurred in the refuge in 1990, precluding survey overflights in July and August. However, I re-surveyed the area in Piper Supercub and Cessna 206 aircraft during the 1990 Alaska Trumpeter Swan census 28 August–8 September. There were no flights in 1991 following the nesting survey in June.

Nest Lakes and Habitat Classification: I recorded data on nest site and habitat of nest lakes from the air during the initial helicopter survey and in subsequent overflights in 1989. I described the terrestrial habitat setting of each nest lake by estimating from aerial photographs the percentage of shoreline habitat immediately surrounding (shoreline to ≥ 50 m back) each lake. I also measured size and elevation of lakes and the amount of cover of interspersed vegetation (island, peninsula) or earthen island in each from maps and photos I had taken of each nest lake.

Results

Phenology, Nesting Chronology and Hatching

1989: Ice on the Koyukuk River broke up on 8 May 1989 in Bettles of the northern part of the refuge. Swans were first seen on melt water lakes in the Kanuti area on 10 May, when lakes were still 85% ice-covered and snow cover was 45%. Peak arrival of swans occurred two weeks later and ice and snow were gone by early June. Hatch of cygnets began about 25 June and peaked in the first week of July.

1990: The Koyukuk broke on 10 May 1990 at Bettles.

1991: An earlier break-up occurred in 1991, and I observed a pair of swans in overflow on a lake in the SE part of the refuge on 21 April. Data from the Koyukuk were not available.

Populations

Sixty swans were tallied (25 Tundra and 35 Trumpeter Swans) in June 1989, including 11 and 16 pairs of Tundra and Trumpeter Swans, respectively. Only three singles of each species were seen.

Fifty-two white swans (22 pairs, 5 singles, 3 flocked) were recorded during fixed-wing surveys between late August and early September 1990; ≥20 of which were Trumpeter Swans.

Nest Distribution, Density and Habitat 1989

Tundra Swan nest lakes averaged 169 ± 7% m elevation (range = 158–194 m) and Trumpeter Swans, 181 ± 10% m (range = 162–219 m; $t = -1.26$, df = 11, $P > 0.20$). Four of six Tundra Swan nests were in the Kanuti River drainage, and four of seven Trumpeter Swan nests were in the Kanuti-Chalatna Creek drainage (Figure 1).

Density of swans was 1 Tundra/163 km^2 and 1 Trumpeter/111 km^2 of suitable habitat. Combined densities of nests was 1 nest/625 km^2 averaged across the potential nesting area. Although nests were widely spaced, average interspecies straight-line distances measured on topographic maps (15.6 ± 50.0% km; $N = 7$ Trumpeter Swans, 6 Tundra Swans) were closer than intraspecies distances. The mean linear closest distance between Tundra Swan nests was 20.3 ± 56.7% km and 17.6 ± 20.5% km between Trumpeter Swan pairs.

Most Tundra Swan nest lakes occurred in meadow (dwarf shrub-graminoid tussock peatland [as described by Talbot et al. 1985]), whereas Trumpeter Swans favored forest (Table 1). However, over the three year period, I observed a few Tundra Swan nests on lakes in boreal forest and some Trumpeter Swan nests on lakes in open meadows.

Four of six Tundra Swan and two of seven Trumpeter Swan nests were on islands with an earthen substrate. Two Tundra Swan nests and four Trumpeter Swan nests were constructed in emergent vegetation in lakes (1989). I could not distinguish the species of swan from the air by differences in nest construction as described by Hansen et al. (1971).

Most swan nest lakes were characterized by an interspersion of islands and peninsulas of earth and emergent vegetation over 20–25% of the surface area (Table 2). Half of the Tundra Swan nests were without inlets or outlets and just more than half the Trumpeter Swan nest lakes had only outlets. No lakes had more than one pair.

Clutches, Hatching and Fledging

In 1989, six of eleven and six of sixteen Tundra Swan and Trumpeter Swan pairs had clutches, respectively. Tundra Swans had larger clutches than Trumpeter Swans in two of the three years (Table 3). Trumpeter Swan pairs defended clutchless nests in five observations during the three years of survey. These swans were presumed to be pre-breeders.

Tundra Swans hatched ≥ 1 cygnet in two of six nests, whereas Trumpeter Swans hatched four of six nests which contained eggs, but both species hatched

TABLE 1. Composition, cover (mean % ± CV), and frequency (% of nest lakes) of habitat along immediate shoreline to ≥50 m back of nest lakes of Tundra ($N = 6$) and Trumpeter swans ($N = 7$) in the Kanuti National Wildlife Refuge, Alaska, 1989.

	Tundra		Trumpeter	
Habitat	Cover[1]	Frequency	Cover	Frequency
Forest[2]	63 ± 63	100	95 ± 12	86
Meadow	73 ± 10	50	65 ± 76	29

[1] Nest lakes with no cover in habitat category were not calculated in cover value.

[2] Includes *Picea* forest; *Betula-Picea* forest; scattered *Betula-Picea* woodland, dwarf forest; *Picea* burn, *Betula* regeneration; and *Betula* forest (after Kessel 1979).

TABLE 2. Mean surface area, interspersion of islands and emergent vegetation cover, and occurrence of inlets/outlets in nest lakes of Tundra (N = 6) and Trumpeter Swans (N = 7) during the incubation period (June) in the Kanuti National Wildlife Refuge, Alaska, 1989.

	Tundra	Trumpeter
Surface area (km^2 ± CV)	0.27 ± 92	0.33 ± 143
Range	0.08 – 0.75	0.03 – 1.45
Interspers. of islands/veg. (%)	20.4 ± 53	23.2 ± 74
Range	2.5 – 37.5	15.0 – 62.5
Lake inlet/outlet (% with both)	33	14
Lake outlet only (%)	17	7

TABLE 3. Sizes of clutches (mean ± CV [N]) of Tundra and Trumpeter Swans recorded in the Kanuti National Wildlife Refuge, Alaska, June 1989–1991.

	Tundra	Trumpeter
1989	4.7 ± 10.1 (6)	4.0 ± 15.8 (5)[1]
1990	4.8 ± 10.5 (4)	4.0 ± 40.8 (6)
1991	2.0 (1)[1]	5.0 ± 28.1 (6)[1]
Total	(11)	(17)

[1] Another nest with clutch was recorded, but total eggs not counted.

similar proportions from total observed eggs in clutches (10 of 28 [36%] vs. 9 of 24 [38%] for Tundra Swans and Trumpeter Swans, respectively) in 1989.

By late August, 1989, cygnet numbers were 18% of the original clutch size for Tundra Swans and 17% for Trumpeter Swans. Only one pair of Tundra Swans fledged young. This pair laid five eggs and fledged five young. The size of three Trumpeter Swan broods in late August was 1, 1, and 2 young, respectively. In late August 1990, I recorded total cygnets from seven of eight Trumpeter Swan broods with an average of 3.4 ± 91.9% (range = 2–5) young. This mean was 85% of the average clutch size I recorded for six Trumpeter Swan nests in June (see Table 3), significantly larger than the previous year's sample.

In mid-September 1989, Trumpeter Swans were still with young (no Tundra Swans with young were seen) and on 11 October the last observed brood was about 100 days old and may have been volant. Most lakes were nearly completely covered with ice at that time (P. A. Martin, personal communication). I could not ascertain the fates of two other Trumpeter Swan broods by freeze-up as they were not seen on the lakes that they previously occupied.

In 1989, only two of eleven Tundra Swan pairs produced young and only one pair fledged young. Three of sixteen Trumpeter Swan pairs were productive, and 1-3 pairs fledged young. Recruitment (number of young as proportion of the population) at fledging was 20% for Tundra and 6-11% for Trumpeter swans.

Discussion

The summer range of both species of swans in Alaska has expanded in recent years (King and Conant 1981; Conant et al. 1991). However, it appears that there is much available habitat in the northern interior not occupied by swans. To the east of the Kanuti, in the Yukon Flats, vast wetlands supported few swans (King and Conant 1981). Hypotheses suggest that significant temperature changes in Interior Alaska during this century may have stimulated Trumpeter Swans to pioneer these northernmost latitudes (King and Conant 1981), or that a remnant population survived in unglaciated valleys, providing the nucleus of this expanding population (King 1981).

Parameters of productivity I recorded were low for both species (cf. Bellrose 1980). Banko (1960) speculated that less desirable territories may have accounted for lower reproductive success in an expanding population of Trumpeter Swans in Montana. The low productivity of both species in the Kanuti may also have been related to the inexperience of younger and/or pioneering individuals in new breeding areas.

At the Arctic Circle, Trumpeter Swans may be nesting in the northern limit of their range. Smaller lakes were frozen over when a pair of Trumpeter Swans with young was still occupying a larger nest lake (11 October 1989) which had ice cover on an estimated two-thirds of its area. The young were expected to have fledged between 5 and 20 October. Tundra Swans have a shorter growth period (60–75 days) and apparently fledged long before freeze-up. In late springs (or early autumns) it is not likely that all young Trumpeter Swans would fledge by freeze up.

I believe that the present population and available habitat of KNWR swans favors the marginal expansion of Trumpeter Swans. I observed a least two nests previously occupied by Tundras Swans in 1989 that were occupied by Trumpeter Swans in subsequent years. The reverse was not documented. In one case, I recovered a fresh Tundra Swan carcass guarded by two Trumpeter Swans on a lake shore < 1 km from an active Tundra Swan island nest being incubated by an adult (22 June 1989). An examination of the carcass revealed a sexually mature male adult that died of traumatic exsanguination and shock as the direct result of a compound fracture of the distal left humerus (R. W. Van Pelt, DVM, Ph.D., Alaska Veterinary Medical Center, Fairbanks, Alaska, personal communication, case number VP-54-89, 24 June 1989). I believe this male was defending its breeding territory, but lost the conflict to the pair of Trumpeter Swans. In 1990, a Trumpeter Swan pair occupied this same nest island, defended by Tundra Swans in 1989 (unnamed lake, 66° 10' N lat., 152° 10' W long.).

The quinquenniel Trumpeter Swan census conducted in Alaska does not distinguish species in overlapping range — all swans were counted as Trumpeter Swans because previously those counts were based upon broad habitat ranges — boreal forest for Trumpeter Swans, the treeless region for Tundra Swans. Accordingly, the study area had not been included in surveys of Tundra Swans. In the late 1990 census, I could only verify a sample of Trumpeter Swans, but no Tundra Swans. Tundra Swan families may have dispersed from nesting areas by that time. Although Trumpeter Swans comprised the majority of the swans occurring in the tundra-boreal forest ecotone (Loranger and Lons 1988; this study), the observations reported here may indicate likely small count discrepancies of the Tundra and Trumpeter swan populations from Alaska's interior in the statewide census.

If both species continue to occupy the same range, future censuses might best be served by initiating counts in early to mid-September, or as late in the season as possible. My observations from fixed-wing aircraft in late August-early September 1990 could not verify the presence of Tundras, but 60% of the swans observed were not identified to species. The growth period of the smaller Tundra Swan requires less time than that of the Trumpeter Swan, therefore Tundra Swan young were capable of flight sooner (1989). My observations suggest a differential migration between the species that may leave open a survey window to count Trumpeter Swans after Tundra Swans have left the area, and prior to the migration of Trumpeter Swans.

Acknowledgments

A. Rhynschmidt piloted the census helicopter in 1989. J. G. King (USFWS, retired, Juneau, Alaska) and R. W. McKelvey (CWS, Delta, British Columbia) reviewed an early version of the manuscript. Two anonymous reviewers helped improve the published version. Funds from the Kanuti National Wildlife Refuge made the census possible. USFWS-Migratory Bird Management funded the KNWR portion of the 1990 Trumpeter census.

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Received 2 September 1992
Accepted 18 August 1993

A Review of Nest Heights of Three *Buteo* Species in Eastern and Central North America

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An analysis of data from the literature on three congeneric eastern and central woodland hawks indicates significant differences between the species' nest heights. Red-tailed Hawks (*Buteo jamaicensis*) generally placed their nests highest, followed by Red-shouldered Hawks (*B. lineatus*) and Broad-winged Hawks (*B. platypterus*). Nest height variability was not significantly different between the hawk species. Nest height may be a compromise between constraints of habitat requirements, differences in body morphology among the species and nest approach method.

Key Words: Red-tailed Hawk, *Buteo jamaicensis*, Red-shouldered Hawk, *Buteo lineatus*, Broad-winged Hawk, *Buteo platypterus*, nest heights, morphology.

Broad-winged Hawks (*Buteo platypterus*), Red-shouldered Hawks (*B. lineatus*) and Red-tailed Hawks (*B. jamaicensis*) are broadly sympatric throughout much of eastern and central North American deciduous and mixed forests (Brown and Amadon 1968), but these species are often found nesting in different habitats. Red-tailed Hawks nest near open agricultural areas with small scattered woodlots and fencerows (Bohm 1978; Bednarz and Dinsmore 1982; Peck and James 1983) and also in heavily forested regions (Titus and Mosher 1981; Spieser and Bosakowski 1988). However, Orians and Kuhlman (1956) found only about 10% of Red-tailed Hawk nests enclosed in dense forest. Red-shouldered Hawks and Broad-winged Hawks are typically associated with more extensively wooded areas that often include small forest openings and wet areas (Titus and Mosher 1981; Peck and James 1983; Rosenfield 1984). In this paper, I examine data from the literature to see if differences in nesting habitat are also reflected in the pattern and variability of these species' nest heights. Although nest sites probably constitute a relatively stable geographic resource (Parker 1986), a shortage of suitable nest trees may be a locally limiting factor in otherwise acceptable raptor territories (Titus and Mosher 1981).

Study Area and Methods

I searched the literature up to 1989 for studies of nest tree use by the three species in eastern and central North America. I found 5 references with usable data for Broad-winged Hawks, 11 for Red-shouldered Hawks and 6 for Red-tailed Hawks (Table 1). Most of these studies provided data for only one species. Analyzed studies were required to include all the following: number of nests studied (N), mean nest height ($\overline{x}$), and either the standard deviation (SD) or range (R) of nest heights. When SD was not specified, it was estimated from R and N, following Snedecor and Cochran (1967: 39). Although the efficiency of R as an estimator of SD declines with increasing N, I have included such data because they are still useful for the purposes of this paper. The coefficient of variation ($CV = SD/\overline{x})\bullet 100)$) was also calculated. I encourage the consistent inclusion of $\overline{x}$, SD, R and N in all future studies of raptor life history traits. I used the SAS analysis of variance (SAS Institute 1982) with the results of each study ($\overline{x}$ and SD) treated as a separate datum, regardless of N. In two cases, I combined data from two Red-shouldered Hawk studies from the same geographic area: Campbell (1975) with Sharp and Campbell (1982) and Stewart (1949) with Henny et al. (1973).

Results

A one-way analysis of variance of the mean nest heights from the 22 studies surveyed showed a significant difference (F = 11.2; 2, 19 df, $p = 0.0006$) among the three species. Generally, Red-tailed Hawks placed their nests highest, followed by Red-shouldered Hawks and Broad-winged Hawks in decreasing order (Table 1). Scheffe's test revealed that the mean nest height of Broad-winged Hawk was significantly ($p < 0.05$) lower than that of Red-tailed Hawks. Mean nest height of Red-shouldered Hawks was between the two other species but not significantly different from either one. Three studies that examined nest heights of at least two of the three species also reflected this general pattern in nest height (Titus and Mosher 1981; Armstrong and Euler 1982; Bednarz and Dinsmore 1982). A more recent study of the two smaller species (Crocoll and Parker 1989) also supported this trend.

I also looked for differences in nest height variability among the three forest hawks. The CVs of nest height for the 22 studies surveyed ranged from approximately 10 to 35%. An analysis of variance of

TABLE 1. Nest heights of Broad-winged, Red-shouldered, and Red-tailed hawks in Eastern and Central North America.

Species and Literature Source	Location	Nest Height (m)		
		N	$\bar{x}$	SD
Broad-winged Hawk				
Matray 1974	New York	14	13.3	1.4
Keran 1978	Minnesota/Wisconsin	29	9.4	1.4
Titus and Mosher 1981	Maryland	24	13.7	30.0
Armstrong and Euler 1982	Central Ontario	27	11.8	2.8
Rosenfield 1984	Wisconsin	72	8.2	2.7
Red-shouldered Hawk				
Wright 1916	New York	69	12.7	3.0*
Stewart 1949 and Henney et al. 1973	Maryland	136	15.8	2.4
Portnoy and Dodge 1979	Massachusetts	12	12.0	1.7
Titus and Mosher 1982	Maryland	10	13.4	3.4
Campbell 1975 and Sharp and Campbell 1982	Southern Ontario	14	14.4	4.1*
Kimmel and Frederickson 1981	Missouri	13	13.9	2.3
Armstrong and Euler 1982	Central Ontario	9	14.0	3.6
Bednarz and Dinsmore 1982	Iowa	12	19.1	4.8
Morris et al. 1982	SW Québec	54	14.0	3.6
Woodrey 1986 and personal communication	Ohio	15	14.2	2.9
Red-tailed Hawk				
Orians and Kuhlman 1956	Wisconsin	49	17.4	4.0
Beardslee and Mitchell 1965	New York	100	17.6	2.7*
LeDuc 1970	SE Minnesota	8	17.8	3.9*
Bohm 1978	Central Minnesota	72	13.6	1.4
Titus and Mosher 1981	Maryland	13	17.6	3.2
Bednarz and Dinsmore 1982	Iowa	26	17.1	4.2

*SD estimated from N and range of nest heights

the CVs of nest height revealed no significant differences among the three hawk species (F = 0.42; 2,19 df, p = 0.66).

Discussion

The vertical placement of a nest is probably the result of several interacting factors. However, not all trees and tree species are completely suitable for nest location because the size and branching geometry must produce an acceptable fork within the preferred vertical range of the species (Titus and Mosher 1987). Peterson (1979) and Bednarz and Dinsmore (1982) could detect no significant preferences for any particular tree species beyond their availability. There is also some evidence (Dijak et al. 1990) that some characteristics of the nest tree (i.e., tree size, understory) influence nest success.

Lower wing loading (body weight/wing area) and increased tail area are usually associated with increased maneuverability (Mueller et al. 1981b) and with species that need wider avenues of approach to the nest (Petersen 1979; Speiser and Bosakowski 1987). Red-tailed Hawks weigh about 1.7 times as much as Red-shouldered Hawks and about 2.5 times as much as Broad-winged Hawks (Brown and Amadon 1968; Dunning 1984) However, the Red-tailed Hawk's length is only about 15% more than the Red-shouldered Hawk's and about 35% longer than the Broad-winged Hawk's (Brown and Amadon 1968; Godfrey 1986), and its tail is about 5 to 10% longer than that of the Red-shouldered Hawk and 35 to 40% longer than that of the Broad-winged Hawk. According to Poole (1938), the Broad-winged Hawk has the lowest wing loading (0.371 g/cm^2) of the three buteos. The two smaller hawks generally have longer tails and wing per unit bodyweight. Data from Mueller et al. (1976, 1981a, 1981b) indicate that, in the accipiters, larger species also tend to have higher wing loadings.

These morphometric combinations suggested that the Red-tailed Hawk may be somewhat less maneuverable in confined forest locations than either of its two congeners. To compensate for decreased maneuverability, its nests could be positioned higher in the forest canopy in order to improve accessibility. Accessibility may be particularly important in the vertical positioning of Red-tailed Hawk nests (Petersen 1979; Titus and Mosher 1981, 1987). The relatively high position of the Red-tailed Hawk nests in the nest tree, usually at least 75% (Titus and Mosher 1981), supports this theory. Red-tailed Hawks might further improve the accessibility of their nests by using trees that extend above the canopy, or that occur at the edge of wooded areas or on steep slopes (Spieser and Bosakowski 1988). Spieser and Bosakowski (1988) suggest that "flight energetics" may play a role in nest site selection for large, soaring raptors. Smaller body size and a consequently increased ability to maneuver through heavily-wooded areas may have reduced the problem of accessibility for Red-shouldered and Broad-winged hawks which place their nests lower in the forest canopy (relative nest height — usually 50 to 60%; Titus and Mosher 1981; Morris et al. 1982; Woodrey 1983 and personal communication). Bednarz and Dinsmore (1982) also suggested that the morphology of Red-shouldered Hawks should at least "theoretically" improve their maneuverability. Moore and Henny (1983) suggested that placement of nests of three *Accipiter* species may also be influenced by accessibility, with an apparent association between increasing body size and changes in the vegetative structure of nesting habitat. They concluded that this factor may be important for species with "inferior flight control". Similar general patterns in nest heights of both the buteos and accipiters suggest that such differences in nest height may be influenced by differences in habitat selection, flight behavior, morphology and consequent accessibility of the nest.

It is also possible that some of the interspecific and intraspecific differences in nest height indicated in this review could be partially accounted for by regional differences in habitat, including forest composition and structure, climate and geography, all factors that could also influence what trees are available for nesting hawks. Research that addresses both local raptor communities and broader geographic patterns in raptor nesting habitat (i.e., Titus and Mosher 1988) will be valuable in starting to understand intraspecific and regional differences.

Acknowledgments

I am grateful to all the researchers whose results I have used in this paper. I also acknowledge the support of the McGill University Computing Centre, Mono Cliffs Outdoor Education Centre and the North York (Ontario) Board of Education.

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Received 4 September 1992
Accepted 31 August 1993

Seabird Predation of Pacific Herring, *Clupea pallasi,* Spawn in British Columbia

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Haegele, C. W. 1993. Seabird predation of Pacific Herring, *Clupea pallasi,* spawn in British Columbia. Canadian Field-Naturalist 107(1): 73–82.

The abundance of seabirds and their impact on Pacific Herring (*Clupea pallasi*) eggs was estimated for the largest herring stock, of approximately 25 000 tonnes, in the Strait of Georgia. Maximum number of birds was 50 407 in 1989 and 61 378 in 1990. I estimated that seabirds consumed 3.1% and 3.8% of the spawn deposited in 1989 and 1990. Gulls, scoters, and other ducks were the main predators. Seabirds may remove most of the eggs when herring stocks are low, and most of the eggs from spatially or temporally isolated spawns even when herring stocks are not low.

Key Words: Pacific Herring, *Clupea pallasi,* spawn, British Columbia, predation, seabirds.

The British Columbia coast supports a large population of wintering seabirds, including a large number of migratory seaducks (Vermeer 1983; Butler et al. 1989; Savard 1989). Many of these seabirds concentrate nearshore in association with the spawning areas of Pacific Herring (*Clupea pallasi*). In British Columbia, herring spawn in the intertidal and upper subtidal zones in the late winter and early spring, and the eggs hatch after approximately two weeks (Haegele and Schweigert 1985). During this period seabirds feed on herring spawn. Estimates of egg loss to bird predation in several previous studies varied considerably from 3–100%, with most reporting 40–60% (Munro and Clemens 1931; Cleaver and Franett 1946; Outram 1958; Bayer 1980; Spratt 1981; Palsson 1984; and Haegele and Schweigert 1989). The magnitude of this egg loss is of concern primarily because herring stock assessments in British Columbia use spawn survey data to estimate spawner biomass (Schweigert et al. 1985, 1990). Other jurisdictions in the NE Pacific Ocean also employ spawn surveys to estimate herring spawner biomass: California (Spratt 1981), Washington State (Burton 1990) and SE Alaska (Collie 1990). If egg loss before spawn surveys is considerable then spawner biomass may be underestimated.

In this study two approaches were used to estimate the potential impact of seabird predation on herring spawn. (1) A field study estimated the abundance of seabirds and the impact of their predation on the largest herring spawning stock in the Strait of Georgia, for which good estimates of total spawn were available. (2) The herring spawn deposition records collected by Fisheries and Oceans Canada in British Columbia were examined to determine whether spawns were associated with documented incidents of large flocks of seabirds occurring at unusually high local abundance.

Methods

The field study site was Lambert Channel, between the west shore of Denman Island and the east shore of Hornby Island, in the Strait of Georgia. This area was divided into five sectors, each incorporating about 7 km of shoreline and extending 1.5 km offshore (Figure 1). Birds were enumerated from a boat, travelling close to and parallel to the beach at about 5 km/h, by two observers using binoculars. Birds were identified to species, where possible, and grouped into five categories of abundance and behaviour (gulls, scoters, other ducks, other diving birds, and non-diving birds). Daily counts, by sector and for individual species, are published elsewhere (Haegele 1991). Herring spawn was sampled throughout the development period to estimate egg density (Haegele 1991). Samples were collected on transects perpendicular to shore (Figure 1) in 0.5 m^2 plots, a square with 0.7 m sides, with at least 10 plots • $transect^{-1}$ and a maximum distance of 20 m between plots.

The incidents of large flocks of seabirds occurring at unusually high local abundance were obtained from the monographs of Campbell et al. (1990a,b) and studies by Munro and Clemens (1931), Vermeer (1981), and Haegele and Schweigert (1989). The associated herring spawn records were obtained from the original Fishery Officer reports on file at the Pacific Biological Station.

Results

Lambert Channel field studies (1989, 1990)

(1) Herring spawn

In 1989, herring spawned in Lambert Channel 2–16 March. Within this period, spawning was intermittent, with increased activity coinciding with high tides. In any one location, spawning averaged four days. On Denman Island it began in sector 3, and

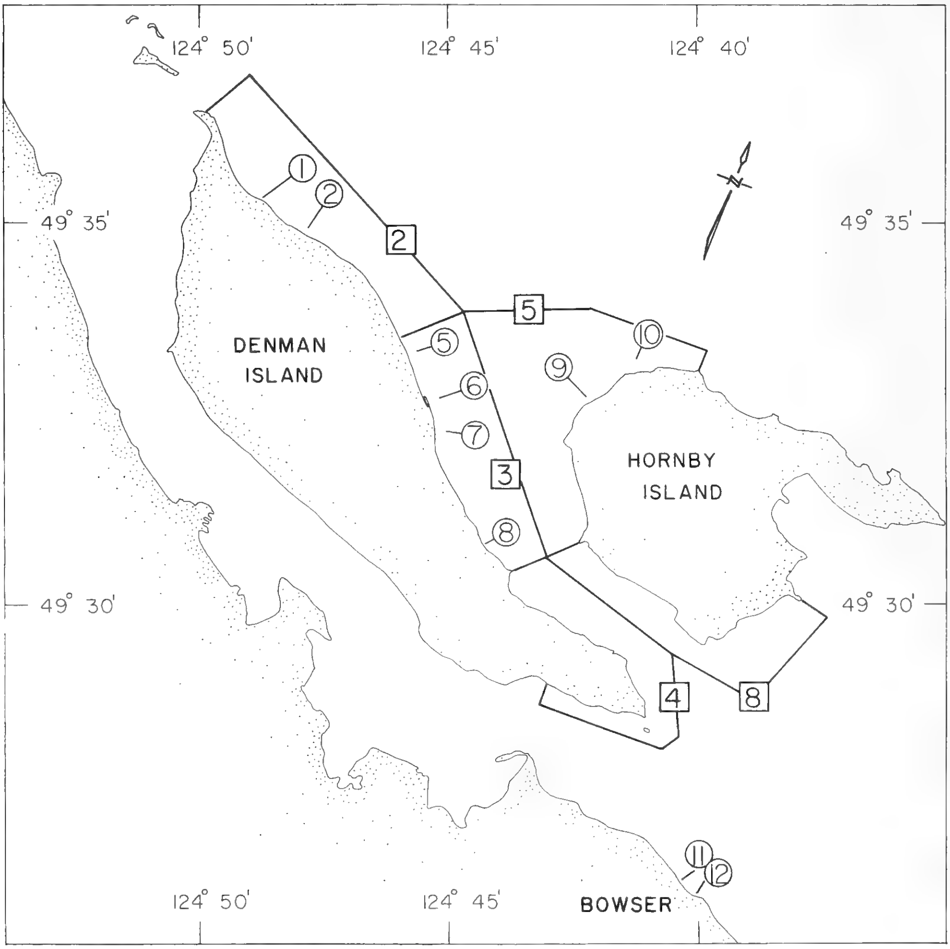

FIGURE 1. Lambert Channel study area showing sectors used for bird counts (numbers in squares) and transects used for bottom sampling (numbers in circles).

progressed NW to sector 2 and SE to sector 4. On Hornby Island it began in sector 5 and progressed SE into sector 8, as well as along the NE shore, which was outside the study area. In 1990, herring spawned over a shorter period, 2–10 March, and spawning averaged only three days in any one location. The progression of spawning was similar to 1989, except that no spawning was observed in sector 8. Using an average 14-day development period, spawn was available to birds for 28 days, 2–29 March, in 1989 and for 23 days, 2–24 March, in 1990. Spawn was sampled between the third and twelfth egg development day on eight transects in 1989 and six transects in 1990. Initial egg densities were estimated by linear regression of geometric means with development time. Geometric means were used because log transformation normalized the data. Initial egg densities on transects were 0.1–1.2 • 10^6 eggs • m^{-2}, averaging 0.6 • 10^6 eggs • m^{-2}.

(2) Bird abundance

Birds increased in numbers from about 23 000 on 3 March 1989 to about 50 000 on 17 March 1989. On April 4 1989, about one week after hatching was completed, there were about 8000 birds (Figure 2). In 1990, there were about 15000 birds on 28 February, two days prior to spawning. This increased to about 61 000 birds on 19 March, and decreased to about 45 000 birds on 25 March, when all of the herring eggs in the study area had hatched (Figure 2).

(a) Gulls

About 20 000 gulls, mostly *Larus glaucescens*, were present in both years when spawning began and they were observed feeding on herring on and

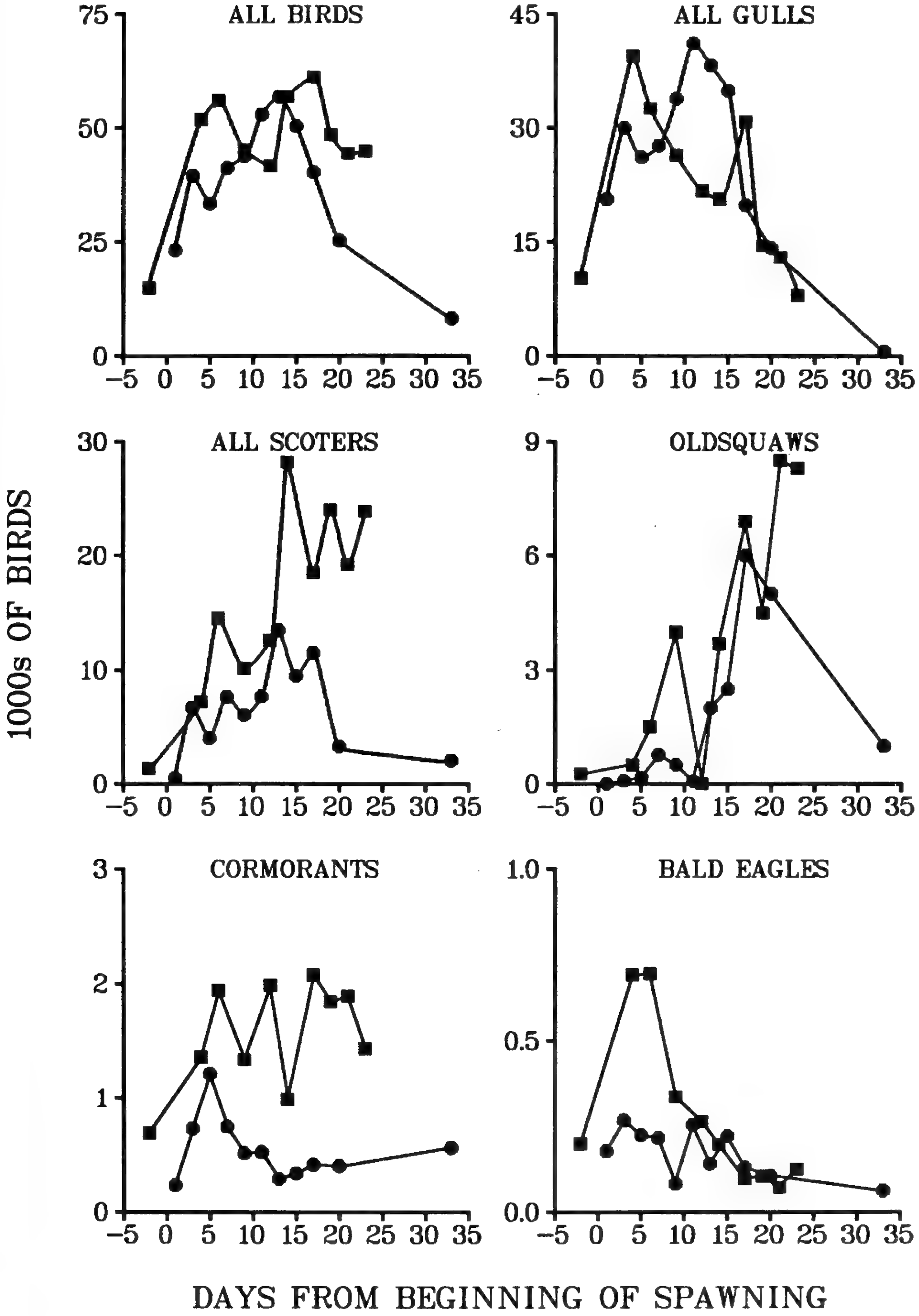

FIGURE 2. Total bird abundance and abundance of the most common birds in each of the five categories, for the Lambert Channel study area in 1989 (circles) and 1990 (squares).

near the spawning grounds. Gull abundance peaked early in 1990 at about 39 000 on 6 March, and halfway in the development period in 1989 at about 41 000 on 13 March. The subsequent decline coincided with spawning occurring outside the study area in other parts of the Strait of Georgia. Gulls occurred in substantial numbers in all sectors and were more likely than other birds to move to sectors where there was active spawning (Figure 3). They were observed feeding on spawn when it was exposed in the intertidal zone. In 1989, when birds were counted on 4 April, seven days after hatching was completed, only about 600 gulls were sighted in the study area.

(b) Scoters

Scoters, mostly Surf (*Melanitta perspicillata*) and White-winged (*M. fusca*) but also Black scoters (*M. nigra*), occurred almost exclusively in sectors 3 and 5, with some in sector 2 in 1990 (Figure 3). During daylight scoters occurred mostly 500–1500 m offshore and were not observed feeding on spawn. In 1989, scoters increased from about 500 on 3 March to about 13500 on 15 March, and declined quickly to about 3300 on 22 March. About 2000 scoters were still in the area on 4 April 1989. In 1990 scoters were about twice as abundant and increased from about 1400 on 28 February to about 28 000 on 16 March. Their numbers remained stable at about 21 000 until the end of the survey on 25 March (Figure 2).

(c) Other ducks

Abundance patterns of other ducks were similar to scoters. They increased in 1989 from about 1600 on 3 March to about 8 200 on 19 March, with about 4500 remaining on 4 April. In 1990 they increased from 2 300 on 28 February to about 11 000 on 25 March. They frequented sectors 3 and 5 (Figure 3). Oldsquaws (*Clangula hyemalis*) were the most numerous of these ducks, increasing in 1989 from a few birds on 2 March to about 6000 on 19 March, and decreasing to about 1000 on 4 April (Figure 2). In 1990, they increased to about 8500 on 23 March. Oldsquaws frequently occurred with the scoters, but were occasionally seen nearshore feeding on spawn in shallow water. Buffleheads (*Bucephala albeola*), Goldeneyes, both Barrow's (*B. islandica*) and Common goldeneyes (*B. clangula*), and Harlequin Ducks (*Histrionicus histrionicus*) did not show significant increases in abundance over the egg development period, but fluctuated about means of about 600, 1400, and 600 birds, respectively. They were frequently observed feeding on spawn in shallow water. Mergansers, both Common (*Mergus merganser*) and Red-breasted mergansers (*M. serrator*), and Mallards (*Anas platyrhynchos*) increased in numbers slowly over the survey period, but they never exceeded about 440 mergansers and about 350 Mallards. They were observed feeding on spawn in shallow water.

(d) Other diving birds

Cormorants, mostly Pelagic (*Phalacrocorax pelagicus*) but also Double-crested (*P. auritus*) and Brandt's cormorants (*P. penicillatus*), were the most abundant other diving birds and, in 1989, were most abundant when there was active spawning (Figure 2). In 1990, as many as 2080 cormorants were observed and most of these occurred in the southern portion of sectors 4 and 8 (Figure 3). Common Loons (*Gavia immer*), Common Murres (*Uria aalge*), Marbled Murrelets (*Brachyramphus marmoratus*), and Pigeon Guillemots (*Cepphus columba*) occurred in low numbers, generally less than 20. Grebes, both Horned (*Podiceps auritus*) and Western grebes (*Aechmophorus occidentalis*), averaged 35 birds. These birds were not observed feeding on herring spawn.

(e) Non-diving birds

Bald Eagles (*Haliaeetus leucocephalus*) and North-western Crows (*Corvus caurinus*) were the most abundant non-diving birds. Bald Eagles were most abundant during herring spawning and 692 were counted in 1990 (Figure 2). A maximum of 254 were seen in 1989. After herring spawning was finished the number of Bald Eagles declined to about 100 in both years. Bald Eagles were seen frequently on the beach, but were not observed eating spawn. North-western Crows increased and then declined in numbers during the development period and reached a peak of about 360 birds in 1990, averaged 130 birds, and were observed eating herring spawn. Brant (*Branta bernicla*) were not seen until late in the spawn development period and Canada Geese (*B. canadensis*) were seen only occasionally in small numbers, but both species were observed eating herring spawn. Great Blue Herons (*Ardea herodias*) were present in small numbers and American Wigeons (*Anas americana*) were seen occasionally. Neither species was observed eating spawn. The non-diving birds were evenly distributed throughout the study area (Figure 3).

(3) Herring spawn consumption

Previous studies reported on the digestive tract content of seabirds occurring in the proximity of herring spawn (Munro and Clemens 1931; Cleaver and Franett 1946; Outram 1958; Vermeer 1981; Palsson 1984; Haegele and Schweigert 1989). Several species of gulls and many species of ducks ingested herring eggs (Table 1). Other diving birds, i.e., cormorants, Common Murres, Marbled Murrelets and Pigeon Guillemots, had not ingested herring eggs. Bayer (1980) observed that, of the 30 species of birds present on herring spawn areas, all but cormorants, grebes, loons and mergansers fed on spawn. Maximal egg consumption was 240 cc for gulls, 50 g for scoters, and 45 cc for other diving ducks. However, a limitation of this sampling was

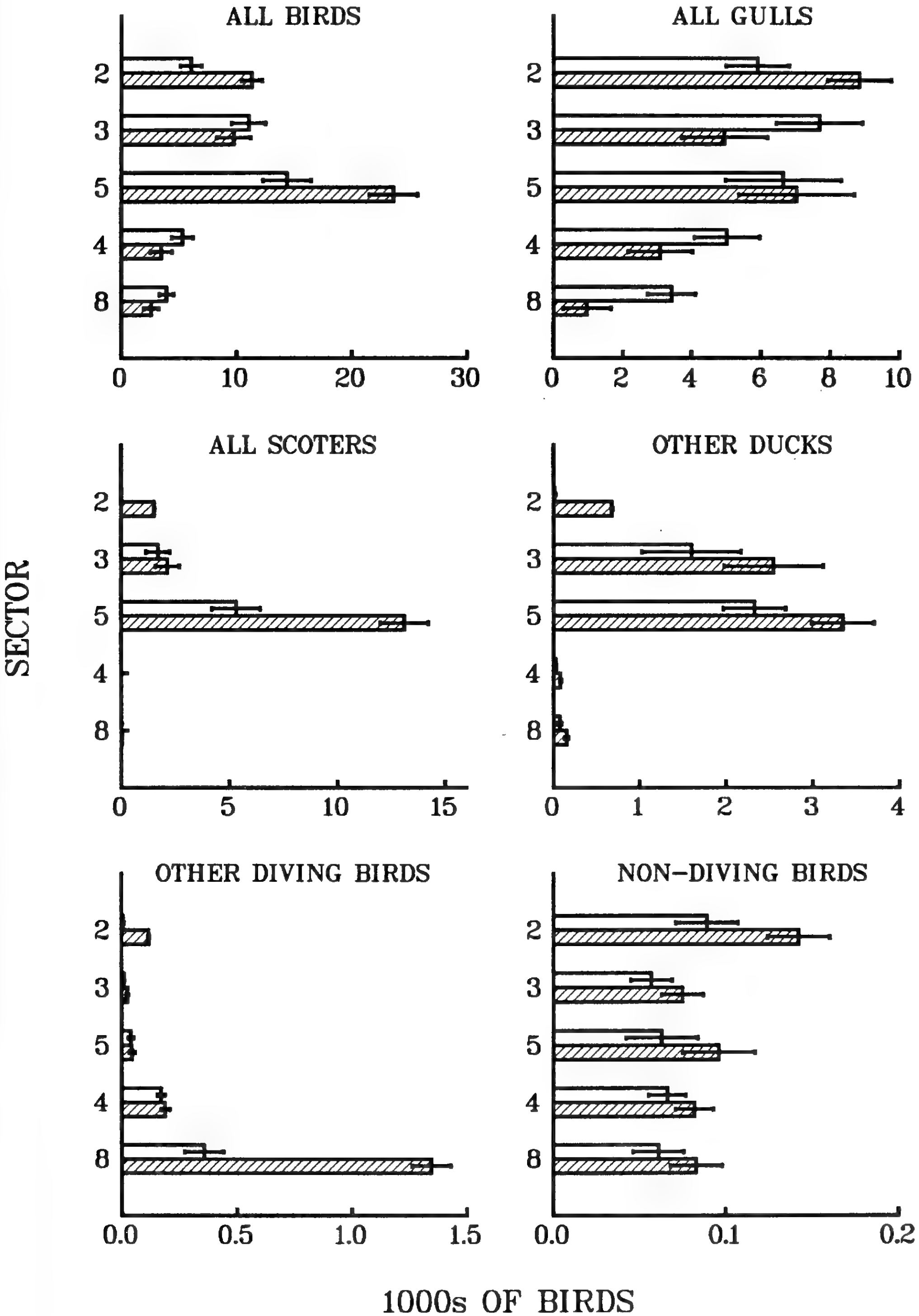

FIGURE 3. Mean (± 1 SE) number of birds during the period with herring spawn, by category and sector, for the Lambert Channel study area in 1989 (clear) and 1990 (shaded).

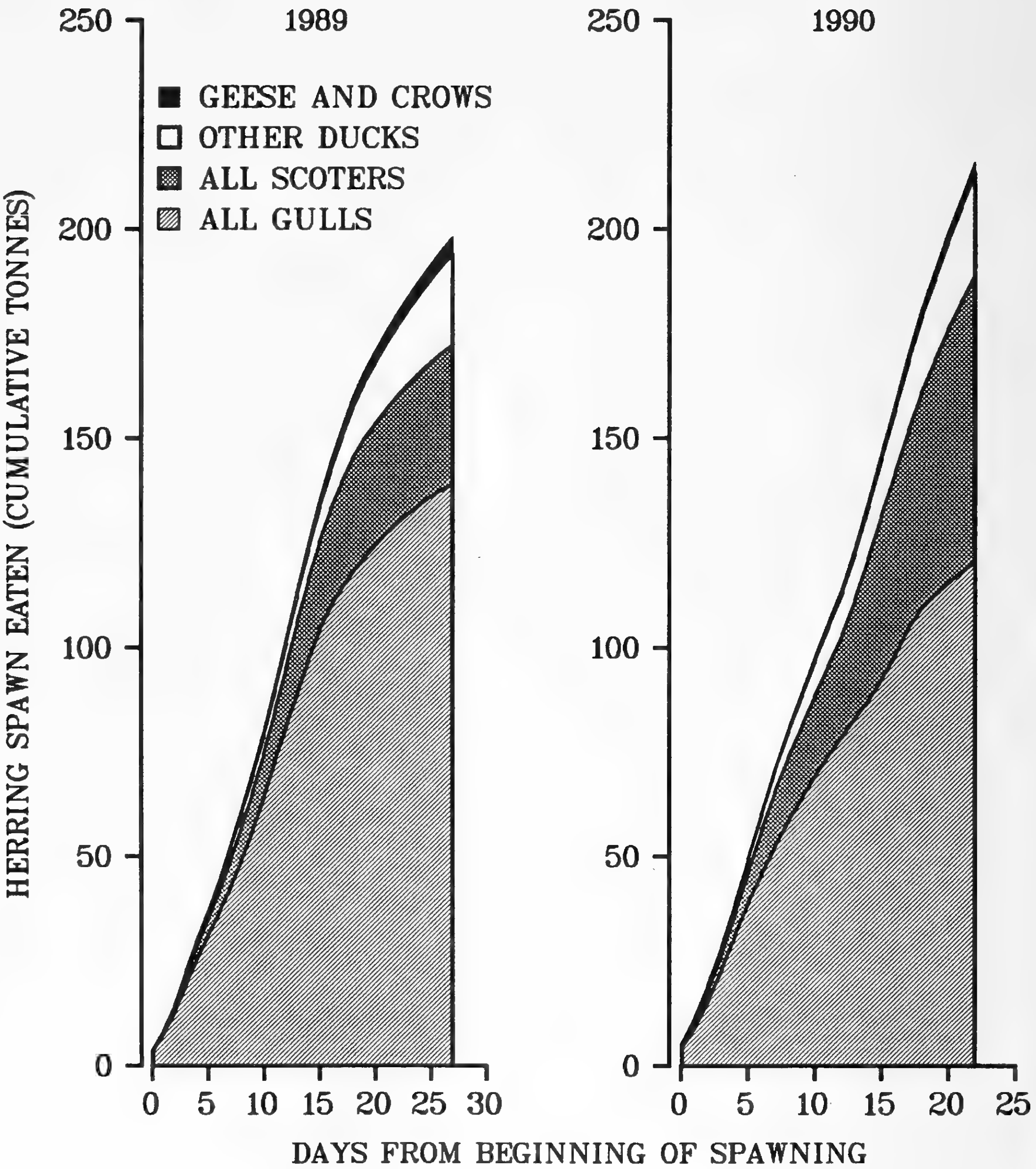

FIGURE 4. Extrapolated estimate of herring spawn consumed by birds, by category, in the Lambert Channel study area in 1989 and 1990.

the uncertainty of whether birds had fed to satiation. Estimates based on body weight, from Nilsson and Nilsson (1976), may better approximate daily ingestion rate (Table 2). The regression is $F = 0.51 \cdot W^{0.85}$, where F = daily food consumption in g and W = bird weight in g. Herring egg removal by birds was estimated using these rations and daily bird abundance, with abundance for days with no bird counts interpolated from the census data (Figure 4). During the 28 days in 1989 and the 23 days in 1990 that herring spawn was present in Lambert Channel, birds were estimated to have removed 198.2 and 216.3 tonnes of herring eggs, respectively (Table 2). Herring spawn may be converted to herring biomass

TABLE 1. Maximum herring eggs observed in digestive tracts of birds sampled near Pacific Herring spawn. (Location codes are: WS = Washington State, GS = Strait of Georgia, WCVI = west coast of Vancouver Island, NC = North Coast.)

Species	Location	Number of birds		Max. eggs observed	Source
		sampled	with eggs		
Bonaparte's Gull	WS	2	2	1.5 g	Palsson (1984)
California Gull	WCVI	1	1	1.2 g	Haegele and Schweigert (1989)
Glaucous-winged Gull	GS	25	13	240.0 cc	Munro and Clemens (1931)
	WCVI	12	12	14.5 g[1]	Outram (1958)
	WCVI	8	7	78.0 g	Haegele and Schweigert (1989)
Glaucous Gull	GS	5	4	97.0 cc	Munro and Clemens (1931)
Herring Gull	GS	5	0	—	Munro and Clemens (1931)
	WCVI	9	9	9.1 g[1]	Outram (1958)
	WCVI	4	3	25.7 g	Haegele and Schweigert (1989)
Mew Gull	GS	7	4	6.0 cc	Munro and Clemens (1931)
	WCVI	1	1	6.1 g	Haegele and Schweigert (1989)
Thayer's Gull	WCVI	3	3	103.8 g	Haegele and Schweigert (1989)
Western Gull	WCVI	2	1	14.4 g	Haegele and Schweigert (1989)
Common Scoter	GS	3	1	6.0 cc	Munro and Clemens (1931)
Surf Scoter	WS	6	5	24243 eggs	Cleaver and Franett (1946)
	WS	3	3	38.4 g	Palsson (1984)
	GS	2	2	49.7 g[1]	Vermeer (1981)
	GS	5	4	23.0 cc	Munro and Clemens (1931)
	WCVI	8	8	25.3 g	Haegele and Schweigert (1989)
	NC	7	7	30.1 g[1]	Vermeer (1981)
White-winged Scoter	WS	7	7	20370 eggs	Cleaver and Franett (1946)
	GS	3	1	1.0 cc	Munro and Clemens (1931)
	GS	?	2	?	Vermeer and Bourne (1984)
Bufflehead	WCVI	1	1	4.2 g	Haegele and Schweigert (1989)
Barrow's Goldeneye	GS	1	1	11 eggs	Munro and Clemens (1931)
	WCVI	4	4	6.2 g	Haegele and Schweigert (1989)
Common Goldeneye	GS	1	0	—	Munro and Clemens (1931)
Greater Scaup	WS	2	2	6958 eggs	Cleaver and Franett (1946)
	GS	3	1	17.0 cc	Munro and Clemens (1931)
Harlequin Duck	GS	2	1	45.0 cc	Munro and Clemens (1931)
	WCVI	3	3	10.7 g	Haegele and Schweigert (1989)
Oldsquaw	GS	2	2	22.0 cc	Munro and Clemens (1931)
Common Merganser	GS	2	0	—	Munro and Clemens (1931)
	NC	1	1	150 eggs	Munro and Clemens (1937)
Red-breasted Merganser	GS	3	0	—	Munro and Clemens (1931)
Brandt's Cormorant	GS	1	0	—	Munro and Clemens (1931)
	WCVI	4	0	—	Haegele and Schweigert (1989)
Double-crested Cormorant	GS	2	0	—	Munro and Clemens (1931)
Pelagic Cormorant	GS	6	0	—	Munro and Clemens (1931)
	WCVI	1	0	—	Haegele and Schweigert (1989)
Common Murre	GS	8	0	—	Munro and Clemens (1931)
Marbled Murrelet	GS	4	0	—	Munro and Clemens (1931)
Pigeon Guillemot	GS	4	0	—	Munro and Clemens (1931)

[1] Average content because maximum not available.

using an individual egg weight of $2.38 \cdot 10^{-3}$ g (Hay and Miller 1982) and a relative fecundity of $1.0 \cdot 10^{8}$ eggs $\cdot$ $tonne^{-1}$ (Hay 1985). Using these relationships, 3.1% and 3.8% of the spawn from an estimated 27 000 tonnes and 24 000 tonnes of herring in Lambert Channel (Haist and Schweigert 1991) was removed by birds in 1989 and 1990.

Incidents of high seabird abundance (1928-1988)

There were 94 records of large flocks of seabirds associated with documented herring spawns, with a progression from mid-March in the Strait of Georgia, to late March on the west coast of Vancouver Island, to mid-April on the coast north of Vancouver Island, including the Queen Charlotte Islands (Table 3). Scoters, gulls, Oldsquaws, and goldeneyes were the most frequently observed birds.

At a similar geographic scale as my field study in Lambert Channel in 1989-1990, bird abundance was comparable in other locations. In Ganges Harbour in

TABLE 2. Estimated daily ration for birds observed eating herring spawn and estimated total spawn consumption in the Lambert Channel study area in 1989 and 1990.

Bird type	Bird weight (g)[1]	Daily ration (g)[2]	Total eaten (t)	
			1989	1990
Gulls	1203	211	139.1	120.4
Scoters	1126	200	33.2	68.7
Other ducks	932	169	21.8	24.3
Geese	5000	709	3.0	1.5
Crows	900	165	1.1	1.4
Total			198.2	216.3

[1] From Haegele and Schweigert (1989).

[2] Based on $F = 0.51 \bullet W^{0.85}$, where F = daily food consumption in g and W = bird weight in g (Nilsson and Nilsson 1976).

the lower Strait of Georgia, 9500 gulls, 22 500 scoters and 16 250 other diving ducks (total of 48 250 birds) were observed in March 1978. Between Hammond and Nanoose bays in the middle west portion of the Strait of Georgia, 46 000 gulls, 7400 scoters and 5000 other diving ducks (total 58 400 birds) were observed in March 1928. On the west coast of Vancouver Island, 21 800 Surf Scoters occurred in Hesquiat Harbour in March 1976, 23 000 Surf Scoters in Barkley Sound in March 1978, 20 000 Glaucous-winged Gulls near Tofino in March 1980, and 14 800 gulls, 11 800 Surf Scoters and 1200 other diving ducks (total 27 800 birds) in Barkley Sound in March 1988. Even larger flocks of seabirds were observed in northern British Columbia: 300 000 Surf Scoters in Big Bay in April 1975 and 100 000 Surf Scoters in Kitkatla Inlet in May 1977. Scoters and geese were observed in smaller flocks, 1000 to 2800 birds, in the Queen Charlotte Islands.

Discussion

Local and migratory seabirds encounter an abundance of readily available food when herring move

TABLE 3. Summary of records of birds feeding on herring spawn or of large flocks (>1000) of birds, known to consume herring spawn, observed in the proximity of herring spawn in Canadian waters. The source for the bird observations were the monographs of Campbell et al. (1990a,b) and studies by Munro and Clemens (1931), Vermeer (1981), and Haegele and Schweigert (1989). The associated herring spawn records were obtained from the original Fishery Officer reports on file at the Pacific Biological Station.

Species	N	Average Number	Average Date of	
			Count	Spawn
Strait of Georgia				
Glaucous-winged Gull	7	6 536	8 March	6 March
Herring Gull	3	210	14 March	8 March
Mew Gull	4	3 175	16 March	13 March
Thayer's Gull	1	1 130	6 March	2 March
Surf Scoter	10	5 844	17 March	11 March
White-winged Scoter	6	2 498	18 March	14 March
Bufflehead	2	500	10 March	7 March
Barrow's Goldeneye	3	370	14 March	8 March
Common Goldeneye	5	1 166	14 March	10 March
Harlequin Duck	1	778	26 March	20 March
Red-breasted Merganser	1	100	6 March	3 March
Oldsquaw	12	2 737	19 March	14 March
Greater Scaup	10	5 098	21 March	15 March
Brant	3	3 077	26 March	16 March
West Coast Vancouver Island				
Glaucous-winged Gull	3	8 768	6 March	12 March
Mew Gull	1	224	28 March	22 March
Thayer's Gull	1	10 279	28 March	22 March
Surf Scoter	5	14 126	23 March	17 March
Bufflehead	2	743	27 March	16 March
Barrow's Goldeneye	1	619	30 March	22 March
Common Goldeneye	1	291	30 March	22 March
Harlequin Duck	1	120	30 March	22 March
Canada Goose	2	1 413	6 April	29 March
North Coast				
Surf Scoter	4	109 625	22 April	14 April
White-winged Scoter	2	3 150	18 April	10 April
Oldsquaw	1	3 000	2 May	30 April
Brant	1	1 190	18 April	14 April
Canada Goose	1	1 000	16 April	4 April

nearshore to spawn in the intertidal and upper subtidal zone. Spawn washed into the supra-littoral zone after being dislodged by wave action and spawn exposed on receding tides is eaten by gulls, Mallards, crows, geese, and possibly other shorebirds. Submerged spawn is eaten principally by scoters, Oldsquaws, goldeneyes and other diving ducks. Predation by birds was stratified and localized. In Lambert Channel, gulls fed only on exposed spawn and were distributed throughout the study area. Scoters and the other diving ducks, however, frequented mostly sectors 3 and 5 during daytime, but likely fed on spawn in the other sectors at other times. Cleaver and Franett (1946) found that scoters moved at dawn and dusk, when they persistently attempted to enter a herring spawning area, protected from birds by patrols with a speed-boat.

In British Columbia, major spawns typically involve many thousands of tonnes of herring that deposit about 238 kg of spawn per tonne of spawning fish. Coastwide spawner biomass has averaged 200 000 tonnes over the past decade. After an approximately 30 000 tonnes annual catch, with an estimated landed value of 60 million dollars, 40 460 tonnes of spawn (170 000 tonnes • 238 kg spawn • tonne^{-1}) is available, mainly within a 45-day period from the beginning of March to mid-April. If bird predation was approximately 3.5%, as found in the Lambert Channel study, then 1416 tonnes of spawn was consumed, on average, by birds. This represents the spawning products of about 6000 tonnes of herring. Assuming that individual birds feed on spawn for 20 days and consume 200 g of spawn per day, then this level of predation would support about 350 000 birds.

When herring stocks are abundant and spawn is heavy, as at Lambert Channel in 1989 and 1990 (where average initial egg density was 5.75 • 10^5 eggs • m^{-2}), then, at an average abundance, birds have only a minor impact, consuming 3.1–3.8% of eggs. In Lambert Channel there was 671 ha of spawn along 36 km of shoreline in 1989 (Chalmers 1990) and 669 ha of spawn along 28 km of shoreline in 1990 (Chalmers 1991). Therefore, at peak bird abundance of 50 407 (1989) and 61 378 (1990), there were 75 and 92 birds • ha^{-1}, respectively. Under similar herring and bird abundance in Barkley Sound, birds consumed about 3.5% of herring eggs (Haegele and Schweigert 1989). Vermeer (1981) estimated that 75 000 Surf Scoters occurred along the coast of Vancouver Island during two weeks in March 1978, and calculated that they consumed 103 tonnes of herring eggs per week. The herring spawning stock biomass for this area in 1978 was estimated at 90 000 tonnes (Haist and Schweigert 1991); consequently Surf Scoters would have removed about 1.0% of the eggs. This is similar to the Lambert Channel results, where scoters were estimated to have consumed 0.5% and 1.2% of the herring spawn in 1989 and 1990, respectively.

When herring stocks are low, birds may have a significant deleterious impact on herring egg survival. Palsson (1984) reported egg losses of 95–99% from very light density spawns in Puget Sound. Bird predation was the major cause of loss, accounting for 20–50% of the daily egg loss rate. Also in Puget Sound, during a period of low herring abundance, Cleaver and Franett (1946) compared egg survival to hatching between sites protected from birds, where it was 61.9%, to unprotected sites, where it was 0.4–6.2%. In San Francisco Bay gulls appear to consume a large proportion of the eggs in the 50% of the herring spawn that was exposed at low tide (Spratt 1981). In small spawns from 43–263 tonnes of herring, as much as 83% of the eggs were lost within a day, and in larger spawns from about 5000 tonnes of herring, 87% of eggs were lost within a week. Localized bird predation may also be high in British Columbia. Outram (1958) reported 30–55% bird predation of spawn on intertidal eelgrass (*Zostera marina*) on the west coast of Vancouver Island. At high bird abundance, predation may be devastating. The 300 000 Surf Scoters observed in Big Bay in 1975 could conceivably have consumed, over a 20-day period, the eggs from 5042 tonnes of herring, when the estimated herring spawner biomass was 10 578 tonnes for the North Coast (Haist and Schweigert 1991), of which approximately two-thirds traditionally spawn in the Big Bay area. Hence, at these herring stock levels, there was a potential for approximately 70% egg removal by these scoters.

Ultimately, the impact of birds on herring egg survival depends on the quantity of spawn available. If birds congregate on small spawns, which may occur early and late in the season, then the impact on those spawns may be very high. At present, in British Columbia, birds appear to consume not more than 5% of total herring spawn, and those birds that are migrating northward are especially benefitting from this food abundance.

Acknowlegments

Doug Miller and Jake Schweigert of the Pacific Biological Station and Jane Watson, Caroline Heim, Laurie Convoy and Leah Saville of Archipelago Marine Research Ltd. of Victoria, British Columbia, assisted with the bird counts. Kees Vermeer of the Canadian Wildlife Service, Neil Bourne and Doug Hay of the Pacific Biological Station, and two anonymous reviewers made many valuable suggestions.

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Received 8 September 1992
Accepted 9 September 1993

Epibenthic Invertebrate Predation of Pacific Herring, *Clupea pallasi*, Spawn in British Columbia

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The extent of predation of Pacific Herring (*Clupea pallasi*) eggs by epibenthic invertebrates was estimated. In selected field locations invertebrates were enumerated and their guts were sampled. In the laboratory daily consumption rates were estimated. Egg loss attributable to invertebrate predation averaged 8.0% at 14 sites, but varied from 1% to 30% between sites. It was estimated that 3.7% of total eggs were eaten. Crabs were the major invertebrate predator, accounting for 60% of this egg loss.

Key Words: Pacific Herring, *Clupea pallasi,* spawn, British Columbia, predation, epibenthic invertebrates.

When Pacific Herring (*Clupea pallasi*) spawn in the intertidal and upper subtidal zone (Haegele and Schweigert 1985), they provide an abundance of readily available, nutritious food to predators. Herring egg loss to predation is of concern primarily because herring stock assessments in most NE Pacific Ocean jurisdictions from California to Alaska use spawn survey data to estimate herring biomass (Spratt 1981; Schweigert et al. 1985, 1990; Burton 1990; and Collie 1990). Previous studies of herring egg loss have focused primarily on bird predation (Munro and Clemens 1931; Cleaver and Franett 1946; Outram 1958; Bayer 1980; Vermeer 1981; Palsson 1984; and Haegele and Schweigert 1989), although the latter two studies also estimated predation by some invertebrates.

Oophagy appears widespread among invertebrates. Sea stars have been observed to eat nudibranch and other opisthobranch eggs (Mauzey et al. 1968) and fish eggs (Christensen 1970), prosobranchs nudibranch eggs (Perron 1975), opisthobranchs other opisthobranch eggs (Jensen 1986) and the eggs of the Cornish Sucker Fish (Miller 1961), nemerteans opisthobranch and decapod eggs (Haderlie 1980), and chitons fish eggs (Putnam 1990).

In this study I estimate the potential impact that epibenthic invertebrates may have on herring egg survival through estimates of abundance, laboratory experiments on feeding rates, and field collection of invertebrates and herring spawn.

Methods

Feeding experiments were conducted in 1989 in 30 litre aquaria at ambient seawater temperatures of 12–14°C. Both static and flow-through seawater aquaria were used. Static water was aerated; about 50% of the water was replaced halfway through two-day trials, but not during one day trials. There were 47 trials; 21 trials were conducted 5–11 April with eggs from a 31 March herring spawn and 26 trials were conducted 17–21 April with eggs from a 12 April herring spawn. Experimental animals were weighed and allowed to acclimatize in aquaria before herring eggs (2–50 g) were introduced. The eggs remaining at the end of the trial were weighed and daily consumption (number of eggs and percent of body weight) calculated. Three crab species (*Hemigrapsus* sp., *Pagurus* sp. and *Pugettia producta*), six sea star species (*Dermasterias imbricata, Henricia leviuscula, Mediaster aequalis, Pisaster* sp., *Pycnopodia helianthoides* and *Solaster* sp.), and four marine snail species (*Aglaja diomedea, Bittium eschrichtii, Margarites* sp. and *Mitrella* sp.) were tested in separate aquaria. There were an average of 7 crabs, 7 sea stars, and 342 snails per aquaria. The same animals were used in repeat trials.

A total of 218 specimens of 21 of the most common invertebrate species were collected on herring spawning grounds in 1991 and preserved in 10% seawater formalin. The animals and their stomach contents were weighed and the stomach contents identified.

Invertebrate and herring egg density estimates were made on transects that were perpendicular to shore and across the spawning bed and marked with gillnet leadline. SCUBA divers enumerated the abundant small epibenthic organisms (eg., small crabs, snails, amphipods) in sample plots. The more infrequently occurring large animals (eg. large crabs, sea stars, sea anemones, sea cucumbers, and sea urchins) were enumerated within 1 m of the transect line. Sample plots were squares with 0.7 m sides (0.5 m^2). Plot placement was made non-selective by laying one side of the square along the transect line and flipping it once to the left. As a guideline, a maximum distance of

20 m between sampling stations and at least 10 plots per transect were required. As a result, the spacing between sampling stations and the number of stations per transect depended on transect length; the minimum distance was 5 m and the maximum number was 31. In 1989 counts were made once on each of 8 transects: on day 8 of the herring egg development period for transects 7 and 8, on day 10 for transects 1 and 2, on day 12 for transects 6 and 10, and on day 14 for transects 5 and 9 (see Figure 1 in Haegle 1993, page 74). In 1990, counts were made 4–5 times on each of 6 transects.

Herring spawn was sampled in the 0.5 m^2 plots, periodically between the third and twelfth egg development day (Haegele 1991). Initial egg densities were estimated by linear regression of geometric means with egg development time. Geometric means were used because log transformation normalized the data.

Results

The Kelp Crab (*Pugettia producta*) was a particularly voracious feeder, and fed on eggs immediately upon their introduction into aquaria, eating up to 450 eggs • day^{-1}. Sea stars, in contrast, reacted slowly to prey introduction, although Leather Stars (*Dermasterias imbricata*) ate up to 744 eggs • day^{-1}. The snails, all of which weighed <1 g, consumed <1 egg • day^{-1} (Table 1).

Three of 15 Kelp Crabs collected on herring spawning grounds contained eggs, but the other 16 crabs (2 *Cancer antennarius*, 7 *C. productus*, 1 *Loxorhynchus* sp., 4 *Pagurus* sp., and 2 *Paguristes* sp.) were empty. Forty-eight specimens of 5 species of sea stars (5 *Evasterias troschelii*, 11 *Henricia leviuscula*, 8 *Pisaster brevispinus*, 17 *P. ochraceus*, and 7 *Solaster* sp.) had empty guts while 12 of 39 *Dermasterias imbricata*, 4 of 39 *Mediaster aequalis*, and 9 of 13 *Pycnopodia helianthoides* contained eggs. None of the 21 marine snails (11 *Diodora aspera* and 10 *Archidoris* sp.) contained food, but 1 of the 2 sea slugs (*Dendronotus* sp.) contained eggs. Five of 7 sea anemones (*Urticina* sp.), 6 of 9 sea cucumbers (*Parastichopus californicus*), 6 of 7 sea urchins (*Strongylocentrotus franciscanus*), and both of 2 chitons (*Cryptochiton stelleri*) consumed eggs. Maximum eggs as percent of body weight was 2.4% for crabs, 3.2% for sea stars, 10.0% for sea anemones, 4.3% for sea cucumbers, 6.5% for sea urchins, and 3.0% for chitons.

Small marine snails were the most abundant epibenthic organism on the spawning grounds, especially *Margarites* sp., *Mitrella* sp. and *Bittium eschrichtii*, while *Haminoea virescens* occurred infrequently and the larger Moon Snail (*Polinices lewisii*) was rare (Figure 1). Limpets (mostly *Diodora aspera*) and nudibranchs (mostly *Dirona* sp.) occurred at low abundance. Small crabs were also abundant; *Pagurus* sp. and *Pugettia producta* were present on most transects, *Oregonia gracilis* and *Petrolisthes eriomerus* occurred occasionally, while *Hemigrapsus* sp. and *Telmessus cheiragonus* were rare. Two species of large crabs, the Dungeness Crab (*Cancer magister*) and the Slender Crab (*C. gracilis*), occurred rarely. Sea stars occurred on all transects and there were eight species (*Dermasterias imbricata*, *Evasterias troschelii*, *Henricia leviuscula*, *Mediaster aequalis*, *Pisaster brevispinus*, *P. ochraceus*, *Pycnopodia helianthoides* and *Solaster* sp.) of about equal abundance, while *Orthasterias kohleri* occurred only once. The brittle star *Amphipholes squamata* occurred at high abundance on one transect. Sea anemones (*Anthopleura artemisia*, *A. elegantissima*, *Metridium senile*, *Pachycerianthus* sp. and *Urticina* sp.) and sea cucumbers (*Cucumaria* sp., *Eupentacta quinquesemita*, and *Parastichopus californicus*) occurred on most transects, while sea urchins (*Strongylocentratus franciscanus* and *S. droebachiensis*) occurred infrequently. Amphipods, shrimps (mostly carideans, including both pandalid and crangonid and *Heptacarpus* sp., but also macrurans (eg., *Callianassa* sp.)), polychaete worms (mostly *Nereis* sp. and *Thelepus crispus*), nemertean worms, and chitons (mostly *Tonicella lineata*, *Cryptochiton stelleri* and *Katharina* sp.) also occurred on most transects, occasionally at high abundance.

Total initial eggs in a 1 m wide transect was the product of estimated initial egg density and transect length. Mean (SE) density was 5.75 (1.01) • 10^5 eggs • m^{-2}, mean (SE) length was 256 (42) m, and there were an average (SE) of 1.55 (0.39) • 10^8 eggs • $transect^{-1}$. Egg removal was estimated from the abundance estimates of potential predators and esti-

TABLE 1. Size of animals and their egg consumption from 1989 laboratory experiments.

			Consumption rate (daily)			
	Body weight (g)		Eggs		% of body wt.	
Group	Mean	SE	Mean	SE	Mean	SE
Crabs	9.00	0.47	163.43	26.72	4.32	0.65
Sea stars	79.31	15.97	145.10	41.93	0.51	0.08
Snails	0.08	0.03	0.54	0.10	2.71	0.59

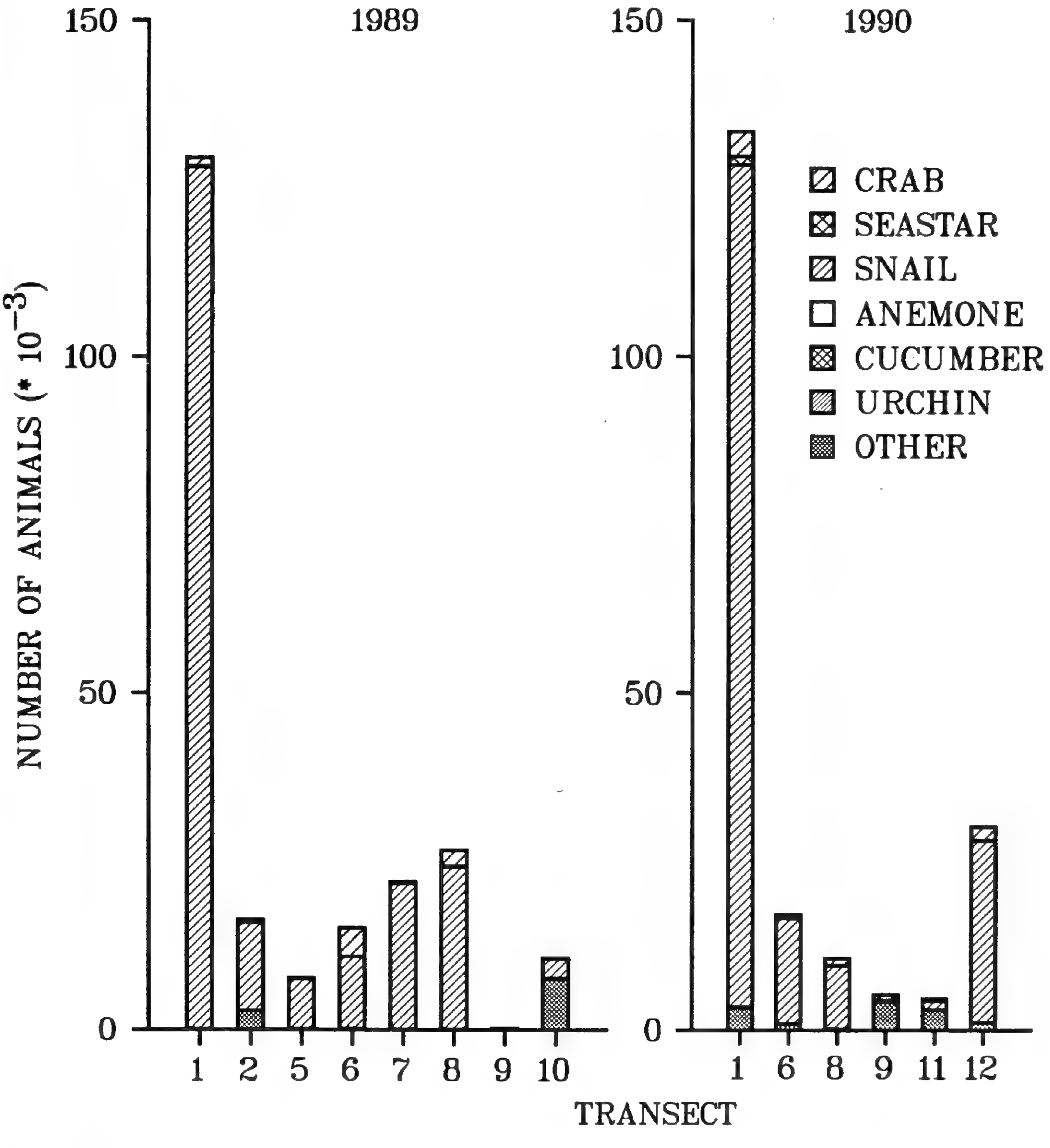

FIGURE 1. Estimates of the number of invertebrates on 1 m wide transects in Lambert Channel in 1989 and 1990.

mated daily rations, and all organisms were assumed to consume their full daily ration over the 18 day period that spawn was available. Daily rations for most epibenthic organisms were estimated from (1) the results of the feeding experiments and the gut collections for species examined or (2) by extrapolation from those results and estimated body weights for species not examined but in the same taxa (Table 2). For taxa with no experimental results, 2% of estimated body weight was used. Crabs were the major predator, accounting for about 60% of the total eggs consumed by invertebrates (Figure 2). Sea anemones accounted for 12%, sea cucumbers for 8%, and snails, sea stars, and sea urchins for about 4% each. Collectively, the chitons, worms, amphipods and shrimps accounted for less than 8%. We also observed fish, mostly rockfish (*Sebastes* sp.), poacher (Agonidae), sandab (*Citharichthys* sp.), gunnel (Pholidae) and sculpin (Cottidae), on the transects. These fish were never abundant in daylight, when

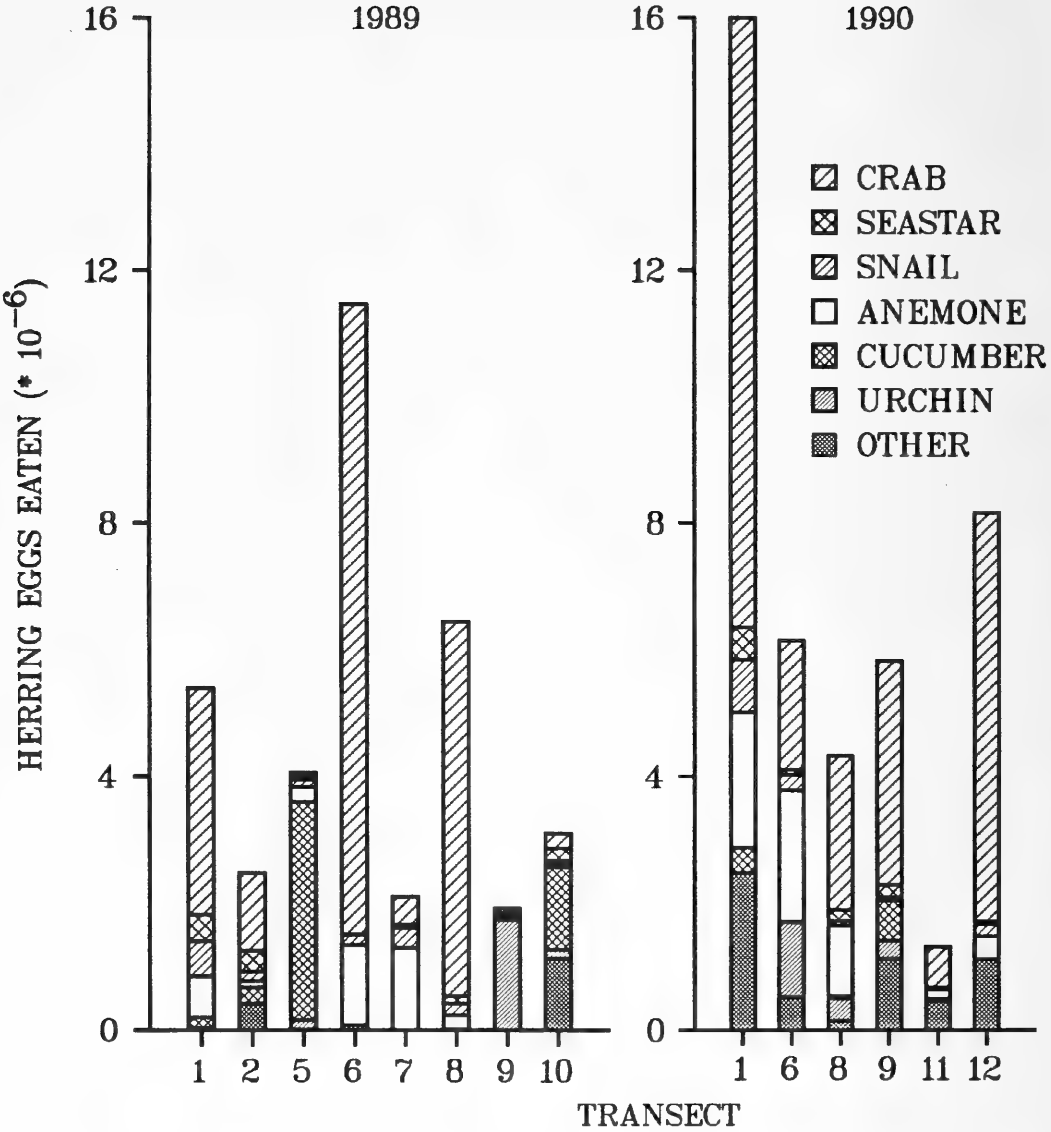

FIGURE 2. Estimates of herring egg consumption on 1 m wide transects by invertebrates in Lambert Channel in 1989 and 1990.

we sampled, and were estimated to have consumed fewer eggs than any of the invertebrate groups. Epibenthic predators were estimated to consume as much as 30% of eggs on transect 8 in 1990 and as little as 1% of eggs on transect 9 in 1989 (Figure 3). Overall removal averaged 8.0 (SE=2.2)% for the 14 transects and it was estimated that 3.7% of total eggs were eaten.

Discussion

Herring eggs adhere to marine algae and sea grasses and the bottom substrate (Haegele and Schweigert 1985). Some of the eggs become detached and are washed up into the supra-littoral zone (Hay and Miller 1982) or accumulate as a slurry in bottom depressions. Hence, herring eggs are available to all marine invertebrates, including ses-

TABLE 2. Estimates of daily rations, used in calculating herring egg consumption, for epibenthic predators.

Species	Eggs • day^{-1}	Source
Crabs (true, hermit, and porcelain)		
Cancer gracilis	2710	4.3% (1989 feeding exp. crab mean) of 150 g est. body weight
Cancer magister	3613	4.3% (1989 feeding exp. crab mean) of 200 g est. body weight
Hemigrapsus sp.	41	mean of 1989 feeding experiments
Oregonia gracilis	218	similar size crab (*Pugettia producta*) ration
Pagurus sp.	120	mean of 1989 feeding experiments
Petrolisthes eriomerus	218	similar size crab (*Pugettia producta*) ration
Pugettia producta	218	mean of 1989 feeding experiments
Telmessus cheiragonus	218	similar size crab (*Pugettia producta*) ration
Sea and brittle stars		
Amphipholes squamata	40	similar size sea star (*Henricia leviuscula*) ration
Dermasterias imbricata	456	mean of 1989 feeding experiments
Evasterias troschelii	73	similar size sea star (*Pisaster* sp.) ration
Henricia leviuscula	40	mean of 1989 feeding experiments
Mediaster aequalis	71	mean of 1989 feeding experiments
Orthasterias kohleri	73	similar size sea star (*Pisaster* sp.) ration
Pisaster brevispinus	73	mean of 1989 (*Pisaster* sp.) feeding experiments
Pisaster ochraceus	73	mean of 1989 (*Pisaster* sp.) feeding experiments
Pycnopodia helianthoides	139	mean of 1989 feeding experiments
Solaster sp.	110	mean of 1989 feeding experiments
Marine snails and sea slugs		
Limpet	100	est. 4% of 6 g est. body weight
Nudibranch	168	est. 4% of 10 g est. body weight
Bittium eschrichtii	0.6	mean of 1989 feeding experiments
Haminoea virescens	0.5	mean for snails of 1989 feeding experiments
Margarites sp.	0.2	mean of 1989 feeding experiments
Mitrella sp.	0.8	mean of 1989 feeding experiments
Polinices lewisii	840	est. 2% of 100 g est. body weight
Sea anemones		
Anthopleura artemisia	1000	50% (size adjustment) of *Urticina* sp. ration
Anthopleura elegantissima	1000	50% (size adjustment) of *Urticina* sp. ration
Metridium senile	1000	50% (size adjustment) of *Urticina* sp. ration
Pachycerianthus sp.	2000	*Urticina* sp. ration
Urticina sp.	2000	1991 gut content collection
Sea cucumbers		
Cucumaria sp.	900	10% (size adjustment) of *Parastichopus californicus* ration
Eupentacta quinquesemita	1800	20% (size adjustment) of *Parastichopus californicus* ration
Parastichopus californicus	9000	1991 gut content collection
Sea urchins		
Strongylocentrotus droebachiensis	8000	*Strongylocentrotus franciscanus* ration
Strongylocentrotus franciscanus	8000	1991 gut content collection
Miscellaneous		
Polychaete worms	25	est. 2% of 3 g est. body weight
Nemertean worms	25	est. 2% of 3 g est. body weight
Amphipods	8	est. 2% of 1 g est. body weight
Shrimps	40	est. 2% of 5 g est. body weight
Chitons	65	3% (1991 gut collection) of 5 g est. body weight
Fishes	1000	Speculation

sile ones, with the capacity to ingest or macerate eggs of ≈1.4 mm diameter.

Crabs were the major herring egg predator, because crabs were abundant and consumed an average of 4.3% of body weight • day^{-1}. The larger crabs (*Cancer gracilis*, *C. productus* and *C. magister*) have a diverse carnivorous diet, feeding on dead and live clams, crustaceans, barnacles, and fish (Knudsen

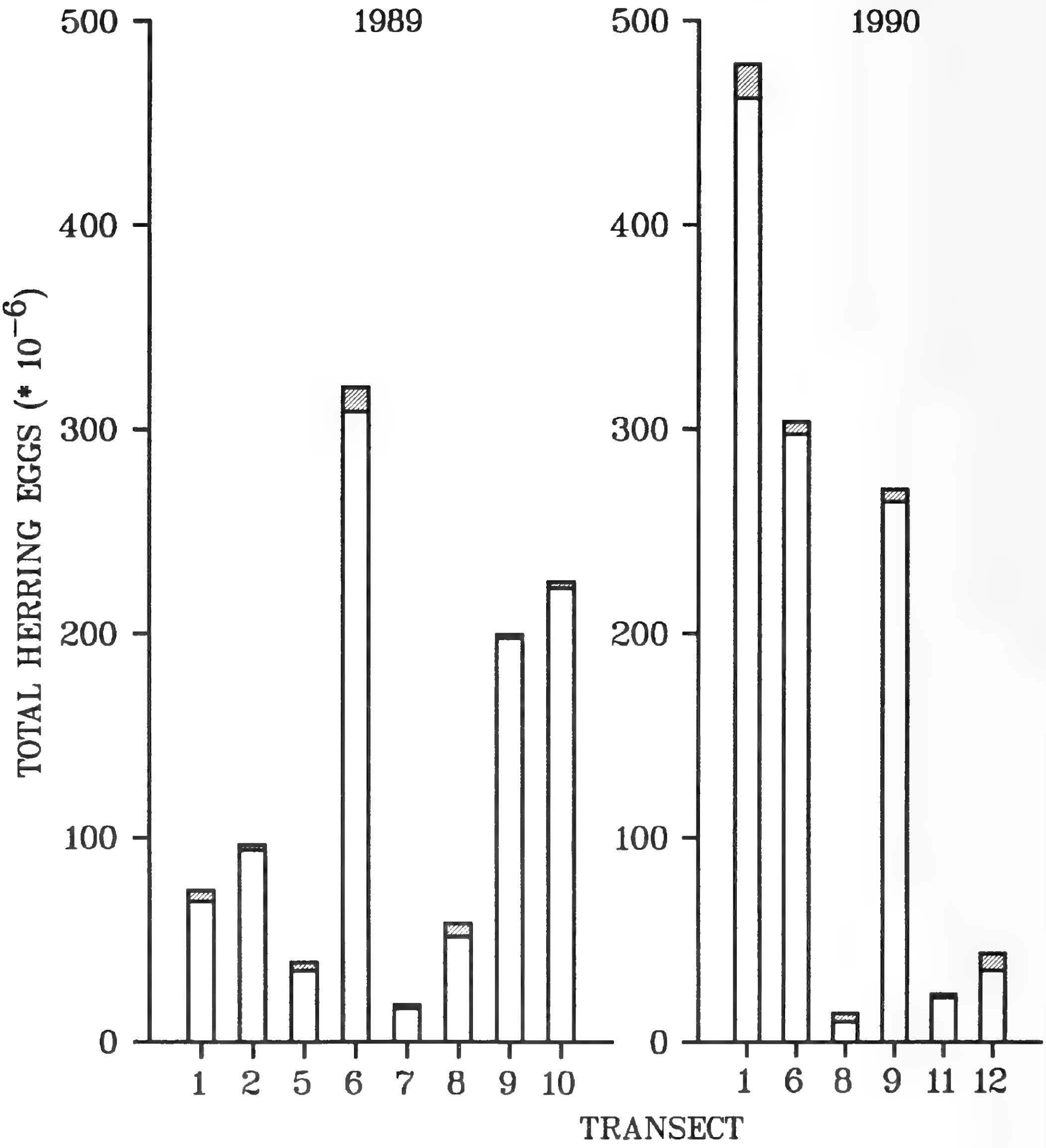

FIGURE 3. Estimates of total eggs on 1 m wide transects in Lambert Channel in 1989 and 1990. The shaded portion are those eggs estimated to have been consumed by invertebrates (see Figure 2).

1964; Gotshall 1977). Smaller true crabs and hermit and decorator crabs (eg. *Hemigrapsus nudus*, *H. oregonensis*, *Pagurus samuelis*, *Petrolisthes eriomerus*, *Pugettia producta*, and *Loxorhynchus crispatus*) are mostly herbivorous, although scavenging of dead animal matter and predation on barnacles, mussels, hydroids, and bryozoans have been demonstrated for them (Knudsen 1964; Wicksten 1977; Haig and Abbott 1980). All crabs, therefore, would be expected to feed exclusively on herring eggs when they are readily available.

Sea anemones, although they were not very abundant, were the second greatest herring egg predator. The Cnidaria are generally carnivorous. Their food, after capture, is transferred to the mouth by the tentacles (Haderlie et al. 1980). Sea anemones will ingest a single type of prey that is temporarily abundant, but unusual, such as moths or gelatinous masses of Foraminifera (Ayre 1984). Similarly, they consume herring eggs dislodged from the substrate and floating loose near the bottom.

Sea cucumbers were also not abundant, but were the third greatest predator. Detritus feeding sea cucumbers (eg., *Cucumaria* sp.) use tentacles with adhesive papillae to trap small particles, while others (eg., *Parastichopus* sp.) feed on organic detritus ingested with bottom sediment (Brumbaugh 1980). Both types of feeding result in the ingestion of loose herring eggs.

Although snails were the most abundant invertebrates, they were a minor herring egg predator because of their small size. Prosobranchs (snails and limpets) and opisthobranchs (sea slugs) are mainly polyphagous. Several species eat both invertebrate and fish eggs (Miller 1961; Jensen 1986; Robilliard 1971; Perron 1975). In the laboratory, snails consumed 2.7% of body weight in herring eggs, which is comparable to the average consumption of 3.8% of dry body weight estimated for *Dirona albolineata* by Robilliard (1971).

The other groups of minor predators for which herring egg predation was demonstrated were sea stars, sea urchins, and chitons. Sea and brittle stars feed on the detritus and organisms associated with algal beds (Mauzey et al. 1968; Feder 1981; Shivji et al. 1983). They were not a major herring egg predator because they occurred at low densities and were estimated to consume only 0.5% of body weight • day^{-1} in the laboratory feeding studies, where they were slow to initiate feeding. They may have been responsible for up to six times greater egg consumption then was estimated. In the Mediterranean, *Astropecten aranciacus* consumed 0.3% of dry body weight • day^{-1} in the wild, but 1.3% of dry body weight • day^{-1} in enclosures. This indicates that consumption increases when food is abundant, as suggested by Ribi and Jost (1978). In Monterey Bay laboratory studies, *Pisaster ochraceus* consumed an average of 1.1% of wet weight • day^{-1}, *Asterias rubens* ate up to 3% of body weight • day^{-1}, and *Pycnopodia helianthoides* was observed to eat up to 15% of body weight • day^{-1} over a three-day period (Feder 1970). One *P. helianthoides* specimen that I collected had ingested 3.2% of its body weight in herring eggs. Sea urchins are generally herbivorous (Durham et al. 1980), but Lasker and Giese (1954) found *Strongylocentrotus purpuratus* to be omnivorous. The *S. franciscanus* specimens I collected fed exclusively on herring eggs. Chitons are omnivorous. Algae, barnacles, and amphipods are their main diet (Demopolous 1975; Piercy 1987; Putnam 1990). The latter author also observed fish eggs in the gut of *Stenoplax heathiana* and both specimens of *Cryptochiton stelleri* that I sampled had fed on herring eggs.

None of the worms, amphipods or shrimp were sampled for gut content, but other studies suggest that these animals may be carnivorous and able to feed on particles the size of herring eggs (*see* Hobson 1967; Shaffer 1979; Oug 1980; Abbott and Reish 1980 for polychaetes; Haderlie 1980 for nemerteans; Keith 1969 and Caine 1977 for amphipods; and Chace and Abbott 1980 for shrimps). It appeared reasonable from these studies to assume rations of 2% of body weight • day^{-1}.

The proportion of herring spawn consumed by epibenthic invertebrates is a function of the density of the spawn and the abundance of the predators. Palsson (1984) concluded that invertebrates can consume most of the eggs from light density herring spawns. My study was conducted in an area where herring abundance and egg density were substantially higher. Presumably, epibenthic invertebrates were of average abundance. Under these conditions, herring egg loss to invertebrate predators is not greater than 30%, the maximum observed at one site. The total egg loss to invertebrate predation was 4% and at this level the effect on herring spawn surveys is likely undetectable.

Acknowledgments

Doug Miller and Jake Schweigert of the Pacific Biological Station and Jane Watson, Caroline Heim, Laurie Convoy and Leah Saville of Archipelago Marine Research Ltd. of Victoria, British Columbia assisted with sampling. Alan Campbell, Neil Bourne, and Doug Hay of the Pacific Biological Station and two anonymous reviewers made many valuable suggestions.

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Received 8 September 1992
Accepted 9 September 1993

Notes

Infanticide in Brown Bears, *Ursus arctos*, at Brooks River, Alaska

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On two occasions, adult male Brown Bears (*Ursus arctos*) were observed to kill dependent young at Brooks River in Katmai National Park, Alaska. In July 1988 a yearling bear was killed at Brooks Falls, and in July 1989 a spring cub was killed there.

Key Words: Brown Bear, *Ursus arctos*, infanticide, mortality, Alaska.

Observations of intraspecific killing by Brown Bears in the field are rare and most accounts provide few details. Those reported are most frequently only of a bear observed on the carcass of another, with the cause of death inferred.

Direct observations of infanticide by Brown Bears are especially few. Troyer and Hensel (1962) reported a case of infanticide by a large adult male. Dean et al. (1986) described two cases: one involved an attempted infanticide and killing of the mother, the other the killing and consequent consumption of a yearling bear, both by adult males.

Here I report two cases of infanticide observed on Brooks River in Katmai National Park, Alaska. Both incidents were witnessed from the public viewing platform at Brooks Falls. Because use of Brooks River by Brown Bears was intensively monitored between 1988 and 1990 (Olson 1993), I am able to document the bears involved and circumstances of the incidents in detail.

Study Area

Brooks River is a 2.5 km river connecting Brooks Lake and Naknek Lake within the interior of Katmai National Park on the Alaska Peninsula. The Naknek drainage, of which Brooks River is a part, is one of the four most productive salmon spawning drainages in the region.

During July Brown Bears fish for migrating salmon jumping at Brooks Falls, a 2-meter high falls at mid-river. In September-October the number of bears using Brooks River increases. Then bears forage over the entire river on accumulating dead and dying, spawned-out salmon.

Descriptions of Observed Infanticides

On 13 July 1988 at 1425 h, I observed an attack on a yearling bear at Brooks Falls from a distance of ≤ 40 m. Although seven bears had been at the falls earlier in the day, only two single adult bears and an adult female with one yearling were present when the infanticide occurred. Fish capture rates on the day of the attack were relatively low, with 0.8 fish caught per bear hour of presence (8 fish were caught during 9.7 bear hours). Fish capture rates prior to this date had been variable; the average fishing rate during July was 1.5 fish per bear hour.

The large adult male that attacked the yearling had been fishing at the falls regularly during the previous two weeks. He was one of the more dominant males, and at times had driven all bears from the falls. The female and yearling had not been commonly seen at the falls; they were more frequently observed near the lodge at the mouth of the river, sometimes at distances of <50 m from developed facilities. The female was small for an adult; she appeared to be less than half the size of the large male.

At 1425 h the female with yearling was fishing from the top edge of the falls (about 30 m from the viewing platform), when the large male suddenly appeared upriver behind the two. The female retreated down off the falls away from the male, and the yearling tumbled over the falls into the whitewater below.

The male remained oriented towards the yearling, and climbed quickly down off the falls towards it. As the male continued his pursuit of the yearling, the mother reached shore, looking over her shoulder several times and huffing, as if the yearling were behind her. The yearling fled from the large male, swimming downstream away from its mother until the small, shrub covered island 25 m downriver of the falls separated the female and yearling.

When the male reached the yearling behind the falls island, he landed on it with both paws extended (rather similar to his fishing technique). According to several park visitors with a better view than mine, he held it under water briefly, then shook it vigorously by the neck. The yearling was obviously dead when the male carried it by the scruff of the neck into the woods, approximately 70 m downstream. The female appeared stressed, huffing intermittently, but at no point attempted to defend the yearling from the male. Less than 3 min had elapsed from the arrival of the male until the death of the yearling.

The male returned to the falls within about 5 min after carrying the yearling into the woods. He caught and consumed a salmon, and continued to fish until we left the platform at 1450 h. The female passed by the platform, huffing, and eventually left the area. Both the large male and the female were observed fishing at the falls a few days later. The carcass of the yearling was retrieved by NPS personnel several days after the attack; it had been almost completely consumed.

A second incident of infanticide was observed on 21 July 1989, at 1100 h, from a distance of ≤15 m. Bears present within the vicinity of the falls at the time of the attack included a subadult, a female with two spring cubs, and an adult male. The fish capture rate that day appeared to be relatively low, with 0.9 fish caught per bear hour of presence (5 fish / 5.5 bear hours). Bear activity and rates of fishing success had been fairly high for at least a week prior to the observed events; the mean rate during July was 2.1 fish per bear hour.

The adult male that attacked the cub had been observed on only two previous occasions. The female with two spring cubs frequented the river through much of July, but she had only recently begun to fish the falls on a regular basis.

At the time of the attack the mother of the two spring cubs was fishing below the falls near the bank opposite the viewing platform about 40 m away. The two cubs had initially been high in a spruce tree 10 m east of the observation platform, but had joined their mother below the tree to share a fish she had caught. They then followed her to the river bank in front of the viewing stand, and had remained there when she returned to fishing on the other side of the river.

Several minutes before the attack the adult male walked by the viewing platform headed upriver. He returned downriver via that same route where the cubs were then located, and rushed out of the brush towards them. The two cubs began running towards the refuge of the spruce tree. The cubs separated, and the male intercepted one a few meters from the downriver side of the platform. He took it by the neck and shook it, killing it. The other cub reached the spruce, climbed the tree, and bawled intermittently for at least 30 min. The male carried the carcass inland about 5 m, chewed on it briefly, then picked the carcass up and retreated into the woods, ≥20 m from the viewing platform. The female did not notice these events and continued to fish below the falls near the opposite bank.

About 30 min after the cub was killed the female stopped fishing, crossed the river, and approached the platform. She followed the path along which the male had carried the cub into the woods, returned to the viewing stand, and again followed an apparent scent trail. Upon her return she approached the spruce tree where the remaining cub had climbed, then milled around the area near the tree, stopping near the platform where the cub was killed. Blood on the grass appeared to attract her attention, and she sniffed and licked the grass several times.

The surviving cub was hesitant to leave the spruce; it repeatedly returned to the tree upon climbing down, and whenever the female left the base of the tree the cub bawled. The female appeared agitated, but had returned to fishing before 1430 h, at which time we left the platform.

At 1830 h I resumed observations at the falls platform. The male involved in the infanticide earlier in the day fished the falls starting about 1900 h, and left the area 2130 h; the female and cub were not observed. The male was not seen on Brooks River after 22 July, while the female with cub continued to fish the falls until the end of July. NPS personnel searched for the carcass the day after the cub was killed, however no remains were located.

On 19 July 1989, at 1600 h an unsuccessful attack on a yearling bear was observed (R. Rodehaver, National Park Service, personal communication), again at Brooks Falls. Bears using the falls when the infanticide occurred included several adult males and subadults, a single adult female, and a female with three yearlings. Fish capture rates at the time of the attack were reportedly low, but earlier in the day had been 2.9 fish/bear hour, close to the average July rate.

The large male involved in the unsuccessful attack was the same male that killed the yearling in 1988. The female with three yearlings had been observed infrequently at the falls in 1989; she had fished at Brooks Falls during much of July 1988.

The female was fishing in a pool below the falls (40 m opposite the viewing platform) with her yearlings a few meters behind her, when the large adult male rapidly approached the yearlings from downriver. The female's back was to her young, and she initially appeared unaware of the approaching male.

The yearlings immediately fled from the large male. One of the three was unsuccessful in its attempt to escape, and turned to face the approaching male, standing bipedally and swatting at him. The male hit the yearling, knocking it underwater, and lunged his head into the water after it. The female charged at the male hitting and biting him as he retreated 10-15 m, before she withdrew. The large male began to fish within a few minutes afterwards. The yearling was apparently unhurt; the female was last seen with the yearlings on 15 October 1989.

TABLE 1. The total number of different cubs and yearlings observed each season and year. The left number in each column is the total number of dependent young seen on initial observations, the right number is that seen on final observations.

	July		Sept-Oct	
Year	Cubs	Yearlings	Cubs	Yearlings
1988	6/6	3/2	6/6	6/6[a]
1989	2/1	6/6	3/3	6/6
1990	4/4	1/1	7/7	1/1
1991	2/2	4/4	5/5	7/7
Totals	14/13	14/13	21/21	20/20

In 1988 one female with two yearlings was observed the last two days of the field season with only one yearling. Given the short duration of these observations, there was insufficient information to conclude mortality.

Discussion

At least 15-25 independent bears were observed using the river on a regular basis in July each year, and at least 25-30 were regularly seen in September-October; on average about 40% adult males, 30% adult females (15% single and 15% with dependent young), and 30% subadults. During July two dependent offspring were killed by adult males; regular observations of family groups through July of 1988-1991 confirmed that there were no other losses of dependent offspring. In contrast, during the fall (September-October) no deaths of dependent young were recorded (Table 1) despite higher densities of adults.

Several factors could have contributed to the observed mortality at Brooks Falls during July. First, courtship behavior and mating were regularly observed during the first half of July; males could have been more aggressive then. The infanticide observed in 1988 occurred during this time period. However, females with young typically did not use Brooks Falls to a large extent until after mating activity had ceased.

Availability of food could also be related to the occurrence of infanticide. In July of 1990 fish availability was much higher than in 1988, 1989, or 1991, and no dependent offspring were killed (T. L. Olson and R. C. Squibb, National Park Service, unpublished data). Further, both infanticides occurred in July, when bears had their first access to salmon; in the fall after bears had access to food for several months, no losses of dependent young were observed.

Acknowledgments

This study was funded by the National Park Service, partially through the Utah State Cooperative Fish and Wildlife Research Unit. Thanks go to B. Gilbert, R. Squibb, and D. Taylor for helpful comments on the manuscript.

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Received 3 July 1991
Accepted 11 March 1993

Observations of an Interaction between a Barren-ground Black Bear, *Ursus americanus*, and a Wolf, *Canis lupus*, at a Wolf Den in Northern Labrador

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An encounter between an adult male barren-ground Black Bear (*Ursus americanus*) and an adult Wolf (*Canis lupus*) at the Wolf's den near the Ikarut River in northern Labrador (ca. 58° 09′ N, 63° 05′ W) on 7 July 1990 is described in which the wolf was actively aggressive and the bear responded with only low levels of defense.

Key Words: Black Bear, *Ursus americanus*, Wolf, *Canis lupus*, Labrador, den.

There are few published observations of interactions between Wolves (*Canis lupus)* and Black Bears (*Ursus americanus*) although the two species are sympatric throughout much of Canada. It is likely that, as with Brown Bears and Wolves (Murie 1944, 1981), Black Bears and Wolves will normally take little notice of each other. However, when interactions do occur, mortality of either species may result. Black Bears in winter dens have been reported killed by Wolves on five occasions (Rogers and Mech 1981; Horejsi et al. 1984; Paquet and Carbyn 1986) and three Wolves killed a non-denned Black Bear in southeastern Alaska (Ligon 1926, *cited in* Young and Goldman 1944). A Black Bear killed an adult female Wolf at its den (five pups in den) in Algonquin Park, Ontario (Joslin 1966).

The incident we report here occurred during a study of barren-ground Black Bears in the northeastern Labrador Peninsula, the only population of Black Bears that lives year-round north of treeline on the barren-grounds (Jonkel and Miller 1970). The study is based at Kangerdluksoak (Hebron Fiord), Labrador, a region of high relief coastal tundra 220 km N of Nain, Labrador.

On the morning of 7 July 1990 at 0952 h we radio-located an 8-year-old male Black Bear approximately 1.5 km WNW of a Wolf den near the mouth of the Ikarut River (ca. 58° 09′ N, 63° 05′ W). This den has been used by Wolves each year from 1981 to 1991 and Black Bears are not commonly seen in its vicinity (G. Furey, B. Dempson, S. Dawson, Department of Fisheries and Oceans, personal communications). In 1990 the den was occupied by a pair of adult Wolves and three or four pups. When we started our observations (we used 15-40x spotting scope and 10x40 binoculars), the Black Bear was grazing on new grasses and digging for small rodents, while it moved slowly eastward along the river. At the same time a single adult Wolf could be seen on top of the den 1500 m S of our vantage point. At 1018 h the Wolf was intently watching the Bear, but stopped when the Bear went into a willow (*Salix* spp.) and alder (*Alnus* spp.) thicket at 1126 h, apparently to rest. From 1330 h through 1507 h the adult Wolf and pups played on the top of the den.

The Black Bear resumed activity at 1507 h and by 1524 h was approximately 500 m NW of the den and walking directly toward it. At 1529 h the Bear was within 200 m of the den and the adult Wolf was watching it closely. Between 1532 h and 1534 h the Wolf went in and out of the den entrance a minimum of five times, but the reason for this could not be discerned and the pups were not visible. At 1545 h the Wolf moved from the top of the den to the base, swam across a small pond, and ran to a point 50 m S of the Bear. For the next 27 minutes the Wolf maintained a distance of 75-100 m S or SW of the Bear, upwind of it. The Wolf appeared wary, alternately sitting, lying down, standing alert, or pacing about. The Bear, apparently unaware of the Wolf, continued to graze and dig for small mammals. At 1613 h the Bear urinated or defecated, or both, near the river, across from the den, then moved slowly E. The Wolf followed and carefully sniffed where the Bear had urinated or defecated. At 1625 h the Wolf was within 50 m W of the Bear and was moving parallel to it.

The Wolf was still upwind of the Bear when at 1635 h the Bear stopped, turned and sniffed in the direction of the Wolf, which was standing still and alert. Suddenly, the Bear spun around and broke into a fast run away from the Wolf. The Wolf immediately pursued and caught up within a few seconds. The Bear stopped and turned on the Wolf, which also stopped and then retreated. The Bear charged the short distance to the retreating Wolf. Both stopped and faced one another, the Bear stood still, while the

Wolf slowly circled with its hackles raised and its tail between its legs. The Wolf nipped at the rear of the Bear several times, but made no contact. The Bear responded with a sharp lunge.

At 1638 h the Bear charged the Wolf, which turned and ran. After this brief chase ended, the Bear again stood still, while the Wolf slowly circled and occasionally leapt in the air in front of the Bear. The Bear charged once more and a chase ensued, during which they crossed the river. At the end of the chase both animals were on the S side of the river and were 400 m E of the den. At 1645 h the Wolf apparently defecated directly in front of the Bear, while the Bear remained still and watched. The Wolf resumed its side to side leaps in front of the Bear, which backed into a small alder and willow thicket. Over the next three minutes the Bear charged the Wolf at least three times, returning to the alders after each rush. The Bear's charges did not immediately cause the Wolf to leave, but at 1650 h the Wolf moved 80-100 m W of the thicket (toward the den), laid down, and faced the Bear.

The Bear stayed in the thicket until 1713 h when it emerged and ran directly toward, and then past, the Wolf. The Bear was headed directly toward the den and the Wolf gave chase. Both animals ran into a dense alder and willow thicket <30 m N of the den. Over the next 26 minutes we did not see the Bear, but the Wolf came out briefly from the dense cover at least twice. After each emergence it re-entered the thicket < 100 m E of where the Bear had entered. At 1739 h we saw the adult Wolf on the E side of the den with at least two, and possibly three, of the pups. The pups were close to the adult.

The Bear was not seen for the next 2 h 26 min, although the steady radio-signal indicated it was still in the den vicinity and not moving. Throughout this period the adult Wolf was seen frequently at different locations around the den, always alert and watchful. Finally, the Bear emerged and moved toward the den one last time at 2021 h. It was primarily digging for small mammals and did not appear to have any interest in the den or the Wolf. The Wolf watched from approximately 30 m away. Eventually, the Bear turned and walked SW away from the den.

At no point during the interaction did the Wolf vocalize, although it is known that when humans approach an active den site, Wolves will howl or bark (Murie 1944; Joslin 1966; Theberge and Pimlott 1969; Harrington and Mech 1978). In 1989 and 1990 at this same den, on each of four occasions in which Wolves reacted to our presence within 200 m of the den, the Wolves howled and barked, but never approached closer than approximately 30 m of us. Such vocalizations may serve to decoy intruders away from the den, or alert other pack members to the threat (Harrington and Mech 1978). The lack of vocalizations during this encounter with the Black Bear, and in other Wolf-Bear encounters reported in the literature, indicates that Wolves treat disturbances by Bears differently from human disturbance, using a more active defense with Bears and more passive defense with humans.

Our observation is consistent with other published accounts of the interaction between Bears and Wolves at Wolf dens. The Wolf was the aggressor and the Bear responded with what appeared to be a low level of defense. Although the Bear was occasionally "aggressive" toward the Wolf, it never displayed any of the behaviours normally associated with a high level of aggression in Black Bears, such as paw slapping on the ground (Jordan 1976). Murie (1944, 1981) suggested that Bears regard Wolves as a nuisance rather than as a serious threat or as a potential prey item. This was also the impression we had after observing the above encounter.

Acknowledgments

We thank Wayne Barney for assistance in the field and the Department of Fisheries and Oceans, St. John's, for use of their cabin at Ikarut River and for information on the history of the Wolf den. The Labrador-Newfoundland Wildlife Division, Goose Bay, and in particular Regional Wildlife Biologist Stuart Luttich, provided major logistical and equipment support for this project. We thank Ian Stirling (Canadian Wildlife Service) and Lynn Rogers (U.S. Forest Service) for their reviews and comments on the manuscript. Funding was provided by the Canadian Circumpolar Institute, Canadian Wildlife Service, Natural Sciences and Engineering Research Council, and Mount Saint Vincent University.

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Received 28 October 1991
Accepted 24 June 1993

Grizzly Bear, *Ursus arctos*, Predation of a Denned Adult Black Bear, *U. americanus*.

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Smith, Martin E., and Erich H. Follmann. 1993. Grizzly Bear, *Ursus arctos*, predation of a denned adult Black Bear, *U. americanus*. Canadian Field-Naturalist 107(1): 97–99.

During a radio-tracking flight to document denning activity of Black Bears (*Ursus americanus*) in interior Alaska, a Grizzly Bear (*U. arctos*) was seen actively digging at the den of a radio-collared adult female Black Bear. Subsequent investigation of the site revealed numerous bone fragments and a chewed radio-collar indicating predation. The den showed a second entrance where the Grizzly Bear had been digging and was successful in forcing the Black Bear to flee and be killed in the area immediately adjacent to her den.

Key Words: Grizzly Bear, *Ursus arctos*, Black Bear, *Ursus americanus*, interspecific predation, den mortality, Alaska.

Black Bears (*Ursus americanus*) can occasionally be prey to other Black Bears (Alt and Gruttadauria 1984; Dean et al. 1986; Tietje et al. 1986), Grizzly Bears (*Ursus arctos*) (Ross et al. 1988) and Wolves (*Canis lupus*) (Horejsi et al. 1984; Paquet and Carbyn 1986). Cubs and subadults may also fall prey to Coyotes (*Canis latrans*) (Boyer 1949); eagles (*Aquila* spp.) (Nelson 1957, *cited in* Lecount 1987); Mountain Lions (*Felis concolor*); and Bobcats (*F. rufus*) (LeCount 1987) but these occurrences are probably rare.

Intraspecific predation by Grizzly and Black bears, though also uncommon, has been reported in studies throughout the bear range, usually as males killing cubs (Jonkel and Cowen 1971; Pearson 1975; Tietje et al. 1986). This may yield genetic benefits: males kill a competing male's cubs then breed with that female to sire his own cubs (Rogers 1976, 1983; LeCount 1987) or have population regulatory effects: depressing cub recruitment and/or subadult survival (Bunnell and Tait 1981; McCullough 1981; Ruff 1982; Rogers 1983).

Interspecific predation has no direct genetic benefit but may play a significant role in the population dynamics and partitioning of resources between Black and Grizzly bears.

There are few documented cases of Black Bears killed by Grizzly Bears, though interspecific predation is generally believed to occur based on circumstantial evidence (Rausch 1961). The few available reports from the literature are summarized as follows. Arnold (1930) reports a female Brown Bear and her two cubs chased, killed, and consumed a Black Bear cub. Jonkel and Cowen (1971) cited three instances of Grizzly predation on Black Bears but gave no details. Boertje et al. (1988 - Table 3) reported the predation of two 40 kg Black Bears by radio-collared Grizzly Bears but gave no additional information. Murie (1981) reported a Grizzly killing two Black Bear cubs and related a second-hand account of predation by a Grizzly Bear on a Black Bear while digging its den. Only Ross et al. (1988) clearly documented predation of two denned Black Bear cubs by Grizzly Bears. We report a Grizzly Bear killing a denned adult female Black Bear.

A study of Black Bear denning ecology in interior Alaska was conducted in the Tanana River flats, south of Fairbanks, Alaska (64°50'N x 148°00'W). Regular radio-tracking flights were conducted to determine the onset of denning. One marked bear was a 23-year-old female (#327) which weighed 98 kg when captured on 27 July 1989. On 17 September

1989 she was observed feeding and appeared in excellent condition (lots of fat, easy mobility, shiny coat, no apparent injuries). By 22 September 1989 she was localized at a den. During another flight on 9 October 1989 an adult Grizzly Bear (200 kg estimated weight) was seen digging at #327's den site.

The Grizzly Bear appeared agitated and lunged at the plane during a low level pass. No obvious signs of a struggle were yet apparent and #327's radio signal was still coming from the den. After three passes the Grizzly disappeared into the woods in front of the den. No additional flights were made until 10 April 1990. Using helicopters we were able to land and search the area only to find a chewed collar, numerous small bone fragments, and a large amount of Black Bear hair.

A follow-up helicopter visit on 25 June 1990 showed that the den (1.7 m long x 1.2 m wide x 0.33 m high) was located in a Black Spruce (*Picea mariana*) stand and had been used previously as evidenced by *Equisetum* spp. growing on the tailings pile and moss growing on the walls. In addition to the original opening (56cm x 45cm) there was a new opening in the rear (37cm x 28cm) where the Grizzly Bear had been seen digging. Immediately adjacent to this new opening was a 4m x 6m area of severely disturbed vegetation (large bushes uprooted or crushed; small bushes, forbs and grasses still not recovered after nine months) indicating the site of an intense struggle. Aerial photographs also show a freshly broken birch tree (approximately 20 cm DBH) which lay adjacent to this disturbed site.

We theorize that #327 was able to successfully defend the original den entrance which was reinforced by stout tree roots but was forced to flee when the Grizzly excavated a second hole. At this point she may have climbed the small birch which was insufficient to support her weight, or the Grizzly Bear may have caught up to her. In any case, there was clearly a fight and she was then killed in the area immediately adjacent to her den.

The possibility of this only being an act of scavenging is highly unlikely because #327 was observed just five days prior to denning and 17 days prior to the grizzly encounter. She appeared healthy and in good condition (actively feeding, very fat, shiny coat, moving easily through tough terrain, no noticeable injuries) so it is unlikely that an illness would have had debilitating effects during that short time interval. This is also a remote area, inaccessible to hunters so the chances of a crippling gunshot injury are slight. Also if #327 were not alive and defending the den then the second hole would have been unnecessary. The Grizzly Bear could have simply reached in and pulled #327 out through the original entrance.

Ross et al. (1988) theorize that tardiness in denning by the Black Bear in their study resulted in a snow trail which led to its discovery by Grizzly Bears. This was not the case for #327, as she had denned early and prior to snowfall. However, the den entrance opened onto a major game trail and thus may have been discovered by a passing Grizzly Bear. Another factor may be #327's reuse of an old den since a low incidence of reuse may be a mechanism to avoid predation (Alt and Gruttadauria 1984). There were many large climbable trees in the area around #327's den, including immediately above the den, but none showed claw marks of an attempt to escape. Perhaps the time required to free herself from the confines of the den and the immediate presence of the Grizzly Bear precluded her climbing a suitable tree.

Miller (1985) reported that a female Black Bear successfully defended herself and her yearlings from a larger Brown bear and that another female Black Bear appeared to be prepared to defend herself and her treed cubs from a Brown Bear. Mundy and Flook (1973) also reported that a female Black Bear with two cubs attacked a larger Grizzly Bear and forced it to flee. Therefore, Black Bears are often capable of defending against predation by Grizzly Bears. The case presented here is the first documentation of an adult Black Bear being killed at its den by a Grizzly Bear.

Acknowledgments

Funding for this project was provided by the U. S. Army 6th Infantry Division (Light) Alaska through the Alaska Department of Fish and Game and the Alaska Cooperative Wildlife Research Unit. Special thanks to Junior Kerns, Natural Resource Specialist, FT Wainwright, John Hechtel, Biologist, ADF&G, and to Norma Mosso, Administrative Assistant, ACWRU. Flying support was provided by Tamarack Air (Bill Lentsch and Sandy Hamilton), and ADF&G pilots Mark McNay, Pat Valkenburg, and Jim Davis. Helicopter support was provided by the pilots and crews of C Company, 4th Battalion, 123rd Aviation Regiment. Office space and support was provided through Hans Staaland at the Agricultural University of Norway, Department of Biology and Nature Conservation.

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Received 22 November 1991
Accepted 19 April 1993

Grizzly Bear, *Ursus arctos*, Predation on Muskox, *Ovibos moschatus*, Calves near the Horton River, Northwest Territories

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Clarkson, Peter L., and I. Sarma Liepins. 1993. Grizzly Bear, *Ursus arctos,* predation on Muskox, *Ovibos moschatus* calves near the Horton River, Northwest Territories. Canadian Field-Naturalist 107(1): 100–102.

An adult male and adult female Barrenground Grizzly Bear killed five Muskox calves near Horton River, Northwest Territories in May 1989. The calves were with a herd of 40–50 Muskoxen. The bears killed the calves within a two km area. At least three calves escaped. Both bears were observed feeding on the same calf.

Key Words: Grizzly Bears, *Ursus arctos*, Muskoxen, *Ovibos moschatus*, predation, calves, Horton River, Northwest Territories.

Grizzly Bear (*Ursus arctos*) predation on Muskoxen (*Ovibos moschatus*) has been observed and suspected throughout the mainland range of Muskox in the Canadian and Alaskan Arctic. During their travels early explorers saw Grizzly Bears feeding on Muskoxen (Tener 1965). Native people travelling on the land or out hunting also observed Grizzly Bears feeding on Muskoxen (Green, personal communication 1990; Illisiak, personal communication 1990). Biologists conducting field work reported Grizzly Bear predation on Muskoxen (Gunn and Miller 1982; Case and Stevenson 1991). To date all published observations have described solitary Grizzly Bears preying or scavenging on adult Muskoxen. Case and Stevenson (1991) suggest that if Grizzly Bears can prey on adult Muskoxen they could also prey on calves. Grauvogel (1979) further speculated that predation on calves was slowing the increase of a transplanted Muskox herd in Alaska.

During a relocation flight of radio-collared Grizzly Bears in May 1989, PLC saw evidence that two Grizzly Bears had preyed on Muskox calves. We believe this incident is the first documented occurrence of two adult bears preying on the same Muskoxen.

On 18 May 1989, a 15-year-old female Grizzly Bear (GF105) was located with a 17-year-old male (GM114) (Figure 1, site A). Both bears were captured in 1988 as part of a study to determine local bear densities and female productivity (Clarkson and Liepins 1989, 1991). GM114 was identified by colour-coded ear flags. GF105 was radio-collared and was presumed to be in estrous as she did not have cubs.

The bears were travelling together in an easterly direction on the north side of the West River (69°05' N × 126°22' E). A herd of 40–50 Muskoxen, with a minimum of eight calves, was feeding near the junction of the West and Horton Rivers (Figure 1, site B). The bears and Muskoxen were about 4 km apart at this time. Neither the bears nor Muskoxen appeared disturbed by the Supercub.

Inclement weather delayed flying and further observations until 20 May 1989, when the bears were found feeding on a Muskox calf (Figure 1, site B). Four other calf carcasses were observed within two km of the bears. The Muskoxen herd had left the area.

A subsequent ground investigation on 20 May confirmed that the bears had pursued and killed the five calves. The ambient temperature was above freezing and the soft snow provided a good track record of the predation sequence. Grizzly Bear tracks were found at each calf kill site and between kills. A difference in track size indicated that two bears were chasing the Muskoxen. Bite marks on the calves and blood on the snow at each site confirmed that the Grizzly Bears had killed all five calves. Wolf (*Canis lupus*) tracks were not observed in the area.

The bears encountered the Muskox herd between 18 and 20 May and killed the first calf (Figure 1, Number 1). The first calf was 90% consumed when observed. The Muskoxen left their feeding site and ran west from the ridge. A second calf was killed about 1.5–2.0 km from the first calf (Figure 1, Number 2). The second calf was about 60% consumed with just the head and shoulders remaining. The Muskoxen continued running and the bears killed a third calf about 300 m further west (Figure 1, Number 3). A Wolverine (*Gulo gulo*) was feeding on the third calf that was about 30% consumed. The Muskoxen ran about 300 m north, and the bears killed the fourth calf at this location, but did not consume any of the calf (Figure 1, Number 4). An adult Golden Eagle (*Aquila chrysaetos*) was at the site and had just begun to feed on the calf. The Muskoxen ran northwest and the Grizzly Bears killed the fifth calf about 200 m from the fourth calf (Figure 1, Number 5). The fifth calf was not consumed. The Muskox herd then split into two groups for approximately two km and then rejoined and continued travelling in a northwesterly direction for over 50 km.

Grizzly Bear predation on Muskox calves is difficult to detect as the bears quickly consume the carcass, which may weigh less than 25 kg (Latour

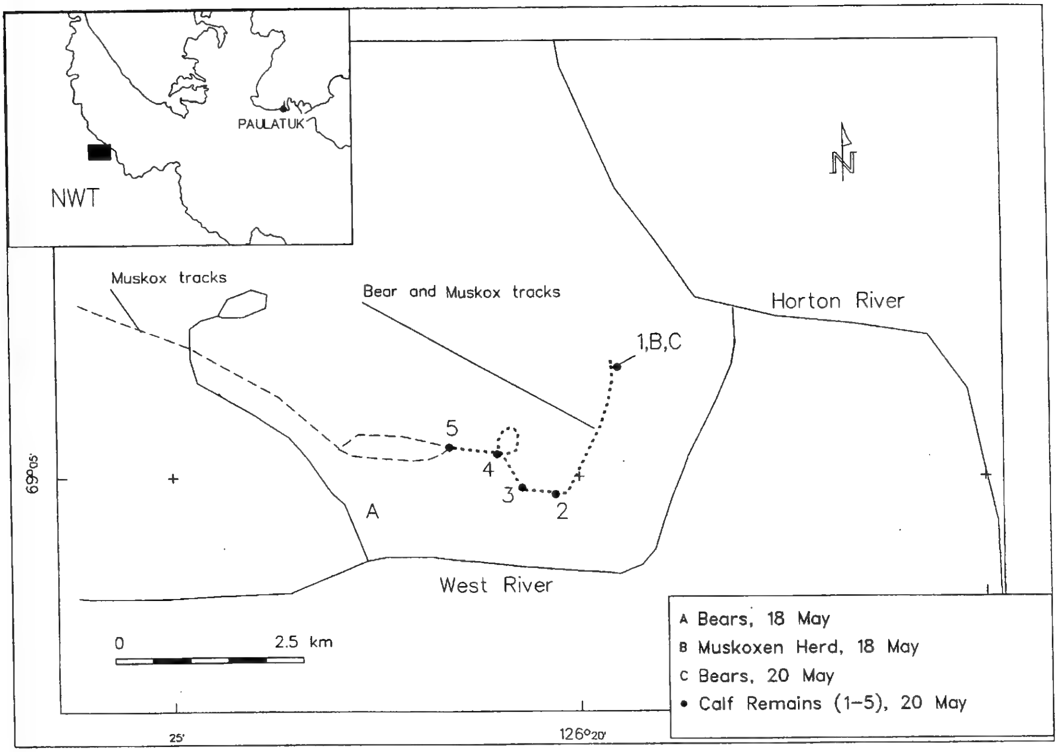

FIGURE 1. Grizzly Bear predation on Muskox calves near the Horton River, Northwest Territories, May 1989.

1987). Other evidence of predation such as Grizzly Bear tracks may be difficult to detect because of the tracks of the Muskox herd. In May 1976, a Grizzly Bear near Paulatuk, Northwest Territories, killed and fed on an undetermined number of Muskox calves (Ruben, personal communication 1992). Hunters travelling in the area saw the partially consumed calves and bear tracks in the snow. The bear left the area when the hunters approached the site with snowmobiles.

To protect themselves from predators Muskoxen often use a group defense formation where the younger and more vulnerable animals are placed between the older Muskoxen (Gray 1987; Miller and Gunn 1979). The older animals face the threat or predator, presenting their horns to a potential predator. In other cases Muskoxen run from predators and do not allow them to get close enough to attack. In our observation the group defense formation, if tried, was not successful.

The calves were likely caught when trailing behind the running adults. Adult Muskoxen have left their calves when fleeing human hunters during commercial harvests on Banks Island (Fraser, personal communication 1991).

Grizzly Bears have learned to search for and prey on the young of Caribou (*Rangifer tarandus*) (Miller et al. 1988), Moose (*Alces alces*) (Franzmann et al. 1980; Boertje et al. 1988; Larsen et al. 1989) and Elk (*Cervus elaphus*) (Cole 1972; French and French 1990; Gunther and Renkin 1990; Hamer and Herrero 1991).

Adult male and female Grizzly Bears get together during the breeding season (June and July). Two bears together may pose a greater threat to potential prey than solitary individuals. Gunther and Renkin (1990) observed three Grizzly Bears (single and a mated pair) kill three Elk calves. Knight and Judd (1983) documented two bears (yearling and two-year-old) that killed 30 domestic sheep in one evening. In our observation, the two bears encountered a Muskox herd and killed five calves. This suggests that once they began to prey on calves, they killed as many as they could before the Muskoxen left the area.

Single Grizzly Bear predation of several young is reported for other ungulate species. French and French (1990) observed a Grizzly Bear capture five Elk calves in 15 minutes. Two of the calves escaped seemingly unharmed, while the bear killed the remaining three calves. McLean (personal communication 1991) observed a Grizzly Bear that killed 10 Caribou calves on the Beverly Caribou Herd calving grounds. The bear killed the calves within a small area (1000 m^2) and was feeding on a calf when observed.

Grizzly Bear predation on mainland Muskoxen could be reducing their productivity and preventing them from increasing as rapidly as Muskox on Banks and Victoria Islands, where there are no Grizzly Bears (McLean and Fraser 1991, Department of Renewable Resources, Government of the Northwest Territories, File Report Number 106, 28 pages; Gunn, personal communication 1991). Although environmental conditions and Wolf predation influences a Muskox population, the role that Grizzly Bears play is also worth considering.

Acknowledgments

Ray Jackson, Inuvik Air Charter, flew the Supercub and helped with the ground investigation. B. McLean and C. Shank reviewed earlier drafts. The Inuvialuit Game Council, Wildlife Management Advisory Council (NWT), and Hunters' and Trappers' Committees are all thanked for their support. A special thanks to those individuals that provided information by personal communications: N. Green, J. Illsiak, and G. Ruben of Paulatuk, Northwest Territories, P. Fraser and A. Gunn of Renewable Resources, Government of the Northwest Territories, Yellowknife; and to two anonymous reviewers for their constructive comments.

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Received 3 March 1992
Accepted 18 August 1993

Report of Two Pregnant Beavers, *Castor canadensis*, at One Beaver Lodge

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Wheatley, Michelle. 1993. Report of two pregnant Beavers, *Castor canadensis*, at one Beaver lodge. Canadian Field-Naturalist 107(1): 103.

The presence in one Beaver lodge of two pregnant Beavers (*Castor canadensis*) is reported. Ice conditions and distance from neighbouring lodges make it likely that both animals were resident in the same lodge.

Key Words: Beaver, *Castor canadensis*, colony composition, reproduction.

Bradt (1938) stated that the typical colony of Beavers (*Castor canadensis*) consists of an adult pair, the yearlings and the young of the year. Hay (1958), Aleksiuk (1968) and Svendsen (1989) have all confirmed this. However, Hay (1958), Bergerud and Miller (1977), Novak (1977) and Payne (1982) all recorded examples of more than one adult female in a lodge. Payne (1982) found one lodge with four females and one with two, but in neither case were any of them pregnant nor was there an adult male present. Novak (1977) reported two cases where he found two females with placental scars and corpora albicantia, but no evidence to suggest that two litters were produced in the same colony. Both Bergerud and Miller (1977) and Novak (1977) argued that their results probably resulted from trapping too close to another active colony.

On 7 March 1991, while working as Registered Trapline Assistant with Bill Conley, who holds Registered Trapline number 10 in the Hole River Region of southern Manitoba, we trapped a pregnant female Beaver at a lodge on Ell Lake (51°02'30" N latitude, 94°14'30" W longitude), 7 km east of Wallace Lake. She weighed 17.3 kg and carried three fetuses - two in the right uterine horn and one in the left. Crown-rump measurements were 12 mm. On 13 March 1991, we trapped a 16.4 kg female at the same lodge. She also had three fetuses, all in the right horn with crown-rump measurements of 22 mm. Two kits weighing 7.7 and 6.4 kg were also trapped at the lodge. We did not trap any male.

Ell lake, where the Beavers were trapped, contained only one active lodge; the next lake was 2 km (including 300 m overland) from the lodge. Ell Lake had last been trapped in 1978 at which time one or two Beavers were taken. The ice at the time of trapping was about 1 m thick and there was no evidence of above-ice Beaver activity. It is therefore probable that both females were resident in the lodge. This lodge site was also unusual because the shores of Ell Lake were forested entirely by coniferous trees. The lodge and foodpile were constructed entirely of Jack Pine (*Pinus banksiana*), indicating that this was not prime habitat for Beaver. Tissue samples from the two females and the fetuses are now being analyzed to try to determine from the DNA whether the two females were related and whether the father of the two sets of fetuses was the same.

Acknowledgments

I thank Bill Conley for allowing me to work on his trap line. I also thank W.O. Pruitt, Jr. and two anonymous reviewers for their comments on the manuscript.

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Received 10 July 1992
Accepted 10 August 1993

Bivocal Distraction Nest-site Display in the Red Squirrel, *Tamiasciurus hudsonicus*, with comments on Outlier Nesting and Nesting Behavior

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Long, Charles A. 1993. Bivocal distraction nest-site display in the Red Squirrel, *Tamiasciurus hudsonicus*, with comments on outlier nesting and nesting behavior. Canadian Field-Naturalist 107(1): 104–106.

In the Red Squirrel, a conspicuous display by a mother in combination with more-emphatic-than-usual scolding and a bivocal call (both menacing and, concomitantly, resembling cries of nearby babies), given simultaneously with fleeing and returning repeatedly, is obviously an adaptive nest-site distraction. Such behavior probably lessens predation on young Red Squirrels when they are especially vulnerable. The mother carries the young or leads them to alternate dreys, and some young help bring grasses into these outlier nests. After weaning the young and adults scold other mammals and one another.

Key Words: Red Squirrel, *Tamiasciurus hudsonicus*, bivocal distraction, nest-site display, drey defense, outlier vocalizations.

Here I describe a bivocal, ventriloquistic call of the Red Squirrel (*Tamiasciurus hudsonicus*) which, accompanied by threats and luring behavior, appears to lead dangerous animals away from the nest-site. To my knowledge, such behavior has not been reported in the family Sciuridae. One sound spectrogram showing a vocal pattern of the Red Squirrel has been published (Smith 1968, 1978), but the best description of vocalizations in this species is descriptive prose (Hatt 1929). The most typical call is characterized as a long vibrant rolling "tcher-r-r-r-r." Another common call resembles the call of *Tamias*, a whistled "whuuk" or, it seems to me, "chirp." The last call Hatt mentioned is the so-called "scolding," which in one of its variable forms was described as follows:

> "Usually mounting a branch, the squirrel, now thoroughly angry, breaks into a long chatter interrupted at varying intervals by an explosive, whistled 'chuck,' or a high-pitched piping note… When the squirrel becomes exceedingly angry its outburst almost defies analysis, for it seems that it has several voices, all carrying different notes at the same time."

In May and early June, 1980, while observing a Black-capped Chickadee's (*Parus atricapillus*) nest at McDill Pond, Stevens Point, Wisconsin, I heard this complex call given by a Red Squirrel from trees near my garage and patio-porch. This call resembled two cries of two different squirrels. Sometimes the squirrel, even when calling, would eat parts of a Jack Pine (*Pinus banksiana*) pinecone (*see also* Hatt 1929: 59). I pursued the squirrel from treetop to treetop, where it descended in each new tree to begin scolding me again. On three other occasions in the next several days, the mother scolded and climbed higher in the tree. Without knowing, I was standing about 2 m from the Red Squirrel's nest.

On 2 June, hearing noises behind the cedar siding of my porch, I removed two planks with a crowbar. There I discovered five nestling Red Squirrels about one-third grown. The mother suddenly appeared only 2 m away on a large chokecherry tree and proceeded to "scold" in a bivocal manner with awing ferocity. As I turned toward her, she scampered up the tree, leaped to a nearby oak branch, and from the top of the oak she proceeded again to "scold." The chattering seemed like both a fierce scolding and a "high piping" or squeaking, resembling an accompaniment of baby squirrels. The mother ran down the trunk to about 2 m above ground and broke forth with full intensity. As I approached her, suddenly with a loud "skreeee" she ran up the tree, clambered into a neighboring oak, and repeated the entire sequence. In the last oak, however, she descended only to about 6 m and became silent. I had been led four trees away from the nest-site.

While I was again observing the young in my porch studding, from less than 1 m distance, the mother appeared among them coming through a gnawed hole, and growling or purring softly she picked up one young, went out the hole, thence from Chokecherry (*Prunus virginiana*) to Red Pine (*Pinus resinosa*), and onward to a hollow dead Red Oak (*Quercus rubra*). Soon I observed her remove two others in the same fashion along the same route, and eventually she had removed all five. She carried them by the loose ventral skin. Two days following repair of my porch she and her family briefly returned. Once again, I induced her to perform her distraction display. This time, after scolding, she climbed into the treetops of nearby Jack Pines with the loud "skreee," leaped over to another, descended to scold me face-to-face, retreated up the trunk with the loud "skreee" again, and so on until I had been led five trees distant.

In the notation used by Hatt (1929), the scolding call seemed to me as follows:

"Tee Teee Tee Teee Tee Teee Tee Teee Tee Teeee,"
Fzzz Fzzz Squzz FzzzFzzz

where the "Tee Teee" resembles a rather loud tin whistle, and is similar to the squeaks of small mammals. The "Fzzz" is a lower chatter which seems incredibly fierce. Sometimes a few squeaks would be sounded, preceding the "skree" when the squirrel scurried up a tree trunk.

In a distraction display it is essential that the communication be very positive, an advertisement in fact, and to enhance the chances for survival of the young a predator ought to be occasionally frightened, diverted, or lured away from the nest. The threatening "scolding" at the disturbed nest-site is combined with a ventriloquist call resembling the cries of nearby babies. The mother advances toward the predator, gains its attention, then scurries up the tree, and usually onward to a more distant one where the sequence may be repeated. A somewhat similar sequence of luring and scolding was described by Hatt (1943) near two nests, attributed to "lack of courage," but distraction was not suspected and is unknown. James N. Layne (personal communication) found in his copious field notes on Red Squirrels a relevant comment on the ventriloquistic quality ("sounds like two squirrels in the same tree").

The discussions of Hatt and others indicate that the bivocal call is used by Red Squirrels in defense of food or territory as well as in defense of the nest. Although I have heard Red Squirrels scolding at various times in the past ten years, I have never seen on other occasions such an intense, prolonged, ventriloquistic and complex display as was the aforementioned example of nest-site protection. Red Squirrels do express bivocal "scolding" on other occasions. In late June several bivocal calls were heard near the nest-site and at some distance away. These occurred at any time of the day. On 26 June, a female (probably the mother) scolded a wandering Woodchuck (*Marmota monax*). Subsequently she scolded me. I climbed an extension ladder and found in an abandoned nuthatch (*Sitta carolinensis*) nest cavity a fresh squirrel nest (dry slender grasses, a few dead oak leaves, and 30 clumps of elongate green grasses). There were no grasses in the other den observed in my cedar porch. The next morning the mother squirrel was seen carrying several green grasses into the hole, but no young were present. On 4 July, and several mornings thereafter, I heard bivocal scolding of the mother from a different tree as young squirrels emerged from the nest. All proceeded to forage in silence. By 8 July, the nest was abandoned. Similar outliers used by female and young have been described by Long and Killingley in European Badgers, *Meles meles*.

Once, shortly after emergence, one of the young squirrels carried a green grass stem into the hole. Perched in a small Jack Pine, one young I approached, which was probably a male (penis protuberant, no obvious scrotum), tried to scold me. The call seemed in this case on three levels:

cheep cheep cheep cheep cheep cheep cheep cheep
moo moo moo moo moo moo moo
fzz fzz

The young then ate part of Jack Pine cone.

In July, bivocal scolding was induced in Red Squirrels by my dog, a Gray Squirrel (*Sciurus carolinensis*), myself, and by several unknown causes. However, Riege (1991) found little interspecific territoriality toward Gray Squirrels in northern Wisconsin. I have seen reds chasing grays three times in 16 years, once even by a young Red Squirrel. On 14 July, an adult male and female both scolded me from treetops while feeding on Jack Pine cones, thereby proving that adult males make the bivocal scolding.

Recently (12–14 August 1993) Douglas Post and his class, Nora Lopez-Rivera, and I camped at Tahquamenon Falls, in Upper Michigan, where an abundance of Red Squirrels provided another example of bivocal scolding. A bivocal call was emitted repeatedly by one or two adults, one trying to take over a tree cavity occupied by the other. The noisy face-to-face scolding (about 40–60 seconds in duration) was repeated several times.

Although performed with full intensity by the mother and simultaneously with exceptionally bold threats and conspicuous fleeing, the nest-site distraction "scolding" resembles other "scolding" of different situations, such as the aggressive calls made toward animals such as Gray Squirrels, Woodchucks, people, and other Red Squirrels.

The distraction call also resembled the scolding of the mother when, at dawn, her young quietly emerged from the nest prior to their departing and foraging. In this situation the call also might serve as a nest-site distraction. Nest-site displays resemble other aggressive displays in some birds such as parids and sittids (Hinde 1952; Long 1982a, 1982b; and others), in which the displays resemble a defensive display against supplanting attacks while foraging.

In the Tassel-eared Squirrel (*Sciurus aberti*) several kinds of stimuli reportedly induced aggressive scolding. "Squealing" by "pups" and adult males was so similar that the function was suggested as probably the same, attracting the female and reducing her aggressiveness (Ferentinos 1974).

The scolding bivocal call of the Red Squirrel seemingly distracts predators as they approach a nest. The bivocal call, however, is often emitted at other times by the squirrels scolding other mammals or even one another. The social interactions of the Red Squirrel, with the mother at a natal den, with her moving the young about to outlier nests, comprise a far more complex social system than has been realized. Possibly its study may elucidate some problems in other social systems.

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Received 27 July 1992
Accepted 9 September 1993

A Range Extension for the Fringe-tailed Bat, *Myotis thysanodes*, in British Columbia

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Milligan, Barry N. 1993. A range extension for the Fringe-tailed Bat, *Myotis thysanodes,* in British Columbia. Canadian Field-Naturalist 107(1): 106–107.

One male juvenile Fringe-tailed Bat was mist-netted along the mouth of the Adams River, British Columbia (50°53'N, 119°33'E) in August 1991. This individual extends the known range approximately 70 km north of previous sightings.

Key Words: Fringe-tailed Bat, *Myotis thysanodes,* mist net, British Columbia.

The Fringe-tailed Bat (*Myotis thysanodes)* is a potentially endangered species in British Columbia. An individual reported here from the Shushwap Lake area, British Columbia, extends the known range approximately 70 km north of previous British Columbia records. Previous observations have been centered around Oliver, British Columbia (49°11'N, 119°33'E; Fenton et al. 1980). The most northern record in Canada (van Zyll de Jong 1985) is a nursery colony near Vernon, British Columbia (50°16'N, 119°16'E; described by Maslin 1938).

On 5 August 1991, a juvenile, male, fringe-tailed bat (mass = 8.3 g, forearm length = 43.2 mm) was captured in a mist net along the mouth of the Adams River, British Columbia (50°53'N, 119°33'E) approximately 4 km NE of Squilax, British Columbia. This individual was captured approximately 2 hours after sunset at 23:10. It was banded, photographed (photos on file at Royal British Columbia Museum), and released (Figure 1). It was classified as a Fringe-tailed Bat due to the presence of a calcar with a prominent keel and a visible fringe of hairs on the outer edge of the tail membrane (Nagorsen and Brigham *in press*).

The biogeoclimatic zone of this area is described as an Interior Douglas-Fir zone dominated by Douglas Fir (*Pseudotsuga menziessi)* and an understory of Pinegrass (*Calamagrostis rubescens)* (British Columbia Ministry of Forests. Biogeoclimatic zones of British Columbia. 1988. Ministry of Forests. Victoria, British Columbia. 1 map. 1: 2 000 000) with an elevation of approximately 1400 m (National Topographic Series, Canada. Chase. 1973. Energy, Mines and

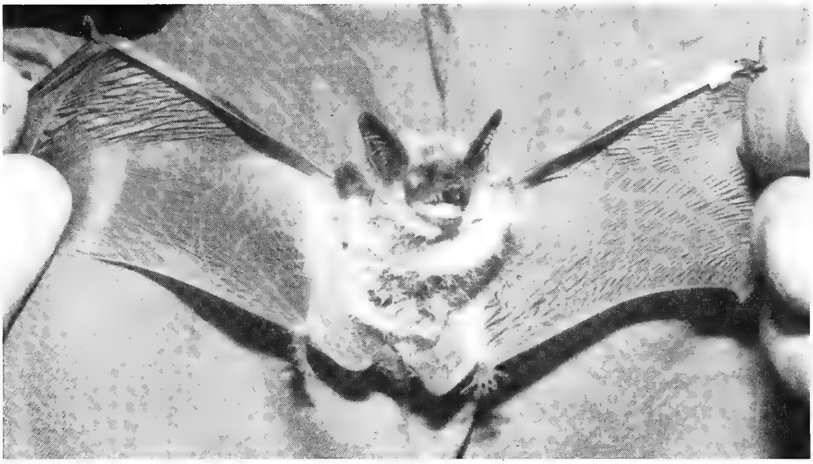

Figure 1. Fringe-tailed Bat, *Myotis thysanodes,* held after being removed from mist-net along the mouth of the Adams River, British Columbia, before release.

Resources Canada. 1 map. 1: 50 000). This area receives a mean annual precipitation of 30-50 cm and a mean daily temperature of 16-20°C (Farley 1979). The biogeoclimatic zone around Oliver is described as a Bunchgrass zone dominated by Bluebunch Wheat Grass (*Agropyron spiratum*) and Sagebrush (*Artemisia* spp.) and widely scattered Ponderosa Pine (*Pinus ponderosa*) and Douglas-Fir (British Columbia Ministry of Forests. Biogeoclimatic zones of British Columbia. 1988. Ministry of Forests. Victoria, British Columbia. 1 map. 1: 2 000 000) with a mean elevation of approximately 350 m (National Topographic Series, Canada. Keremeos. 1988. Energy, Mines and Resources Canada. 1 map. 1: 50 000). This area receives a mean annual precipitation of less than 30 cm and a mean daily temperature of more than 20°C (Farley 1979).

This range extension suggests that the Fringe-tailed Bat may occupy a larger, more diverse range throughout southern British Columbia than previously recognized, but it may also reflect an aberrent wandering, or result of wind storm, etc. The known distribution of this species may also indicate investigator bias in selecting areas. The interior and northern parts of British Columbia, as well as much of Vancouver Island, have been poorly, (sometimes not) studied for bats. To better understand the distribution and biology of the Fringe-tailed Bat and other bat species, previously unsampled areas need investigation.

Acknowledgments

I thank K. Zurowski for help in netting, and R. M. Brigham and D. Nagorsen for reading and commenting on an earlier draft of this paper. This study was funded by a Natural Sciences and Engineering Research Council (NSERC) operating grant to R. M. Brigham and a NSERC summer research scholarship to B. N. Milligan.

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Received 20 March 1992
Accepted 20 July 1993

Bobcat, *Felis rufus*, Dens in an Abandoned Beaver, *Castor canadensis*, Lodge

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Lovallo, Matthew J., Jonathan H. Gilbert, and Thomas M. Gehring. 1993. Bobcat, *Felis rufus*, dens in an abandoned Beaver, *Castor canadensis*, lodge. Canadian Field-Naturalist 107(1): 108–109.

A radio-tagged female Bobcat (*Felis rufus*) was discovered using an abandoned Beaver (*Castor canadensis*) lodge as a natal den site in northwestern Wisconsin. The lodge was adjacent to a small stream, had one entrance above water, and contained three kittens (two females, one male).

Key Words: Bobcat, *Felis rufus*, reproduction, denning, Beaver, *Castor canadensis*.

Bobcats (*Felis rufus*) reproduce in a variety of habitats throughout their range in North America (Hall 1981), yet there are few descriptions of natal den sites (Seton 1929; Rollings 1945; Young 1958; Gashwiler et al. 1961; Bailey 1979). Jackson (1961) suggested that Bobcats in Wisconsin use rock crevices, logs and stumps to rear their litters. Although information on den site selection is limited in the Midwest, we report what we believe is an unusual natal den site used by a Wisconsin Bobcat.

Bobcats were trapped and radio-collared in northwestern Wisconsin, as part of a larger study of Bobcat ecology. On 28 May 1992, we visited the denning area of an adult resident female Bobcat (F04) to observe the den site and to age, weigh and sex the kittens. The den was located in an abandoned Beaver lodge (5.2m X 4.3m) adjacent to a stream (7m wide X 1m deep) (NE1/2, NW1/4, Sec 15. T. 43 N. R. 13 W., Douglas Co., Wisconsin). The lodge was within a sedge meadow (Curtis 1959) with scattered clumps of *Spiraea* spp., *Salix* spp. and *Alnus rugosa*. The meadow followed the course of the stream and was adjacent to a contiguous stand of lowland conifers (*Picea glauca, Thuja occidentalis*) with mixed clumps of Paper Birch (*Betula papyrifera*). The den had one entrance (40cm X 45cm) above the water level and facing the stream. We could not determine whether the Bobcat had excavated the den entrance.

Upon our arrival to the den site, the female fled by swimming the creek. We observed three kittens (two female, one male) approximately 14 days old (Jackson et al. 1988). The female kittens weighed approximately 500g and 350g, and the male weighed 600g. The kittens were not marked, and were replaced to their original location in the den, 2.2 meters back from the entrance. The den cavity was completely dry and contained no nest material (Young 1958; Jackson 1961).

The den was revisited five days later. F04 had moved the den to a windblown White Cedar 60m north of the natal site. Upon revisiting the natal site, we found the carcass of a female kitten just within the entrance of the den. Necropsy results indicated that the kitten was dehydrated and had a slight subcutaneous hemorrhage along the right side of the neck. There was no food in the stomach, the intestines and stomach were full of gas, and the lower intestinal tract was partially full of mucus and bloody material. The kitten had ingested sand and quartz particles, and some plant material prior to its death. Parasites found included *Felicola subrostratus, Levineia felis* and *Isospora felis*. The kitten was estimated to have been dead at least two days prior to its collection, but cause of death could not be determined. We could not accurately compare the time of death to relocation of the den, so it is difficult to assess whether the kitten's death was due to abandonment.

Bailey (1979) reported reuse of natal den sites in Idaho. The Beaver lodge appeared to have been unused by Beaver for several years (Bergerud et al. 1977), but F04 was not believed to have reared a litter in 1991. Radio-telemetry data from 1991 revealed that she frequented the area and had been previously located within 200m of the 1992 natal den site.

We are not aware of other published reports of Bobcats using Beaver lodges to rear their offspring. Future research addressing the factors contributing to natal den site selection in the Midwest is needed as the availability of suitable den sites may play a role in regulating Bobcat density.

Acknowledgments

We thank the Wisconsin Department of Natural Resources, Great Lakes Indian Fish and Wildlife Commision, Safari Club International, Milwaukee Zoological Society, University of Wisconsin - Stevens Point, and numerous Wisconsin conservation organizations for supporting this research. Kerry Bauer (Wisconsin Department of Natural Resources - Wildlife Health Lab) performed the necropsy. Eric M. Anderson (College of Natural Resources, University of Wisconsin - Stevens Point) reviewed a previous draft of the manuscript.

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Received 30 July 1992
Accepted 16 August 1993

Long Distance Homing by the Deer Mouse, *Peromyscus maniculatus*

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Teferi, Taye and J. S. Millar. 1993. Long distance homing by the Deer Mouse, *Peromyscus maniculatus*. Canadian Field-Naturalist 107(1): 109–111.

We studied homing ability by displaced Deer Mice, *Peromyscus maniculatus,* in the Kananaskis Valley, Alberta, over three years. Fifty percent of adult Deer Mice returned home from straight line distances > 1500 m (range 650-1980 m). These distances are 9 to 26 times the home range diameter for Deer Mice in the area. Furthermore, homing mice crossed a natural obstacle (permanent river) and optimal habitat patches in order to reach their home sites. As these mice were unlikely to be familiar with habitats at these distances, our data appear to support the navigational hypothesis, in which the mice follow a direct route home without using habitat familiarity for orientation. Mice with previous homing experience had a higher homing success rate (100%) than inexperienced mice (60%). In addition, experienced mice returned home significantly faster than inexperienced mice. The higher homing success and significantly shorter return time of experienced mice may be due to increased familiarity with habitat or selection for better long distance travellers.

Key Words: Deer Mouse, *Peromyscus maniculatus*, homing, long distance, experienced, Alberta.

Homing has been defined as the ability of an organism to return to the initial capture site (presumed home site) after having been displaced (Cooke and Terman 1977). Factors affecting homing ability (e.g., displacement distance, age, habitat structure) and the possible mechanisms involved in the homing process have been investigated in a variety of animals (reviewed by Joslin 1977).

Three hypotheses have been proposed to explain homing in rodents. Murie (1963) proposed "random wandering" from release sites as a possible mechanism while Robinson and Falls (1965) and Fisler (1967) suggested the use of memory and previous knowledge of the terrain for homing ability. Bovet (1968) suggested that some mechanism for navigation and orientation must be involved while August et al. (1989) concluded that geomagnetic field can be used as compass cues in the White-footed Mouse, *P. leucopus.*

While the mechanisms involved in rodent homing remain controversial, the data indicating homing abilities are not extensive. Although adults have been shown to be better at homing than juveniles, homing success of all sex-age groups is generally low (Murie 1963; Furrer 1973). In addition, although percent homing success is known to be negatively correlated with displacement distance (Murie 1963; Fisler 1967; Bovet 1972; Furrer 1973) the distances involved have not been great (Murie 1963; Robinson and Falls 1965; Fisler 1967; Furrer 1973; Cooke and Terman 1977).

Here, we present data on long distance homing in adult Deer Mice, *P. maniculatus,* in the Kananaskis Valley, Alberta (51° N; 115° W). Two live trapping grids (Longworth traps; 20 m spacing) were used for either adult male removal or adult female removal. A 2.4 ha grid (grid A) was used for adult female removal in 1989 and adult male removal in 1991. In

TABLE 1. Summary of homing success by inexperienced and experienced male (M) and female (F) *Peromyscus maniculatus* over known distances. Mean distances are given in meters.

Trapping grid	Year	No. of mice translocated	No. of mice homed	Mean maximum time (days)	Mean distance travelled
B	89	a. 4 (M)	2	4	650
		b. 2 (M)	2	4	670
		c. 2 (M)	2	3	690
	90	a. 3 (M)	2	7	850
A	89	a. 4 (F)	2	9	1650
		b. 1 (F)	1	3	1500
		c. 1 (F)	1	4	1800
	91	a. 14 (M)	9	6	1394
		b. 7 (M)	7	3.6	1450
		c. 5 (M)	5	3.8	1730

a.= inexperienced
b.= had previously homed once
c.= had previously homed twice or more

the case of females, only those that were not lactating were used in the experiment. A 2.9 ha grid (grid B) was used for adult male removal in 1989 and 1990. Each grid was live-trapped twice each week (on non-consecutive days) from May through August. Data on age (young-of-the-year or overwintered), weight, reproductive condition and trapping site were collected on ear-tagged individuals. All removals were conducted over a two week period (28 June to 11 July). Displaced mice were known to be residents on their grids for at least 30 days prior to translocation. The mice were transported in their traps to designated release sites. At the release sites traps were locked open to allow mice to move of their own volition. Dry, rocky creek beds were used for release sites because such sites are known to be optimum habitat for Deer Mice in the Kananaskis Valley (Millar et al. 1985). Mice translocated from grid A were released at a creek bed about 1650 m south of the capture site and/or at a site across a permanent river about 2000 m further south. Mice from grid B were released at a dry creek bed 900 m north of their capture site. The habitat over which homing mice travelled consisted of areas dominated by stands of Lodgepole Pine, *Pinus contorta,* and White Spruce, *Picea glauca,* as well as more shrubby areas with high creek banks. Distances were estimated from a topographic map of the valley (1:50 000). On both grids, some mice that returned home after the first experiment were used in subsequent homing experiments.

The number of Deer Mice returning home, mean maximum time taken to return and mean straight line distance travelled are given in Table 1. Some mice returning to grid A had to cross a permanent, fast-flowing river either by using a small foot bridge or swimming across. Furthermore, all mice returning to grid A had to cross a dry, rocky creek bed (optimal habitat) between their release site and home site. In this area, the longest straight line distance over which a mouse returned was 1980 m. Table 2 provides a summary of the percent success in homing over three categories of distances (arbitrarily divided) for inexperienced and experienced mice (sexes pooled). Excluding the four females (two inexperienced and two experienced) that successfully homed did not change the percent success.

These data constitute some of the longest homing distances recorded for *P. maniculatus.* Murie (1963) reported a 7.8% homing success from a distance of 1600 yards (1463 m) while Furrer (1973) observed a 29.4% success for *P. maniculatus* homing from 1392-1464 m. Percentage successes of first time homing in this study (50%–64.3%) are in agreement with those

TABLE 2. Percent homing success by inexperienced and experienced *Peromyscus maniculatus* over three categories of distances.

	Percent success (N)			
Distance	Short (<1000 m)	Medium (1000-1500 m)	Long (>1500 m)	Total
Inexperienced	57.1 (7)	64.3 (14)	50.0 (4)	60.0 (25)
Experienced*	100.0 (4)	100.0 (5)	100.0 (9)	100.0 (18)

*Previously returned home one or more times; no difference in homing success between those that returned home once, twice or more.

reported by Furrer (1973) although his distances were ≤ 800 m. For experienced mice (those with at least one successful homing), our data indicate a 100% success rate for all distances measured in this study (Table 2). Our trapping protocol (twice each week on non-consecutive days) did not permit accurate data on the speed with which the mice returned. However, among those that homed, experienced mice had significantly shorter return times than inexperienced mice (means ± SE, respectively; 3.7± 0.2 and 7.1 ± 1.4 days; t=2.49, p=0.03, df=14).

There is continuing debate about the mechanisms involved in homing and orientation (Bovet 1968; Cooke and Terman 1977; Anderson et al. 1977). In our study, *P. maniculatus* transported in closed Longworth traps to release sites successfully homed from a range of 650–1980 m. These distances are more than 9 to 26 times the average home range diameter for *P. maniculatus* in the Kananaskis valley (Hofstede 1991). Therefore, it is unlikely that these mice could have been familiar with any features of the habitat at these distances. Our data on long distance homing over presumably unfamiliar terrain support the navigation hypothesis in which the mice return home without any use of known cues for their orientation (Bovet 1968). However, the significantly higher homing success of "experienced" mice suggests that either familiarity with habitat may improve homing ability or that some Deer Mice are inherently better long distance travellers. Our data do not allow for clear distinctions between these alternative interpretations.

Acknowledgments

C. Grant, J. Millar and J. P. Bechtold assisted with field work. The Small Mammal Group, University of Western Ontario, critically reviewed earlier drafts of the manuscript. Constructive comments by two anonymous reviewers substantially improved the manuscript. Financial support was provided by the Natural Sciences and Engineering Research Council of Canada.

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Received 19 August 1992
Accepted 23 August 1993

Success and Cost of Capturing Coyotes, *Canis latrans*, from All-Terrain-Vehicles

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Gese, Eric M., and David E. Andersen. 1993. Success and cost of capturing Coyotes, *Canis latrans*, from all-terrain-vehicles. Canadian Field-Naturalist 107(1): 112–114.

Three-wheel All-terrain-vehicles were effective for capturing Coyotes in open (prairie) habitats in Colorado. Using cow-carcasses as bait the pursuit time for nine Coyotes captured was 19.0 ± 5.5 (*S.D.*) minutes/animal; without bait three were captured in 26.7 ± 11.6 minutes/animal; but capture success was 100% and 25%, respectively. Cost was $67.62/Coyote captured compared to $271 to $383 for other methods reported in the literature. Four wheel All-terrain-vehicles should be as effective as speed, not maneuverability, is important in the method.

Key Words: Coyote, *Canis latrans*, capture success, cost, all-terrain-vehicle.

Free-ranging Coyotes (*Canis latrans*) have been captured for research purposes with steel leg-hold traps (Linhart and Dasch 1992; Linhart et al. 1986), aerial darting (Andelt 1980; Baer et al. 1978), aerial net-gunning (Barrett et al. 1982; Gese et al. 1987), manual capture from helicopters (Gese et al. 1987), and manual capture from snowmobiles (Nellis 1968). These methods can be time intensive (e.g., running trap lines) and estimated costs range from $271 to $383/animal captured (Andelt 1980; Gese et al. 1987). We present an alternative capture method that is effective and relatively inexpensive using all-terrain-vehicles (ATV) for capturing Coyotes on shortgrass prairie in southeastern Colorado.

Study Area and Methods

We Captured coyotes on the 1040-km^2 Pinon Canyon Maneuver Site (PCMS), northeast of Trinidad, Las Animas County, Colorado (37°20'N, 103°40'W). Elevations on the PCMS varied from 1310 to 1740 m. Topography consisted of open grasslands, limestone breaks, and deep canyons. Two main habitats existed on the study area: shortgrass prairie and Pinyon (*Pinus edulis*)-Juniper (*Juniperus monosperma*) woodland communities (U.S. Department of Army 1980).

We attempted to capture Coyotes on the shortgrass prairie only. The prairie allowed us to maintain visual contact with the animal and provided open terrain where obstacles were visible. We employed two methods to capture Coyotes. The first method involved the placement of a cow carcass to attract Coyotes. The cow carcass was placed >1 km from dense woodland vegetation on open terrain where potential hazards and obstacles were known to the pursuers. The cow carcass was situated on a slope that allowed the pursuers to approach from the other side of the hill and surprise any Coyotes at the carcass. A Coyote sighted feeding or resting at the carcass was pursued by two to three persons driving 3-wheel ATV's (American Honda Motor Co., Inc., Gardena, California; use of commercial trade name does not imply endorsement by the University of Wisconsin-Madison or the U.S. Fish and Wildlife Service). The ability of the ATV's to overtake the gorged Coyote was the main advantage, not tight maneuverability. Coyotes at the carcass were typically satiated from feeding, were slow in running from the pursuers, and tired quickly. We pursued a Coyote until it tired and hid under a ledge, tree, or bush, or was captured with a noose-pole from an ATV. The Coyote was pinned with a forked stick and a noose-pole secured around the animal's neck. Its mouth was taped shut and its legs tied, securing the Coyote for processing and radio collaring.

The second method was similar to the first, but did not involve the placement of a cow carcass. Areas were searched until a Coyote was sighted. We then pursued and captured the Coyote as described previously. Attempts to capture Coyotes by both methods included preventing the animal from escaping into dense vegetation or rough terrain, or losing sight of the animal. The use of two to three ATV's helped prevent the animal from escaping by constantly placing an ATV at a position that forced the animal to turn away from cover. Attempts to pursue Coyotes were terminated whenever the animal ran into rough terrain or dense vegetation where the ATV's could not safely follow. All personnel riding an ATV were experienced drivers and wore protective equipment at all times (i.e., helmet, boots, gloves, eye protection, and heavy trousers).

Results and Discussion

Twelve Coyotes (5 males, 7 females) were captured from 19 September to 13 November 1986. A total of

39.3 man-hours were spent searching for and capturing Coyotes. Pursuit time for capturing Coyotes near the cow carcass averaged 19.0 + 5.5 (*SD*) minutes/animal ($n = 9$); pursuit time for those captured Coyotes not involving the cow carcass averaged 26.7 + 11.6 minutes/animal ($n = 3$) ($t = 1.01$, 10 df, $P > 0.30$). Whereas pursuit time did not differ significantly, capture success was 100% (9 out of 9 attempts) when catching Coyotes engorged on meat from the carcass, and only 25% (3 out of 12 attempts) when catching coyotes not near a cow carcass ($X^2 = 11.83$, 1 df, $P < 0.005$). Six attempts were aborted when the animals escaped into terrain too rough for the ATV's to safely follow; three attempts were terminated when we lost sight of the Coyote. One Coyote mortality occurred during capture when a Coyote from near the cow carcass died suddenly during a 15-minute pursuit. Autopsy of the Coyote indicated that cardiac arrest was the cause of death. Among the other captured animals, no delayed mortality had occurred by one to two weeks after capture.

Our small sample size precluded an accurate comparison of mortality to other capture techniques. However, the 8% (1 out of 12) mortality from ATV captures was similar to the 8% mortality found in trapping (Andelt 1980), 5% for net-gunning (Gese et al. 1987), and 3% for manual capture (Gese et al. 1987). Barrett et al. (1982) lost no animals net-gunning, Baer et al. (1978) and Andelt (1980) had no mortality from aerial darting, Nellis (1968) had no mortality while capturing 14 Coyotes with snowmobiles, Balser (1965) lost 1 (2%) Coyote during trapping with tranquilizer tabs, while snaring had the highest mortality (19%) of all capture techniques (Nellis 1968).

The cost incurred capturing Coyotes with ATV's was low. Our costs included $314.40 for personnel (39.3 man-hours x $8/hour), $242.00 for equipment (noose-pole and three helmets), $62.88 for the ATV's (cost of $2500 for an ATV depreciated over an estimated 10 hours/week over three years of use x 39.3 man-hours), $24.56 for gas (0.5 gallon/hour x 39.3 man-hours x $1.25/gallon), and $100 for the cow carcass, giving a total cost of $743.84 for all attempts and captures ($67.62/Coyote captured).

Safety must be stressed when attempting to capture Coyotes from ATV's. Both the Canadian Government and the U.S. Consumer Product Safety Commission have banned the sale of new 3-wheel ATV's due to the risk of death or severe injury in certain circumstances. Our evaluation was done prior to this ban, however, we believe that 4-wheel ATV's would work equally well because speed rather than maneuverability is required for success of this technique and the 4-wheel ATV's are safer. All our drivers were instructed in the proper, safe use of the ATV through a certified course taught by the ATV manufacturer.

The use of ATV's for capturing other animals is unreported but we believe that ATV's can be used to capture Coyotes in areas with suitable open terrain (i.e., open grassland and prairie in the United States and Canada). The technique is inexpensive compared to other capture techniques and safe as long as researchers are familiar with ATV's and the terrain. While ATV accidents can result in injury, other techniques used in wildlife research such as ultralights (Knight et al. 1986; Looman et al. 1985; Quigley and Crawshaw 1989) and helicopters (Barrett et al. 1982; Gese et al. 1987) pose significantly higher safety risks. Consequences of engine failure or pilot error (i.e., crashing) would likely be far less extensive when using an ATV compared to an ultralight or helicopter.

Acknowledgments

Funding was provided by the U.S. Department of Army, Environment, Energy, and Natural Resources Division, Fort Carson, Colorado, through the U.S. Fish and Wildlife Service, Colorado Field Office, Golden, Colorado, and the Wisconsin Cooperative Wildlife Research Unit, the College of Agricultural and Life Sciences, and the Graduate School, University of Wisconsin-Madison. We thank T. R. Laurion, D. J. Grout, W. R. Mytton, D. E. Sharps, and C. Bandy for field assistance. M. W. Barrett and O. J. Rongstad provided critical reviews of a previous draft of the manuscript.

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Received 14 September 1992
Accepted 25 August 1993

High Incidence of the Edible Morel *Morchella conica* in a Jack Pine, *Pinus banksiana*, Forest Following Prescribed Burning

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Duchesne, Luc C., and Michael G. Weber. 1993. High incidence of the edible morel *Morchella conica* in a Jack Pine, *Pinus banksiona*, forest following prescribed burning. Canadian Field-Naturalist 107(1): 114–116.

Mushrooms of the ascomycetous fungus *Morchella conica* Fr. were observed at a density as high as 2860 kg/ha in a *Pinus banksiana* Lamb. stand in May 1991 at the Petawawa National Forestry Institute, Chalk River, Ontario. This forest stand had been treated with prescribed fire the previous fall. Mushrooms were found singly or in clusters within a radius of 2-3 m around dead *Pinus banksiana* trees but not around dead specimens of *Pinus resinosa* Ait. and *Pinus strobus* L.

On a observé des champignons ascomycètes *Morchella conica* Fr. à une densité aussi grande que 2860 kg/ha dans un peuplement de *Pinus banksiana* Lamb. à l'Institut national forestier de Petawawa en mai 1991 à Chalk River en Ontario. Ce peuplement forestier avait subi le brûlage dirigé l'automne précédent. Les champignons ont été trouvés seuls ou en groupes uniquement à l'intérieur d'un rayon de 2-3 m autour de spécimens morts de *Pinus banksiana* mais pas autour de spécimens morts de *Pinus resinosa* Ait. et *Pinus strobus* L.

Key Words: Jack Pine, *Pinus banksiana,* edible morel, *Morchella conica*, fire, phoenicoid fungi, ascomycetes, mushrooms.

Phoenicoid fungi are those that colonize forest sites soon after fire. Comprising a large number of mushroom species from different taxonomic groups (Carpenter and Trappe 1985), they play an important role in nutrient cycling and nutrient trapping in fire-disturbed ecosystems (Carpenter and Trappe 1985; Carpenter et al. 1987). They also contribute to plant growth and survival through mycorrhizal symbiosis.

Morels are valuable in European or Asian markets where their wholesale value can be as high as $180/kg dry weight (J.A Fortin, personal communication). The knowledge that morels are often associated with fire (Apfelbaum et al. 1984; Weber 1988) leads to substantial commercial harvests in Western Canada and United States where professional mushroom pickers visit recently burned-over forest sites (J. Brown, personal communication). Whereas the fruiting of morels in western Canada and United States after forest fires is well known, the phenomenon has not been documented for eastern Canada. This note reports the high incidence of *Morchella conica* Fr. (synonym: *Morchella angusticeps* in Weber (1988)), an edible mushroom, in a plot of Jack Pine (*Pinus banksiana* Lamb.) treated with prescribed burning.

The Site

The *Pinus banksiana* stand is at the Frontier Lake experimental site (latitude 46°00'N and longitude 77°33'W) which is approximately 5 km east of the Petawawa National Forestry Institute in Chalk River, eastern Ontario. This area is within the Middle Ottawa section (L.4c) of the Great Lakes St-Lawrence Forest region (Rowe 1972). The topography is relatively flat, the surface deposit a fine-grained deep sand (10-30 m) (Gadd 1962), and the soil an humo-ferric podzol (Weber 1988). The stand was clear-cut in 1942 and 1943 leaving behind trees with stump-height diameters of 17.5 cm or less. Dendrochronological analyses of dominant trees and snags with multiple fire scars suggest that the site experienced multiple fires; the most recent was in 1943, presumably from slash burning following clear-cutting (E. Stechishen, personal communication).

Jack Pine, Red Pine, *P. resinosa* Ait., and White Pine, *P. strobus* L., comprise most of the biomass of this forest stand with an average age of 53, 105, and 55 years, respectively. Additional species observed in the vicinity were *Amelanchier* spp., *Comptonia peregrina* (L.) Coult., *Gaultheria procumbens* L., *Kalmia angustifolia* L., *Lycopodium complanatum*

L., *Maienthemum canadense* Desf., *Polygonatum pubescens* (Willd.) Pursh, *Pteridium aquilinum* (L.) Kuhn, and *Prunus pumila* L. This stand contained seedlings of *P. strobus* at a density of approximately 10 000 seedlings/ha.

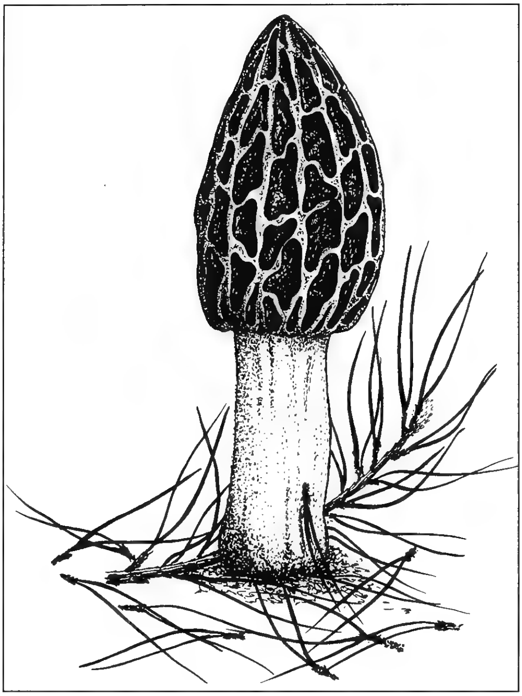

FIGURE 1. Ascocarp of *Morchella conica*

Observations

Large numbers of *Morchella conica* (Figure 1) ascocarps were observed in the last week of May 1991 within a 30 m x 70 m plot of standing timber treated with prescribed fire in early September 1990 (Figure 2). Mushroom identification followed Pomerleau (1980). Ascocarp biomass was determined at 2860 kg/ha (fresh weight) and 710 kg/ha (dry weight) by sampling plots each measuring 1 m^2. Ascocarps occurred in a 2-3 m radius around dead *Pinus banksiana* trees, but none occurred in the neighbourhood of dead *P. resinosa* and *P. strobus* trees. *Morchella conica* ascocarps were not observed in the surrounding unburned forest.

In eastern Canada, *Morchella conica* represents one of five morel species, although it is recognized that morel taxonomy is imprecise (Pomerleau 1980). *Morchella conica* (and related morel species) have been observed in great numbers after fire in other areas of North America (McKnight and McKnight 1987). But this is the first time the high occurrence

FIGURE 2. Ascocarps of *Morchella conica* surrounding a dead *Pinus banksiana* tree at the Petawawa National Forestry Institute. This stand was treated with prescribed burning the previous fall.

of *Morchella conica* ascocarps has been associated with a burned-over *Pinus banksiana* stand in eastern Canada. Moreover, the observation that morels were exclusively associated with dead Jack Pine, although both Red and White pine trees were present in the vicinity, is unique. The ecological significance of our observation is unknown because of the taxonomic and ecological diversity in the morels. This group comprises a large number of species, subspecies, varieties, and ecotypes, each with different ecological requirements (Buscot 1989). Furthermore, morels can be found either in ectomycorrhizal association with plants (Buscot and Kottke 1990) or as pioneers of soils that have been disturbed by herbicide application (Turnau 1987), wildfires (Apfelbaum et al. 1984; Kaul 1975; Weber 1988), and volcanic eruption (Carpenter et al. 1987).

Our observations raise two interesting questions. What was the primary source of the fungal mycelium from which fruiting bodies were developed? And what were the processes initiated by fire that led to fruiting?

Because *Morchella conica* ascocarp formation occurs in spring, we speculate that the ascocarps observed here resulted from fire stimulation of pre-established mycelium in the forest floor. Ascocarp formation by phoenicoid fungi has been shown to be stimulated in heat-treated substrates (Carpenter et al. 1987). Several sources suggest that the effect of heat may stimulate ascospore germination, reduce soil concentrations of substances inhibitory to fungal growth, destroy competing microorganisms, and alter soil pH and carbonate concentration (Carpenter et al. 1987; Wicklow 1975; Wicklow and Hirschfield 1979).

Acknowledgments

Thanks are addressed to N. Coléro, R. L. Peterson, M. Strome, A. Yapa, and two anonymous reviewers for reviewing this manuscript and to E. Stechishen for providing dendrometric data.

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Received 1 September 1992
Accepted 7 July 1993

News and Comment

How Many Bison, *Bison bison*, Should be in Wood Buffalo National Park?

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Nudds, Thomas D. 1993. How many Bison, *Bison bison*, should be in Wood Buffalo National Park? Canadian Field-Naturalist 107(1): 117-119.

Many factors, including disease, have been hypothesized to cause the observed decline of Bison (*Bison bison bison*) in Wood Buffalo National Park from perhaps 12 000 in the 1940s to about 3300 in 1991. However, based on an allometric relationship between population densities and body masses of herbivorous mammals, the mean density of Bison in the park is predicted to be 0.37 individuals/km^2, or about 2035 Bison. This estimate approximates (1) that reported for Bison in the park in the 1920s prior to the introduction of > 6000 bison from the plains, and (2) the dispersal-threshold density reported for Bison in the nearby Mackenzie Bison Sanctuary. Therefore, although a variety of factors may be mechanisms of the decline of Bison in Wood Buffalo National Park, they may not ultimately be the cause. Instead, it appears that, following a sustained population eruption initiated by the introduction of large numbers of bison, their number has simply declined to densities more appropriate for large mammalian herbivores. This hypothesis is consistent with the observation that Bison populations elsewhere, such as the Greater Yellowstone Area, continue to grow in spite of disease.

Key Words: Bison, *Bison bison,* disease, allometry, Wood Buffalo National Park.

Controversy still surrounds the fate of the population of Bison (*Bison bison bison*, *see* Geist 1991) in Wood Buffalo National Park (FEARP 1990), up to 42% of which apparently test positive for bovine brucellosis or tuberculosis (Tessaro et al. 1990). These diseases were introduced to what is believed to have been about 1000-2000 Bison that resided in the newly created park in the 1920s when > 6000 Bison from the plains were released among them. By the 1940s, the Bison population was estimated to be perhaps as large as 12 000 animals, but, by 1991, to be about 3300. A variety of factors have been hypothesized to be responsible for the long-term decline, including occasional slaughters, mass drownings, habitat change brought about by changes in water levels, predators and diseases (FEARP 1990).

In all of this, there have appeared implicit assumptions that (1) the decline of Bison is necessarily a concern, (2) that the current numbers are "too low" and (3) that a return to some previous, higher number of (disease-free) Bison should be a goal of active Bison management in Wood Buffalo National Park (*see* FEARP 1990). However, there has been little attempt to establish, by some independent means, what an appropriate number might be (but *see* FEARP 1989: 168–169, where Novakowski and Choquette [unpublished manuscript] were reported to have estimated "carrying capacity" of the park at 14 000 Bison). Indeed, the inability to define 'carrying capacity' has been a recurrent source of confusion among wildlife researchers for a long time (Macnab 1985). Therefore, in the absence of an appropriate null model for the population size of Bison in the park, it has been difficult to decide whether the observed decline is even a "problem", let alone what caused it and what ought to be done about it (e.g., Peterson 1991).

Allometry, as a means to estimate expected population density (or a variety of other biological or ecological traits) independently from knowledge about body mass (e.g., *see* Peters 1983; Calder 1984), provides just such an appropriate null model. It has been a useful tool to evaluate biological evidence surrounding other controversial issues, such as metabolic rates and rates of food consumption by marine mammals (Lavigne et al. 1986; Innes et al. 1987), and their implications for managing marine mammal-fishery interactions.

Peters and Raelson (1984) reported that population density of herbivorous mammals (D) scales to body mass (W) as

$$D = 67.9\ (W)^{-0.88 \pm 0.04}. \qquad (1)$$

To be useful as a predictor of D, an allometric relationship should span the widest range of W possible (ideally, including the value of W from which D is to be predicted), W should explain a high proportion of the variance in D and, so, should be based on a large sample size. Equation 1 was derived from a sample of 326 species of herbivorous mammals worldwide whose masses ranged from 0.01–2500 kg. Variation in W explained 67% of the variation in D.

A conservative estimate of mean body mass of a population of Bison of variable sex and age is about three-fourths of mean adult ♀ body mass (495 kg), or 372 kg (C. Bergman, personal communication). Substituting this estimate into Equation 1 yields an estimate of mean density of 0.37 Bison/km^2. Wood Buffalo National Park is 44 800 km^2, but only about 5500 km^2 of it is considered principal Bison habitat (Oosenburg and Carbyn 1985: 69). Thus, if Bison populations behave similar to populations of other mammalian herbivores — and there is no *a priori* reason to expect otherwise — the number of Bison in Wood Buffalo National Park should be about 2035 individuals. Peterson (1991: 786) cited unpublished estimates of bison numbers in Wood Buffalo National Park (2500–4500) from an earlier allometric analysis I conducted using a preliminary allometric model (Peters 1983: 294; *see* Peters and Raelson 1984: 500), crude estimates of the area of principal Bison habitat (7482 km^2) and average body mass (500 kg) which were too high, and an inappropriate calculation for the confidence interval.

Using the formula for confidence intervals around predicted values from regression (Montgomery and Peck 1982: 31–33), and regression statistics reported by Peters and Raelson (1984: 525) for Equation 1, the 95% confidence interval around the estimate of mean Bison density is $0 \leq 0.37 \leq 1698$ individuals/km^2! Such wide confidence intervals are common for prediction at the extremes of allometric relationships, specifically, for at least two reasons. First, the value of body mass (372 kg) at which density is estimated is very much (21 times) larger than the mean of body masses used to generate Equation 1 (17.8 kg; Peters and Raelson 1984: 505). Second, allometric relationships of the "mouse-to-moose" type, owing to their interspecific nature, are extremely variable. Thus, for purposes of ascertaining whether the better estimate of Bison density in Wood Buffalo National Park is closer to 0.37 or 2.5 individuals/km^2 (about 2000 or 14 000 individuals), these confidence intervals are not very informative. The ability to state with 95% certainty that the "true" value of density for Bison lies somewhere between them cannot resolve the issue of whether the observed decline from about 2.2 to current levels of about 0.6 individuals/km^2 is necessarily a "problem" in need of management intervention. However, the allometric prediction of 0.37 Bison/km^2 is corroborated by data from two independent sources.

First, the estimate of mean density of bison for Wood Buffalo National Park is corroborated by data about Bison densities in the Mackenzie Bison Sanctuary which ranged most frequently between 0.2 and 0.5 Bison/km^2 (Gates and Larter 1990). When they exceeded a threshold between 0.5–0.8 Bison/km^2, dispersal occurred (Gates and Larter 1990). This apparent upper threshold for Bison density is much lower than that observed for Wood Buffalo National Park in the recent past (i.e., 2.0–2.7 Bison/km^2), and of the same order of magnitude as the allometric estimate.

Second, the allometric estimate approximates that of the population of Bison in the park prior to the introduction of additional Bison in the 1920s, and is less yet than the number of Bison reported to be present now. Thus, further, but smaller, decreases in the number of bison in Wood Buffalo National Park might be expected. Indeed, although Messier (1989: 237) fitted a curvilinear regression with negative slope to data about population size over time, the residuals indicate that a non-linear model with greater concavity would have fitted the data better. The rate of population decline appears to be slowing such that Bison density is levelling out in the neighbourhoods of both the dispersal-threshold density observed in the Mackzie Bison Sanctuary, and the number of Bison in the park prior to the massive introduction.

This suggests that the Bison population may be declining, perhaps *proximately* for reasons related to diseases, mass drownings, slaughter, predators and even habitat loss, but *ultimately* for no other reason than it is attaining a new, appropriate equilibrium with available resources. That is, these factors may all be *mechanisms* of population change, but not the *cause* of it. This idea is consistent with a vast literature about eruptions of ungulate populations to extraordinarily high levels, followed by declines (Caughley 1970). I propose that the introduction of > 6000 Bison in the 1920s initiated such an eruption. Populations of animals fluctuate with a periodicity that is also related to body mass according to

$$T = 8.51\ (W)^{0.26} \qquad (2)$$

where T = "cycle" time in years (Peterson et al. 1984; see also Calder 1984: 327). Using 650 kg as the mean body mass of adult male and female Bison, Bison populations are predicted to rise and fall over about 44 years, although the rise and fall of Bison in Wood Buffalo National Park appears to have taken almost half that again. It is not beyond the realm of possibility that the Bison of Wood Buffalo National Park are near the end of an eruption, albeit sustained for a period longer than normal, perhaps, by predator removal and other management activities in the interim.

Regardless, if the previously high numbers of Bison were maintained artificially by continuous predator removal, then those densities were in no sense "normal". The use of predator control to attempt to maintain inflated densities of herbivore populations is not recommended, especially when there is no evidence that herbivore populations are abnormally low (e.g., Theberge and Gauthier 1985), as appears to be the case in Wood Buffalo National Park. Further, if the observed decline of Bison is merely the downward trend of a population eruption, then it is perhaps impossible that disease or predator management will return the Bison population to the high numbers of the recent past. At the very least, the prospect raises serious questions about whether the high number of the recent past is an attainable management goal.

Finally, if diseases or predators need not be invoked to explain the decline of Bison in Wood Buffalo National Park, then management directed at disease elimination or predator management for that reason is unjustified. Whether there are other agricultural or economic reasons to attempt to eliminate the diseases of Bison in Wood Buffalo National Park remains controversial, but at present there appears to be little reason to kill Bison for purposes of conserving Bison in the park. It is also unclear whether Wood Bison *populations* elsewhere will be affected deleteriously by the bovine brucellosis and tuberculosis that they might one day contract from Bison in the park. Indeed, Bison populations infected with brucellosis in the Greater Yellowstone Area grow as rapidly as uninfected Bison populations (Peterson et al. 1991). These observations further suggest that it is unlikely that disease caused the observed declines of Bison in Wood Buffalo National Park. Certainly, it may be inappropriate to assume (e.g., Tessaro et al. 1990) that the deaths of individual animals from disease necessarily threaten populations (Peterson 1991: 785).

Acknowledgments

I thank J. Ball, C. Bergman, V. Geist, N. Larter, D. Lavigne, R. Peters, M. Porter, O. Schmitz, V. Thomas and an anonymous referee for discussion and/or comments on various drafts of this paper. This research is supported by the Natural Sciences and Engineering Research Council of Canada.

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Received 13 August 1992
Accepted 27 June 1993

Minutes of the 114th Annual Business Meeting of The Ottawa Field-Naturalists' Club 12 January 1993

Place and Time: Auditorium, Canadian Museum of Nature,
Metcalfe and McLeod Streets, Ottawa, 19:30 hrs
Chairperson: Frank Pope, President
Attendance: Fifty people attended the meeting

The first 30 minutes were devoted to perusing the reports to be discussed later. These reports were not read aloud later, prior to discussion and voting, which was a change in procedure from previous meetings.

1. Minutes of the Previous Meeting
It was moved by Michael Murphy (2nd Ellaine Dickson) that the minutes be approved.
(Motion Carried)

2. Business Arising from the Minutes
Only one Vice-President position was filled. Michael Murphy accepted the position.

3. Financial Report
Financial Statements for the year ending September 30, 1992 were reviewed by Ken Young in the absence of the Treasurer, Gillian Marston. Several points of interest were discussed.
The Club had a successful year financially, members' equity growing to $191,984. Considering this situation, the Council had allocated to Alfred Bog an additional $7,320. The drop in membership revenue was noted. Assets are mostly in GICs and Treasury Bills: this practice will be reconsidered due to the drop in interest rates.
It was moved by Bill Cody (2nd Jack Romanow) that the Financial Report be accepted.
(Motion Carried)

4. Nomination of Auditor
It was moved by Ken Young (2nd Jack Romanow) that Janet Gehr continue as auditor of *The Ottawa Field-Naturalists' Club* for the 1992/93 fiscal year.
(Motion Carried)

5. Report of Council
Members were asked if there were any questions or comments concerning the following Committee Reports: Awards, Birds, Computer Management, Conservation, Education and Publicity, Excursions and Lectures, Finance, Fletcher Wildlife Garden, Macoun Club, Membership and Publications.
A question was asked about the 3-year decline in membership. Doreen Watler, Chairman of the Membership Committee, explained that the rise and fall of membership over the years was not unusual, but the greater fall in numbers over the last 3-year period is probably due to the recession.

6. Revised Constitution and By-Laws
Bill Gummer, who had been responsible for the work on the revised constitution and by-laws, presented them. Frank Pope noted that Article 23 of the existing Constitution states that Constitutional changes are to be published in *The Canadian Field-Naturalist* at least one month before being presented at the Annual Business Meeting and, that each proposed amendment to the Constitution shall deal with only one article, and shall be moved by one member and seconded by another. In view of the fact that the issue of *The Canadian Field-Naturalist* containing the revised Constitution was not delivered 30 days before the meeting, he asked the meeting for direction. It was moved by Michael Murphy (2nd Ken Young) that the application of Article 23 be suspended on this occasion. In the discussion, concern was expressed that this would set a bad precedent.
(Motion Defeated)

It was moved by Jane Topping (2nd Bill Cody) that the time constraint of Article 23 be waived and that any specific amendment be sent, in the form of a motion, to the Recording Secretary by the end of June for publication in *The Canadian Field-Naturalist*: such motions to be considered at the 1994 Annual Business Meeting.
(Motion Carried)

Revised Article 17, Amendments, which contains a provision to group articles for voting when major revisions of the Constitution take place was then considered. It was moved by Bill Gummer (2nd Colin Gaskell) that revised article 17 be accepted.
(Motion carried with two opposed)

It was moved by Bill Gummer (2nd David Moore) that the balance of the revised Constitution be accepted.

Bill Gummer then gave a detailed explanation of the changes in the Constitution, stating that they were mostly clarifications, corrections, terminology updating, and changes resulting from a review for consistency.

An amendment was moved by Michael Murphy (2nd Sheila Thompson) that the following sentence be struck from Article 9, Committees of Council. "The Nomination Committee and the Fletcher Wildlife Garden Committee are considered to be *ad hoc* committees."

(Amendment Carried with one abstention)

A vote was then taken on the motion as amended.

(Motion Carried with two opposed)

President Frank Pope informed the meeting that the Council had approved the By-Laws in accordance with Article 18 of the revised Constitution (Article 24 of the 1986 version). He thanked the Committee, especially Bill Gummer, for their dedicated work on the Constitution and By-Laws.

7. Report of the Nomination Committee

Bill Gummer reported the following slate of officers and members nominated for the 1993 Council.

President: Frank Pope
Vice-President: Michael Murphy
Recording Secretary: *Stephen Gawn
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston
Other Council Members:
Ron Bedford (Publications)
Bill Gummer
Fenja Brodo
Jeff Harrison
Lee Cairnie
*David Moore
Martha Camfield
*Mickey Narraway
Bill Cody
Jack Romanow
Francis Cook
*David Smythe
Ellaine Dickson
*Bruce Summers
Enid Frankton
Ken Young
Colin Gaskell

New members' names are preceded by an asterisk.

BARBARA CAMPBELL
EILEEN EVANS
BILL GUMMER

The following are no longer members of Council: Steve Blight, Constance Clark, Don Cuddy, Doreen Watler.

Bill Gummer commented that nominations from the Club's wide membership would be appreciated.

It was moved by Bill Gummer (2nd Ellaine Dickson) that the slate of councillors be accepted.

(Motion Carried)

8. New Business

The President reminded members of the Annual Meeting and Conference of the Federation of Ontario Naturalists to be held this year in Ottawa, June 18 - 20. The next issue of *Trail and Landscape* will outline the need for volunteers.

The Club representative, and a director of the Federation of Ontario Naturalists, Jane Topping, made an appeal for new members to join the F.O.N.

9. Presentation by the Conservation Committee

Jane Topping described the history, accomplishments, and present concerns of the Conservation Committee. It serves as an information resource, facilitator and watch dog. Members of the Committee have worked long and hard in attempts to save many valuable natural areas, with varied success. Now new energy is needed. Any club member with time and enthusiasm is welcome to join the Committee and assist in the constant vigilance required to protect significant natural areas.

10. Adjournment

At 22:15 hrs it was moved by Michael Murphy (2nd Lee Cairnie) that the meeting be adjourned.

Enid Frankton
Acting Recording Secretary

Committee Reports for 1992

Awards Committee

The Awards Committee had the satisfaction of being able to present the full quota of awards to deserving recipients. Two changes which took place during the year should be noted. In honour of the late George McGee, the Service Award will henceforth be known as the George McGee Service Award. An engraved trophy will be presented annually to the recipient of this special award. An additional Conservation Award will be available for a non-member who makes an outstanding contribution to the cause of conservation and who, in the opinion of Council, deserves recognition.

The following awards were presented:

1. *Honorary Member:*

Ellaine Dickson, for many years of dedicated service to the Club, by serving on committees, and on Council, and for having the Club telephone at her home since 1978, answering endless enquiries and booking members on outings.

2. *1991 Member of the Year:*

Michael Murphy, for effectively representing the OFNC concerning local conservation interests and producing *The Green Line*, the newsletter inserted in each issue of *Trail & Landscape*.

3. *George McGee Service Award:*

Bill Gummer, for his dedication and hard work in the interest of the Club, including service as President, chairman of committees and Editor of *Trail & Landscape*.

4. *Conservation Award:*

Albert Dugal, for his consistent effort to protect important natural areas, particularly his leadership in protecting the Leitrim Wetlands.

5. *The Anne Hanes Natural History Award:*

Michael Runtz, for his important contribution in disseminating his wide knowledge of the natural history of the Ottawa Valley by his writings, informal talks, lectures and photography.

6. *President's Prize:*

Larry Neily, for running the Bird Status Line since 1986.

ENID FRANKTON

Birds Committee

The Birds Committee held nine meetings during 1992. Membership expanded to fifteen members by year-end, a core group of seven regularly attending. The format of the meetings was changed to feature some birding related entertainment event such as a slide show or talk on a special project.

Highlights of 1992 include the following:
The 1992 Christmas Bird Count was organized again by Dan St. Hilaire. The Birdfeeder Programme chaired by Dan Perrier was busy again in 1992 with a new feeder location established in the new Wildlife Garden near the Arboretum. The OFNC Bird Status Line had another busy year. Several members participated in the Loggerhead Shrike Survey in cooperation with Don Cuddy. Four known pairs and one new pair of shrikes were located. The Annual Seedathon was conducted in September. We are thankful for the financial support which helps ensure that the feeders are well stocked.

Disappointments of 1992 include the following:
The Bird Records Sub-Committee met only once in 1992. There is now a backlog of eight or nine reports. The last "Recent Bird Sightings" article published in *Trail & Landscape* was for Summer/Fall 1991. The Spring & Fall Counts have been suspended due to limited participation and resources to organize them.

JACK ROMANOW

Computer Management Committee

The Committee ensures the efficient and controlled use of the computer assets of the Club. In 1992 it provided systems maintenance and/or technical support to each of the Club's three computer systems, and set up and maintained an active volunteer database.

MICHAEL MURPHY

Conservation Committee

The Committee met eleven times in 1992 and participated in the following issues: NCC Greenbelt (Long Range Planning), Gatineau Park, Burntlands Alvar, Marlborough Forest, Leitrim Wetlands, Clyde/Merivale Lands, Provincial Wetlands Policy, Environmental Bill of Rights (Ontario), Wild Life Policy Discussion Paper, Class E. A. Hearings on Timber Management, Lanark Timber Management Plan, Sewell Commission on Planning Reform, City of Ottawa Official Plan (Regional Review), R.M.O.C. Environmental Policy OP Review, Britannia/Pinecrest Drainage Study (Mud Pond), McConnell-Laramee Extension, Cardinal Creek (ANSI), Wychwood (Blueberry Point), Fenitrothion (pesticide). It also maintained contact with a number of other conservation groups.

MICHAEL MURPHY

Education and Publicity Committee

In 1992 the club display was taken to a total of seven events, (two more than last year) covering sixteen days. The acquisition of a rear projector greatly enhanced our booth and attracted a large number of people.

Notice of our monthly meetings again returned to all local news media, and leaflets informing the public of our existence were distributed at nature trails throughout the region. More recently a poster has been distributed to local libraries.

We noticed a tremendous increase in the number of requests for talks, slide-shows and walks for private non-profit making groups, homes for Seniors, clubs and schools, of which about 90% were met. Our second and third slide-shows were completed. A request made through *Trail & Landscape* for more slides had an overwhelming response with well over 300 slides being donated, some posthumously: thanks to those involved will be published in the next edition of *Trail & Landscape*. Also, work towards the 1993 Federation of Ontario Naturalists Conference has taken place.

The Committee members, already dedicated, worked so much harder this year, each making an outstanding individual effort, and collectively a very effective union.

I feel special mention should be made of Betty Campbell, who continuously updates the club display for each event; her dedication is also evident in the apparent endless task of sorting and cataloguing our slides. (Duplicate slides or slides unsuitable for us were passed on to the Macoun Club). Also I would like to mention Lee Cairnie for her enthusiasm in answering calls for lectures, talks and walks and for the speed with which she arranges for volunteers to man the club display and for countless other activities.

RAY KNOWLES

Excursions and Lectures Committee

The Excursions and Lectures Committee organized eight monthly meetings throughout the year, involving a variety of interesting speakers and topics. The 1992 Soiree and members' slide night in September were additional entertaining and informative events hosted by the Committee. Once again our group worked closely with the Membership Committee to ensure the success of the New Members' Night.

The majority of the Committee's efforts in 1992 were concentrated on preparing a diverse programme of field trips and related activities that would appeal to the general membership. Visits were arranged to view the Herpetology Collection of the Canadian Museum of Nature, the Butterfly Collection of the Department of Agriculture and the greenhouses at Carleton University. Three identification workshops were planned, focusing on plants, rocks and small mammals. In addition, forty full or half day outings were scheduled with the majority concentrating on either bird watching or on aspects of general natural history interest. Unfortunately, two outings had to be cancelled due to circumstances beyond the Committee's control.

COLIN GASKELL

Executive Committee

No meetings were called during the year.

FRANK POPE

Finance Committee

The Finance Committee met five times during 1992. The main items considered concerned the financial aspects of the Fletcher Wildlife Garden, the accounting for charitable donations to the OFNC and the appropriate level of reserves for the OFNC. Recurring items dealt with included membership fees, insurance and the annual budget.

KEN YOUNG

Fletcher Wildlife Garden Committee

1992 was a key year in the development of the Garden.

Full-time funding for Elise Stevenson's co-ordinator's position was not renewed by the Environmental Youth Corps which did, however, provide grants totalling $10,000.00 for two summer students and for administrative and planting-related uses. Fortunately we got a $36,000 grant from the Environmental Partners Fund which was used to pay Elise's salary and to pay for plant material and gardening supplies. Consumers Gas donated $1,000 for plant materials for the hedgerow which will be planted next year.

Elise has proved to be a great asset. She has performed many diverse administrative and field tasks well, and has given the Fletcher Management Committee solid support. Peter Elliott of Friends of the Farm has also offered invaluable support and timely advice. The Garden now has an accounting system and budgeting process in place.

Almost 400 trees have been planted in the new woodlot above the sedge meadow. Some sedges have been planted in the sedge meadow and a large experimental plot has been developed for butterfly meadow habitat. Robina Bennett, our volunteer co-ordinator, has been a tower of strength. About 60 bird boxes have been installed; species inventories are proceeding.

We have entered into partnership through a Memorandum of Understanding with the Ottawa Chapter of Landscape Ontario, represented by Eileen Chivers, who is managing the development of the model backyard garden. Plant beds, a two-tier pond, a rockery, two patios and a watering system were installed in the Fall. About $10,000 in materials and in kind has been donated by the Ottawa Chapter of Landscape Ontario and member businesses. A $5.00 certificate is being sold to "patrons" to assist in the development of the garden.

A formal submission has been made to Agriculture Canada to secure Building #138 as an Interpretive Centre. A strategic plan to oversee the development of the garden has been developed and the operating structure of the management committee and sub-committees and their relationship with the co-ordinator has been determined.

JEFF HARRISON

Macoun Club Committee

In the 1991/92 school year, the leadership of the Macoun Club was divided among most of the Committee members. Leader of the Senior group was Barry Bendell. The younger groups were led indoors by Ellaine Dickson and Martha Camfield; their twice-monthly field trips were routinely led by Rob Lee, Barbara Gaertner, and Claude Haridge.

The three major issues the Committee continues to wrestle with are 1) a perpetual shortage of volunteers for leadership; 2) declining or marginal membership levels in the older age groups; and 3) means of ensuring the safe conduct of field trips.

The Seniors continued two recently established conservation projects: maintaining a small Bluebird trail near Quyon, Quebec, and refurbishing a nesting platform intended for Common Terns at Shirley's Bay, Ontario.

The Juniors and Intermediates embarked on a long-term study of individual forest trees in their

Greenbelt study area; baseline results were reported in the Macoun Club's annual publication, *The Little Bear*. Coupled with this project is a growing photographic record (colour slides) made with film paid for by the Club.

ROB LEE

Membership Committee

The total paid-up membership as of December 13th, 1992 was 1052. Of this number, 117 were new members. Of these, 62 were individual memberships and 38 were family memberships. Assuming an average of two members per family membership, the total number of members in the Club is estimated at 1401.

The Membership Committee and the Excursions and Lectures Committee again co-hosted New Members' Night on Friday, November 13th. More new members than last year came out and met members of Council and several honorary members. All enjoyed an evening of information about the club's activities and history, as well as wine, cheese and other refreshments. The gathering was moved from its usual location in the Salon of the National Museum of Natural Sciences to the Pinch Room, in the same building. This location proved as suitable as the Salon, and seemed to provide a more informal atmosphere.

DOREEN WATLER

Publications Committee

The Publications Committee, whose role is to oversee the Club's publications, met twice in 1992.

Three issues of *The Canadian Field-Naturalist* were published in 1992: Volume 105, Issues 3 and 4 and Volume 106, Issue 1. These three issues contained 506 pages, 34 articles, 28 notes, 81 book reviews, 248 new titles, nine COSEWIC reports, two commemorative tributes, three obituaries, and 34 pages of News and Comments that included the minutes of the 113th Annual Business Meeting and proposed revisions of the Constitution and By-Laws. There were no changes in the panel of Associate Editors. It is hoped to regain the normal publishing schedule in 1993. The geographical distribution of the large number of non-OFNC-member subscribers to the CFN (approximately 820) is essentially unchanged from that presented in the 1991 report.

The four issues of Volume 26 of *Trail & Landscape* contained 144 pages, for 26% of which birds were the theme. After producing the first two issues of Volume 26, Fenja Brodo departed early in the year for a year's sabbatical. Long-time Associate Editor, Bill Gummer, stepped in in Fenja's absence to edit the second two issues, with exceptional production assistance from Dave Thomson and Sandra Gushue. The Club is greatly indebted to Bill for adding this task to the many other duties he performs on the Club's behalf. He has agreed to carry on until Fenja's return. *The Green Line*, the one-page environmental news supplement to each issue of *Trail & Landscape*, continues to be edited by Michael Murphy.

One manuscript was submitted for consideration for publication as a Special Publication. The Committee agreed not to pursue it.

The Publications Committee and the Club are indebted to all of the large number of members who contribute in various ways to the successful publication of these journals.

RONALD BEDFORD

The following chart summarizes the membership distribution. The figures for 1991 are in brackets. Note that this table does not include non-member subscribers to *The Canadian Field-Naturalist* either as individuals or institutions.

1992 PAID-UP MEMBERSHIP IN THE OFNC					
	CANADA		FOREIGN		
Type	Local	Other	USA	Other	Total
Individual	379 (391)	167 (171)	39 (39)	7 (7)	592 (608)
Family	320 (339)	26 (30)	3 (2)	0 (0)	349 (371)
Sustaining	45 (50)	2 (2)	2 (2)	0 (0)	49 (54)
Life	14 (15)	18 (19)	4 (3)	2 (2)	38 (39)
Honorary	17 (17)	6 (7)	1 (1)	0 (0)	24 (25)
Total	775 (812)	219 (229)	49 (47)	9 (9)	1052 (1097)

Financial Statements for year ended 30 September 1992

Auditor's Report

To the Members of
The Ottawa Field-Naturalists' Club

I have audited the balance sheet of The Ottawa Field-Naturalists' Club as at September 10, 1992, and the statements of operations and members' equity for the year then ended. These financial statements are the responsiblility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, the Club derives most of its revenue from membership fees and subscriptions, as well as from fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the Club.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenue referred to in the preceeding paragraph, these financial statements present fairly, in all material respects, the financial position of the organization as at September 30, 1992, and the results of its operations for the year then ended in accordance with generally accepted accounting principles.

JANET GEHR

North Gower, Ontario
January 6, 1992

The Ottawa Field-Naturalists' Club BALANCE SHEET

September 30, 1992

	1992	1991
Assets		
CURRENT ASSETS		
Cash	$ 214,946	$ 192,493
Accounts Receivable	15,789	10,114
Interest Receivable	1,453	2,019
FON Conference Advance	1,704	
Fletcher Wildlife Garden Loan	6,610	
Prepaid Expenses	1,394	1,394
	241,893	206,020
FIXED (Note 3)	2,756	4,256
LAND - Alfred Bog	3,348	3,348
	$ 247,997	$ 213,624
Liabilities, Funds and Members' Equity		
CURRENT LIABILITIES		
Account Payable	$ 29,750	$ 13,192
Deferred Income	11,296	13,050
	41,046	26,242
FUNDS (Note 4)	8,967	2,721
LIFE MEMBERSHIPS	6,000	6,000
MEMBERS' EQUITY	191,984	178,661
	$ 247,997	$ 213,624

The Ottawa Field-Naturalists' Club STATEMENT OF MEMBERS' EQUITY

Year Ended September 30, 1992

	1992	1991
EXCESS INCOME (EXPENDITURES)		
The Ottawa Field-Naturalist' Club	$ 2,388	$ 12,415
Canadian Field-Naturalist	10,935	30,917
	13,323	43,332
OTHER INCOME (ALLOCATIONS)		
Donations - In memory of George McGee	749	
Donations - For wetlands.	310	
Donations - Misc. upon membership renewal	2,559	3,672
Allocations to Alfred Bog	-3,618	
	0	3,672
TOTAL INCOME	13,323	47,004
MEMBERS' EQUITY, Beginning of Year	178,661	131,657
MEMBERS' EQUITY End of Year	$ 191,984	$ 178,661

The Ottawa Field-Naturalists' Club
STATEMENT OF OPERATIONS - OFNC

Year Ended September 30, 1992

	1992	1991
INCOME		
Membership	$ 14,400	$ 17,003
T&L Subscriptions and Back Issues	487	647
Interest	1,916	3,157
Other Sales	3,056	5,718
Special Publications	646	621
Total Income	20,496	27,146
EXPENSES		
OPERATIONS EXPENSES		
Affiliation fees	435	55
Computer	404	1,355
Depreciation	1,500	1,500
Membership	1,334	1,778
Office assisstant	710	675
Operations	1,931	1,951
OFNC GST Rebate	- 479	- 690
Total Operations Expenses	5,835	6,624
CLUB ACTIVITY EXPENSES (Net)		
Awards	0	29
Birds	131	230
Conservation	30	154
Education and Publicity	1,757	198
Excursions and Lectures	- 370	- 387
Fletcher Wildlife Garden	58	
Macoun Club	1,168	846
Trail & Landscape	5,797	5,490
Wetlands Preservation Coalition		1,547
Total Club Activity Expenses	8,571	8,107
	14,406	14,731
INCOME OVER EXPENSES	6,090	12,415
ALLOCATION TO ALFRED BOG	3,702	
INCOME OVER EXPENSES AND ALLOCATION	$ 2,388	$ 12,415

The Ottawa Field-Naturalists' Club
STATEMENT OF OPERATIONS - CFN

Year Ended September 30, 1992

	1992	1991
INCOME		
Memberships	$ 9,400	$ 10,000
Subscriptions	25,094	24,711
Sub-Total	34,494	34,711
Reprints	4,383	13,570
Publication charges	24,817	38,666
Back numbers	404	708
Interest and exchange	9,029	15,386
Total Income	73,127	103,041
EXPENSES		
Publishing	41,811	47,420
Reprints	3,281	4,586
Circulation	7,985	12,902
Editing	1,637	1,002
Office assistant	4,410	4,200
Office supplies	1,341	663
Advertising	134	
Honoraria	3,000	3,000
GST Rebate	-1,407	-1,649
	62,192	72,124
INCOME OVER EXPENSES	$ 10,935	$ 30,917

The Ottawa Field-Naturalists' Club
Notes To The Financial Statements
September 30, 1992

1. *Authority and Activities*

The Ottawa Field-Naturalists' Club is a non-profit organization incorporated under the laws of Ontario (1884). The Ottawa Field-Naturalists' Club promotes the appreciation, preservation and conservation of Canada's natural heritage; encourages investigation and publishes the results of research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with organizations engaged in preserving, maintaining or restoring environments of high quality living things. Membership is open to any person or family, upon application and payment of dues. Payment of the Annual Dues as set out in the By-laws will be a necessary condition of the continuation of Membership.

2. *Significant Accounting Policies*

Membership, subscriptions and donations are recorded as received. All other revenues and expenditures except for inventory are accounted for on the accrual basis. Memberships are allocated to the Canadian Field-Naturalist publication on a pre-determined percentage.

Supplies, records, tapes and other items held for resale are expensed when purchased.

Fixed assets are recorded at cost and are depreciated on a straight line basis, for assets acquired prior to 1990. Fixed assets acquired after 1989 are expensed.

Life memberships paid since 1977 are recorded at the fee in effect at that time. There are 38 life members.

3. *Fixed Assets*

	1992	1991
Cost	$ 16,748	$ 16,748
Accumulated Depreciation	13,992	12,492
Net Book Value	$ 2,756	$ 4,256

4. *Funds*

	1992	1991
Baldwin Memorial Fund	$358	$ 358
Seedathon	1,018	1,429
Anne Haines Memorial Fund	945	815
Alfred Bog	6,646	119
	$ 8,967	$ 2,721

Errata: *The Canadian Field-Naturalist* 106(3)

Dalby, James E., Jr. 1992. Prey of the sea anemone *Stomphia didemon* (Anthozoa: Actiniaria) on the West Coast of Canada. Canadian Field-Naturalist 106(3): 403-404.

The following author's corrections were omitted:
Abstract (page 403):
line 1: after "until" insert "each specimen extruded"
: correct "wraped" to "wrapped"
line 2: delete "was extruded"
: change "73%" to "63%"
Text (page 403) right column, line 12: after "two" insert "other"
Table 1 (page 403): above heading "# prey items" insert "Total"
: under heading "% anemones with prey" replace "**84**" with "**54**"

JAMES E. DALBY

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Book Reviews

ZOOLOGY

Mammals of the Neotropics, Volume 2: The Southern Cone: Chile, Argentina, Uruguay, Paraguay

By Kent H. Redford and John F. Eisenberg. 1992. The University of Chicago Press, Chicago. ix + 430 pp., illus. Cloth U.S. $95; paper U.S. $39.50.

This is the second of a planned three-volume set dealing with the biology of the mammals of South America. (Volume 1 was reviewed in *The Canadian Field-Naturalist* 105(4): 600–601. The "southern cone" is defined to include Argentina, Chile, Paraguay, and Uruguay. The format is essentially unchanged from the first volume, even though this time Redford collaborates with Eisenberg and takes on the senior authorship.

Three chapters provide an introduction to the biogeography, community ecology, and human effects on mammals of this region. The remaining chapters describe the various orders of extant mammals found in the study area under the topics of diagnosis, distribution, history and classification, and natural history. These chapters are further divided into family, genera, and species with increasingly more detailed taxonomic accounts at each inclusive level. For the nearly 360 species of mammals, subjects typically covered include common names, measurements, description, distribution, life history, ecology, and other comments. Each chapter ends with a list of cited literature. There are also indices for both the scientific and common names found at the end of the book.

One welcome improvement to this volume is the replacement of generalized shading with specific collection localities for the distribution maps of species. This makes the maps more reliable and useful. Another nice addition is the source of the measurements for each species; however, standard deviations have been substituted for minimum and maximum values in many cases. Although there are identification keys for the higher taxa, these are noticeably lacking for species. Admittedly, some groups have no practical keys available, but in the first volume at least some species keys were presented. A disappointment is that there are very few references after 1988. In general, traditional taxonomic classifications are used and published phylogenies are given at the higher levels. As stated by the authors, "we have made no effort to revise taxonomic identifications", a point I found discouraging because many systematic revisions have been published in the recent literature.

There are eight colour and ten black-and-white plates by Fiona Reid representing all orders of mammals in the text. As in the first volume, they are of exceptional quality, and add to the usefulness and attractiveness of the book. Also scattered sporadically throughout the book are skull drawings and external illustrations.

The remark,"… a progress report, a state-of-the-science work, that should be used as much to find out what is not known as what is known", is an apt statement for this three part project. Certainly, through no fault of the authors, scientific work and biological knowledge of the mammals in South America has lagged behind other comparable parts of the world such as Central America. However, interest in Neotropical mammalogy is on the increase with both foreign and local scientists becoming more active in the biology of this area. This is an encouraging sign because tropical conservation and the biodiversity crisis are issues that need to be addressed sooner, not later. Under no circumstances should these books be considered "somewhat premature" as alluded to in the first volume. As science has to build on what we already know, these books are a good addition to the foundation.

For the specialist, especially systematists, the book only begins to scratch at the complex surface of biology but it is a good starting point. When working on South American mammals, I consult it frequently because it covers such a broad geographic area and presents diverse information in a single reference. For students and naturalists, the three planned volumes may be the key to opening up a whole new fascinating area of study and interest. Prior to this, information was found primarily in relatively obscure and inaccessible scientific papers, making it difficult and not encouraging for the uninitiated. I look forward to the publicaiton of the last instalement of this series.

BURTON K. LIM

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Aquatic Invertebrates of Alberta

By Hugh F. Clifford. 1991. University of Alberta Press, Edmonton. xii + 538 pp., illus. Cloth $82; paper $72.

Although there are several publicaitons on freshwater invertebrates of North America or the United States, most welcome is a work on a more limited region, especially a western Candian Province. From the province of Alberta have emerged a number of excellent guides to her flora and fauna, on the mammals, birds, wild flowers, fishes, and, in preparation, the reptiles and amphibians. The intent of the author is that this book complement these existing guides. However it is much larger and is not of the field guide format, as the author explains, due to the very large number of aquatic invertebrates in Alberta.

The book is based on keys written originally for an aquatic invertebrate course taught by the author at the University of Alberta. The keys are to genera, and only the aquatic life stages are identified — non-aquatic adults are not.

The contents are divided into 42 chapters, the first being the Introduction, and the second on Methods (Collecting, Identifying, Relaxing and Mounting, Labels and Vials, and Classification). Chapters 3 to 16 cover the nonarthropods — Porifera (sponges) to Tardigrada (water bears). The bulk of the book, chapters 17 to 42, covers the Arthropods (Arachnida, Crustacea, and Insecta). There is a glossary and a list of addresses of persons cited in the book. References cited occupy 16 pages, and the Survey of References to the Alberta Fauna, which will be most useful in identification to the species level, occupies 46 pages. There is also an index.

Most chapters include such headings as: Introduction; General Features; Collecting, Identifying, Preserving; Species List; Some Taxa Not Reported From Alberta; and a Survey of References. Often included are sections on Reproduction, and Feeding Habits. Easy to use, well-illustrated flow chart keys identify higher taxa and genera. The book is well illustrated with excellent, large, detailed drawings, some of which are full page in size, as well as many colour photographs that are, for the most part, good to excellent in quality. A few appear to be slightly out of focus.

Alberta is the westernmost prairie province of Canada and this book is probably generally useful, with care, across the three prairie provinces. I stress "with care", as, for example, the Alberta freshwater molluscan fauna includes 62 species, whereas Manitoba's freshwater fauna includes at least 78 species of molluscs. Usefulness beyond Alberta's borders might have been enhanced had the general North American distribution been included in the species list. However, this was not the author's intent. I heartily recommend this book to anyone with an interest in freshwater invertebrates.

WILLIAM B. PRESTON

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Hawaiian Insects and Their Kin

By F. G. Howarth and W. P. Mull. 1992. University of Hawaii Press, Honolulu. 160 pp., illus. U.S. $19.95.

The 10 000+ species of insects, arachnids, myriapods, and crustaceans of the easternmost eight (high) islands of the Hawaiian volcanic chain that lies over the central Pacific tectonic plate constitute the world's most isolated large terrestrial and freshwater arthropod fauna. In this superbly illustrated, and very reasonably priced, "gem" of a book on this subject, Frank Howarth, and Bill Mull pool their considerable talents as entomologists and photographers at the Bishop Museum in Honolulu. The result is a concise yet very readable account of the principal species (many not yet formally described), their fascinating (often unique) life styles, and their probable 100-million-year evolutionary history.

The first quarter of the book introduces the reader to the major regional geological, climatological, and edaphic (habitat) features. The following sections, on the origin and evolution of Hawaiian arthropods, are enhanced by informative summaries, by ordinal group, of numbers of both native (endemic plus indigenous) and alien species, and by superb close-up photographs of selected insect life forms. These reveal specialized evolutionary adaptive shifts such as in the unique predaceous caterpillar larvae of the moth genus *Eupethecia*, and in troglophilic (cave-dwelling) crickets. In further chapters, the authors set forth an urgent need for conservation of these relatively fragile endemic faunas and their original ecosystems, many of which, especially at lower elevations and during the past 150 years, have been seriously altered or eliminated by human activities and by introduced animal and plant species. The final introductory chapter provides "thumb nail" summaries of the morphologies, life styles, and representative members of the four main classes of native Hawaiian land arthropods. The account is supported by tables that list numbers of species and genera by family and order (with common names) and by photo-views of lush pristine mesic, cloud-forest, and alpine habitats.

The main portion of the book provides brief sketches and superb, detailed, close-up photographs of 177 of the most commonly encountered (and/or spectacular) species of arthropods, commencing with the spiders and pseudoscorpions, through the "myriapods" and the terrestrial amphipod and isopod crustaceans, and finishing with the major orders of insects, of which the beetles (Coleoptera) comprise about one-quarter of the fauna. Especially remarkable are the views of the hyaline bodies of cave-dwelling land-hoppers (*Spelaeorchestia*), the short-gilled "terrestrial" nymphs of the damselfly genus *Megalagrion*, and the "long-rostrate" toxin-storing adults of the leafhopper genus *Dictyophorodelphax*. Completing the book are lists of references on Hawaiian natural history and Hawaiian arthropods, and an index of scientific names.

This book is well written and carefully edited, with very few errors of any kind. It contains a wealth of information, much of it new to the scientific community as well as to the lay reader. Whatever may be the reader's personal opportunity to visit these unforgetable Hawaiian high islands, the authors have realistically encapsulated the yet pristine environments of this tropical faunistic paradise. This work is a "must" for the bookshelf of every entomologist and field-naturalist who would see the living results of a natural (outdoor) evolutionary laboratory in progress.

E. L. BOUSFIELD

Research Associate, Royal British Columbia Museum, 675 Belleville Street, Victoria, British Columbia V8V 1X4

Peregrine Falcons

By Candace Savage. Douglas and McIntyre, Vancouver, British Columbia. 160 pp., illus. $35.00.

One of the most recent joys for those interested in ornithology has been the renewal and rise in Peregrine Falcon populations.

This "coffee-table" book by Candace Savage, author of such books as *Wolves* and *Grizzly Bears*, celebrates the history of the widely distributed Peregrine Falcon. Savage accomplishes this task by exploring the problems faced by the species and its present comeback through three informative chapters that are wonderfully accompanied with 100 colour photographs by some of the world's best known wildlife photographers. The text also examines many aspects of the peregrines' existence from the time of the ancient Egyptians to present-day, and why the species was revered by some and despised by others.

The second chapter briefly addresses what was a major turning point for the species: "The DDT Crisis". In the 1960s it was observed that Peregrine Falcon populations worldwide were declining and the cause was unknown. Further research resulted in the discovery that insecticides such as DDT, aldrin, and dieldrin were aiding in the population decline by contaminating food, killing birds, and causing infertile eggs as well as secondary characteristics such as eggshell thinning. To further aid the reader in grasping the severity of the number of decline the author includes a graph showing peregrine populations worldwide. It is unfortunate that "after thirty years of intensive research — scientists still do not know which chemical was the main culprit in the peregrine's near demise."

The author gives recognition throughout the book to the efforts and dedication of agencies and individuals in assisting the successful hatching of peregrine eggs. In the final chapter the peregrine populations are examined throughout the world where numbers are on the rise or at least stable. Savage expresses her concern that, although DDT-type chemicals are not used in some countries, they are still used in other such as Central and South America and Africa where the long term effects are still left to be realized.

Throughout the book one will delight in the powerful imagery depicted in the photographs. This is one of the most exceptional presentations of a singular species that this reviewer has chanced to come upon. This compilation of photographs includes some two-page spreads with additional photo inserts. They depict many aspects of peregrine behaviour, as exemplified in shots of them in their nests, with their young, in flight, and residing in urban areas. The strength of the photos are further appreciated when one recognizes the inaccessability of natural nesting sites, the difficulty in obtaining clear, detailed telephoto images, and the challenge of successfully capturing a species behaviour in still pictures. To add to the enjoyment there are included lengthy photo captions which provide good reading throughout.

This book is highly recommended for any personal library as it is visually delightful and can be enjoyed by all ages time and time again.

JO-ANNE MARY BENSON

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BOTANY

Catalog of the Colorado Flora: A Biodiversity Baseline

By William A. Weber and Ronald C. Wittmann. 1992. University Press of Colorado, Niwot. xi + 215 pp. Cloth U.S. $34.95 + $2.00 postage.

This is not just a list but a real catalogue of not only the vascular plants but also the mosses, hepatics, and lichens that are known to occur in the state of Colorado. The catalogue is divided into the following sections: Accepted Names for each of the plant groups listed alphabetically by genus; a General List of taxa of the above groups in alphabetical order of families, genera, and species within the families, together with synonyms that have been used in eleven treatments of all or various parts of the Colorado flora dating back to T. C. Porter and J. M. Coulter, *Synopsis of the Flora of Colorado*, published in 1874, and in many cases, an evaluation of these names.

This work will be invaluable in the preparation of any future floristic or taxonomic study dealing with the state of Colorado. It contains a myriad of cryptic comments such as "known from a single collection", "The alpine race in Colorado deserves taxonomic recognition", "Erroneous report", "Type: Clear Creek Co: Idaho Springs, *Shear 739* (US)", "Abundantly naturalized in vicinity of Air Force Academy, and spreading Adventive", that demonstrate the meticulous work of the authors over many years. Those using it must however make their own decisions as to whether they prefer to use such a genus as Rafinesque's *Chamerion* for what many authors have included in the genus *Epilobium* as *E. angustifolium* and *E. latifolium*, and to check carefully such species *Potentilla rubricaulis* which is so far disjunct from its type locality and relatively limited distribution in northern Canada; and to make sure that *Draba weberi* which honours the senior author has been published.

Another interesting feature in the book is the use of acronyms. These have been designed as a means to enable the user to find the accepted names for any of the synonyms in the synonym lists. Again a tremendous accomplishment, but perhaps a part of the book which will only be used by the very dedicated.

One of the most important features of this book, and one that should not be overlooked by any botanist or curator, is in the introduction. Here the authors stress the fact that institutions that maintain our collections, together with their research staff "are the first line resources in the study of biodiversity. Here is where the specimens of living things are documented and preserved for future study, and where the expert knowledge is concentrated among their curators. If support is lost for the vast network of complementary museum collections and scientists, as is happening now, the study of biodiversity, which as a requirement of the scientific method depends upon preserved material for study and comparison, will be forced to rely on hearsay evidence." They stress the fact that while research is getting vast support, the institutions in which the evidence for biodiversity is housed are being abandoned all over the world. The inference is that those working in this field should make known the importance of their part in the study of biodiversity and not just work at it quietly.

Again, the authors must be congratulated in the completion of this very meticulous work.

WILLIAM J. CODY

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Plants of Northern British Columbia

Edited by Andy MacKinnon, Jim Pojar, and Ray Coupé. 1992. Lone Pine Publishing, Edmonton. 352 pp., illus. $19.95.

This delightful publication will be a welcome companion for anyone interested in the natural history of the northern two-thirds of British Columbia east of the coastal ranges. It contains a collection of absolutely beautiful colour photographs of the more common plant species in the area, together with many line drawings, short descriptions, habitat information, and a wealth of interesting notes.

The text was written by ten individuals, each an expert in his or her field: George Argus (willows), Frank Boas (mosses), Ray Coupé (shrubs and dwarf shrubs), Craig DeLong (grasses), George Douglas (composites, ferns, and allies), Trevor Goward (lichens), Andy MacKinnon (lilies, orchids), Jim Pojar (trees, dwarf shrubs, other flowers), Rosamund Pojar (notes), and Anna Roberts (illustrated willow key, grasses, sedges, and rushes). There is a short introduction which includes a map of the Biogeoclimatic zones of British Columbia (in colour), together with brief descriptions of the eight biotic zones. This is followed by sections on trees, shrubs, willows, dwarf shrubs, and other plant groups. Some keys are provided, including a picture key to grass genera, and these are quite easy to follow.

An index to both common and scientific names is provided and the last page gives the reader an opportunity to meet each of the ten authors.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6

ENVIRONMENT

Wildside — Rainforests by Paul Appleby
Wildside — Oceans by Nick Davies
Wildside — Woodlands by Tess Lemmon
Wildside — Rivers, Lakes and Wetlands by Susan McMillan

Wildside Series, 1992. BBC Enterprises. (McClelland & Stewart, Toronto.) 64 pp. each, illus. $14.95 each.

This four-book series is designed to give children a better understanding of plants and animals and the unique environments in which they live. This relationship is constantly under threat from a variety of ecological pressures. Through these superb educational books children learn to be more aware of environmental problems pertinent to their area and beyond.

Children are introduced to the many plants and animals that live in the subject areas and learn how the delicate balance can and is being disrupted by human activity. The authors point out that industrial pollutants are being dumped in the seas, rainforests are vanishing at an alarming rate, and animal habitat is constantly being encroached upon.

Though the books are predominantly designed to educate, one of this series' strengths lies in the encouragement of problem-solving activities that engage the reader. One feature that is particularly appealing is an index box entitled "WILDSIDE WATCH". Within these boxes there are provided activities, suggestions, and additional information on how children can contribute to protecting different environments.

Each of the books is sixty-four pages in length and addresses approximately thirty topics. The series is recommended for children ages 8–12, but can be appreciated by all. The material is beautifully presented with well-written text, colour photographs, and illustrations. Due to the nature of the subject matter and the broad coverage of a variety of topics, the books can be equally appreciated by adults as well.

The books conclude with a listing of British based organizations one may wish to contact, though for many a North American equivalent exists (i.e., Greenpeace, Friends of the Earth, World Wildlife Fund, etc.). This BBC production is truly international in its scope.

This is an excellent series that is reasonably priced and can be enjoyed over the years. It not only contributes to a youth's general education of the natural world but would be a useful reference tool for school assignments.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

The Greater Yellowstone Ecosystem: Redefining America's Wilderness Heritage

Edited by Robert B. Keiter and Mark S. Boyce. Forward by Luna B. Leopold. Yale University Press, New Haven, Connecticut. xvii + 428 pp., illus. U.S. $45.

Mark Boyce and Robert Keiter are both professors at the University of Wyoming and they have done an excellent job of selecting representative essays and papers originally presented at a 1989 symposium on the Greater Yellowstone Ecosystem held in Laramie, Wyoming. Each chapter, in one way or another, attempts to redefine and clarify wildlands management issues and chronicles the change in management from one based upon human utilitarian interests which attempts to control, manipulate, and direct natural ecological processes for direct human advantage to one which tries to avoid undue manipulation of ecosystem, and instead attempts to control incompatible human uses.

Although the focus of the book is clearly on the Greater Yellowstone Ecosystem, and provides an excellent overview of current natural resources in the

Yellowstone region, its value goes well beyond the bounds of Yellowstone. In the broader view the controversies of this ecosystem are issues being faced by conservationists and land managers throughout the world. How do we, for example, manage for biodiversity? Should we manage for anything, whether it is biodiversity or anything else? What is natural and what is manipulation? Are humans a part of the wildlands environment and to what extent? In essence, the authors are attempting in one fashion or another to answer a fundamental question of how a diverse array of human wants, needs, and desires can be integrated into a natural setting while still maintaining ecosystem integrity.

These and other relevant questions are posed and answered from a variety of perspectives. The authors of the 24 chapters include out-spoken critics of such federal government policies as endangered species protection legislation as well as their supporters, private property rights advocates and ecosystem protection proponents. Most of the chapters are written by researchers and scientists doing field work in the ecosystem on everything from stream ecology to public attitudes about wolf restoration. As with any compendium, the writing and quality of thought varies from author to author, but overall this book has some very good and thought provoking ideas presented by a host of different individuals.

The book is divided into five parts, each focused on current controversial natural resource issues — wolf reintroduction, wildfire management, ecosystem management, and wildlife issues related to elk and range condition. Some of the research highlighted is recent and challenges popular perception and mythology. Several researchers conclude that Yellowstone's winter range is not being "overgrazed" by ungulates as many have suggested in the past. A number of fire ecologists present their view that large wildfires are the norm in the Yellowstone environment and can not be precluded by prescribed burns. Another researcher presents study results that shows strong support for wolf reintroduction across the country and even within Wyoming and nearby states. Nevertheless, there are also papers by other scientists, lawyers, and researchers which present their own interpretations that support popular notions such as elk are ruining Yellowstone's winter range or that Yellowstone National Park officials have mismanaged grizzly bears to the latter's detriment. Thus it can be said that the text provides a diverse array of opinions and views about how Greater Yellowstone should be managed or unmanaged.

The Greater Yellowstone Ecosystem would serve as an excellent textbook for a course in wildlands management, public lands policy, or environmnental ethics as well as good, rich reading, for anyone interested in the on-going and current debate about how to manage or not manage the Greater Yellowstone Ecosystem, and by inference, the world. I highly recommend the book.

GEORGE WUERTHNER

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Tomorrow Will Be Too Late

By Rolf Edberg and Alexei Yablokov. University of Arizona Press, Tucson. 210 pp. Cloth U.S. $29.95; paper U.S. $14.95.

In 1987, Rolf Edberg, a Swedish writer and statesman, and Alexei Yablokov, a Russian ecologist and Academician (and, from 1989, while it lasted, a member of the Soviet parliament), met for seven days to discuss the survival of life on Earth. Their conversation was recorded in this book, published simultaneously in Russian and Swedish in 1988, and in English translation in 1991. Although representing different cultures, east and west, they found to their surprise that they agreed on all but a few minor points: their discussion became an antiphonal chorus.

They decry militarism (especially nuclear), pollution (including agricultural), overpopulation, consumerism, ..., and propose as necessary, but not sufficient, parts of the remedy an ecological morality — what is ecologically unsound is therefore immoral — and some sort of world authority to govern natural resources.

Their arguments are buttressed with strange statistics, quotable nuggets of information illustrating the arguments, but not really integrated into them. Opening the book at random, I learn that a ton of water in the developed countries costs ten cents and is clean; a ton of water in Third-World countries costs twenty dollars, and is foul. From another page, the total area (of the world) taken up by roofs and roads is greater than the territory of France.

I agreed in general with their arguments and conclusions, except that I would have put much more stress on overpopulation, yet found the book unsatisfying. Because of the dialog format a page or paragraph from one, then from the other, there was no long well-developed argument, but a jerkiness reminiscent of a radio or TV interview. It wasn't really a book.

The book suffers too from being late. The world has changed since they spoke together, and it has changed again since they wrote prefaces to the English edition. We are now less surprised that a

Swede and a Russian agree that ecological disaster is imminent, and that they agree by and large on what we must do to escape that disaster. But from last summer's Earth Summit we know that Third-World ecologists can have different views, and they must be heard too.

Yet if you want to hear the arguments, to listen in on a conversation between two wise men, and are not put off by the jerkiness, the abrupt changes, of a conversation, you will probably enjoy this book.

BRUCE WINTERBON

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Ecological Risk Estimation

By Steven M. Bartell, Robert H. Gardner, and Robert V. O'Neill. 1992. Lewis Publishers, Chelsea, Michigan. xv + 252 pp. U.S. $84.

The objective in ecological risk assessment is to use available toxicological and ecological information to estimate the probability that some undesired ecological event will occur. This book outlines a practical approach, with particular reference to aquatic ecosystems. In a sense, the book is a progress report, presenting state-of-the-art methods, noting current limitations, and identifying future research needs in a rapidly evolving discipline.

The book is organized in eight chapters, addressing respectively: (1) the need for ecological risk analysis, (2) the toxicological and ecological data requirements, (3) an aquatic ecosystem model, (4) an aquatic toxicology model, (5) the risk forecasting methodology, (6) evaluation of the methodology, (7) comparison of predicted and observed effects, and (8) conclusions and future directions. Chapters 5, 6 and 7 highlight particular examples of ecological risk analyses, associated model sensitivity analyses, and field experimental validations which the authors have performed.

In chapter 1 the authors define risk analysis, as distinct from simple assessment, by its quantitative consideration of uncertainty and expression of the estimated effect as a probability. A major source of uncertainty is our incomplete understanding of ecological process, which also contributes to our difficulty in defining the ecological endpoints for which we desire risk estimates. The basis for risk analysis in U.S. environmental legislation is reviewed, with the conclusion that it could usefully contribute to required evaluations in most cases (the same is true in Canada) and is explicitly required in one case.

In chapter 2 the sources and limitations of available toxicological, chemical fate, and ecological data are discussed. While acute toxicity data are widely available for a few species and chemicals, there is a paucity of data on response to chronic exposure, particularly for the sublethal responses, such as feeding, growth, and reproduction, that can be critical to ecological function. Extrapolations from acute to chronic exposure, from one species to another, and from one chemical to another are often required. Structure activity relationships are discussed as extrapolation tools.

The aquatic ecosystem model in chapter 3 is based on processes such as consumption, production, and combined respiration-mortality, which vary among species, and are more easily measured than the traditional Lotka-Volterra population model parameters. They also vary in time as non-linear functions of temperature, light, and nutrient supply, with the result that species interactions also vary. Phytoplankton, zooplankton, planktivorous fish, and piscivore trophic levels are represented.

Chemical stress effects on ecosystem model parameters are estimated from best available toxicity data, as described in chapter 4. Effects factors are considered to be variables with defined probability distributions. The risk of a particular ecological outcome is then estimated by Monte Carlo simulation at each exposure concentration, as described in chapter 5. Risk can be plotted as a function of chemical (or mixture) concentration.

In chapter 6, the general issue of model validation is discussed, noting that models are necessarily simplified representations of nature and can never be entirely valid. However, they can be evaluated by using sensitivity analysis to identify critical assumptions for subsequent scrutiny, and by comparison of predicted to observed ecological outcomes in field experiments (chapter 7). Evaluation methods are presented, and illustrated by evaluation of the author's aquatic ecosystem model.

The authors conclude in chapter 8 that their risk estimation methods may be useful at least for screening purposes or comparison of risks among chemicals. Accuracy depends on site-specific information, and effects estimates must pertain to a local site. Future directions include development of methods for spatial integration to forecast on a larger regional scale.

The book is clearly focused at a broad ecosystem level, and gives only brief attention to more detailed age-specific population models tht have been used successfully to estimate risk to a single species, reflecting age variation in the toxic response. However, the general approach presented is applicable to a wide variety of ecological and toxicological models, for aquatic or terrestrial environments, at different levels of detail. The book should prove useful both as a technical guide for environmental researchers and as a philosophical guide for environmental regulators attempting to define ecological objectives.

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MISCELLANEOUS

Nature Lost? Natural Science and the German Theological Traditions of the Nineteenth Century

By Frederick Gregory. 1992. Harvard University Press, Cambridge, Massachusetts. viii + 341 pp. U.S. $39.95.

Gregory is well known as an intellectual historian, particularly for his fine *Scientific Materialism in Nineteenth Century Germany* published in 1977. In this new volume he explores the reaction of theologians to the advent of Darwinism. The opening section provides essential background which will surely be lacking in most readers: the transformation over two centuries from nature being viewed as a component of theology to the present situation in which science and theology are seen as fundamentally different enterprises dealing with How and Why, respectively; the related issue of whether persons or matter-in-motion are fundamental; the pursuit of truth through correspondence or coherence approaches; and the political and philosophical dimensions from the Enlightenment through the Romantic Era to the present.

The middle section focusses on three theologians whose diverse views nevertheless all retained nature. The *Life of Jesus* by David Friedrich Strauss produced a storm of controversy similar to that of Darwin's contemporaneous *Origin of Species*. Subsequently Strauss embraced Darwinism in his *The Old Faith and the New*; drew on DuBois-Reymond's opposition to spontaneous generation and on materialist scientists generally; and provided a natural interpretation of human evolution. The natural theology of Otto Zöckler included criticism of Darwin, alternative evolutionary arguments of the earth and humans, and the conclusion of the irreconciliability of science and religion. In between, Rudolf Schmid attempted to mediate between Darwinian and religious claims and criticized monism.

The final section attends to theological arguments in which nature plays no role. Led by his view that science and religion are radically separate, Wilhelm Hermann became embroiled with other theologians and also attacked science and metaphysics. These arguments contributed to modern existentialism in which human morality must be raised in an indifferent universe.

With good cause many question the existence of a "science of theology" in general or, at least, the specific Judaeo-Christian beliefs which were the core of Western civilization for seventeen centuries. Nonetheless, this book provides insights into the broader intellectual landscape in which natural history and theology are located and into central contemporary issues such as the treatment of animals, and human attitudes of domination versus stewardship towards the rest of nature. Excellent reading awaits those who wish to deepen their understanding of the intellectual relations of natural history and religion.

PATRICK W. COLGAN

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Peterson First Guides: Rocks and Minerals

By Frederick H. Pouch. 1991. Houghton Mifflin Company, New York. 128 pp., illus. U.S. $4.95.

This "first" guide to rocks and minerals is designed as an introduction to the subject matter. It is useful not only to young naturalists but to beginners of all ages. Its purpose is to simplify and aid persons in the identification of the common rocks and minerals one might encounter.

Pough begins with a brief introduction that gives people a basic understanding of what to look for and where. The book describes how rocks were formed, includes a description of the elements, the various classes of rocks and minerals, and descriptions of crystal forms. This material is presented using a terminology that is directed towards the non-specialist.

In comparing this *First Guide* to the original *Guide to Rocks and Minerals*, the most obvious difference is the reduced size, that of only 128 pages as compared to the 317 pages of the regular guide. The second most obvious feature is the style of presentation, with brief paragraphs appearing directly opposite the corresponding colour plates in an easy-to-understand vocabulary for the beginning collector. The original guide is better appreciated by the experienced collector or specialist. The original provides plates in the centre with descriptions that are considerably more detailed and address topics such as distinguishing characteristics, environment, physical properties, and testing procedures.

The *First Guide* is useful as a brief, simply presented introduction to collecting that is detailed enough to pique your interest but not enough to overwhelm. After one is more comfortable with identification and collection one can easily graduate into the excellent, but more complex regular guide.

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NEW TITLES

Zoology

†**Animal minds.** 1992. By Donald R. Griffin. University of Chicago Press, Chicago. 310 pp. U.S.$24.95.

Annotated list of Ontario Lepidoptera. 1992. By J.C.E. Riotte. Royal Ontario Museum, Toronto. viii + 208 pp. + maps. $19.95.

Bats: a community perspective. 1992. By James S. Findley. Cambridge University Press, New York. c200 pp., illus. cU.S.$49.95.

Biology of blood-sucking insects. 1992. By M.J. Lehane. Harper Collins, New York. xv + 280 pp., illus. Cloth U.S.$50; paper U.S.$29.95.

Bird life of coasts and estuaries. 1992. By Peter N. Ferns. Cambridge University Press, New York. c350 pp., illus. cU.S.$49.95.

***The bird watcher's book of lists (eastern region): lists for recreation and record keeping.** 1992. By Lester L. Short. Raincoat Books, Vancouver. 128 pp., illus. $8.95.

†**The birdwatcher's book of lists (western region): lists for recreation and record keeping.** 1992. By Lester L. Short. Raincoat Books, Vancouver. 128 pp., illus. $8.95.

†**Britain's birds in 1989-90: the conservation and monitoring review.** 1991. Edited by David Stroud and David Glue. Nature Conservancy Council, Thetford, England. 216 pp., illus. £6.95 plus £5 overseas airmail.

The common names of North American butterflies. 1992. Edited by Jacqueline Y. Miller. Smithsonian Institute Press, Washington. 200 pp. U.S.$14.95.

***Cougar: ghost of the Rockies.** 1992. By Karen McCall. Douglas and McIntyre, Vancouver. 324 pp., illus. $35.

CRC handbook of avian body masses. 1992. By John Dunning, jr. CRC Press, Boca Raton, Florida. c400 pp. U.S.$49.95 in U.S.A.; U.S.$60 elsewhere.

†**Crickets and katydids, concerts and solos.** 1992. By Vincent G. Dethier. Harvard University Press, Cambridge. 144 pp., illus. U.S.$18.95.

***Ecology and conservation of neotropical migrant landbirds.** 1992. Edited by John M. Hagan III and David W. Johnston. Smithsonian Institute Press, Washington. viii + 609 pp., illus. Cloth U.S.$48; paper U.S.$17.95.

†**Hormones, brain, and behavior: biology of the Reptilia, volume 18, physiology E.** 1992. Edited by Carl Gans and David Crews. University of Chicago Press, Chicago. 578 pp., illus. U.S.$75.

Individual development and evolution: the genesis of novel behavior. 1992. By Gilbert Gottlier. Oxford University Press, New York. xii + 231 pp., illus. U.S.$35.

Killer bees: the Africanized honey bee in the Americas. 1992. By Mark L. Winston. Harvard University Press, Cambridge. xiii + 162 pp., illus. U.S.$19.95.

***Mammals of the neotropics, volume 2: the southern cone: Chile, Argentina, Uruguay, Paraguay.** 1992. By Kent H. Redford and John F. Eisenberg. University of Chicago Press, Chicago. ix + 430 pp., illus. + plates. Cloth U.S.$95; paper U.S.$39.50.

***Peregrine Falcons.** 1992. By Candace Savage. Douglas and McIntyre, Vancouver. 160 pp., illus. $35.

The philosophy and practice of wildlife management. 1992. By Donald G. Dodds. 2nd edition. Krieger, Melbourne, Florida. 326 pp. U.S.$34.50.

†**Sensorimotor integration: biology of the Reptilia, volume 17, neurology C.** 1992. Edited by Carl Gans and Philip S. Ulinski. University of Chicago Press, Chicago. 790 pp., illus. Cloth U.S.$92; paper U.S.$42.50.

Snakes in Thailand and their husbandry. 1992. By Merel J. Cox. Krieger, Melbourne, Florida. 564 pp., illus. U.S.$69.50.

Snakes of the world, volume 2: synopsis of living and extinct species. 1993. By Kenneth L. Williams and Van Wallach. Krieger, Melbourne, Florida. U.S.$33.50. (2 volume set U.S.$59.50).

Spiders in ecological webs. 1992. By David H. Wise. Cambridge University Press, New York. c300 pp., illus. cU.S.$74.95.

Venomous and poisonous animals. 1992. By Andres Edstrom. Krieger, Melbourne, Florida. 208 pp. U.S.$28.50.

Venomous reptiles of North America. 1992. By Carl H. Ernst. Smithsonian Institute Press, Washington. 216 pp., illus. U.S.$35.

The venomous sea snakes: a comprehensive bibliography. 1992. By George V. Pickwell. Krieger, Melbourne, Florida. cU.S.$48.50.

***Wildlife habitat relationships: concepts and applications.** 1992. By Michael L. Morrison, Bruce G. Marcot, and R. William Mannan. University of Wisconsin Press, Madison. ix + 343 pp., illus. U.S.$26.95.

***Wildlife habitat relationships in forested ecosystems.** 1992. By David R. Patton. Timber Press, Portland, Oregon. 392 pp., illus. U.S.$15.

Wings along the waterway. 1992. By Mary Barrett Brown. Orchard, New York. 80 pp., illus. U.S.$17.95.

Botany

British plant communities, volume 3: grasslands and montane communities. 1992. Edited by J.S. Rodwell. Cambridge University Press, New York. c750 pp., illus. cU.S.$195.

***Catalogue of the Colorado flora.** 1992. By Ronald C. Whittmann and William A. Weber. University Press of Colorado, Niwot. 272 pp. U.S.$34.95.

Coastal plant communities of Latin America. 1991. Edited by Ulrich Seeliger. Academic Press (Harcourt, Brace, Jovanovich, San Diego). 392 pp. U.S.$77.

Ferns. 1992. By Theresa Greenway. Steck-Vaughn, Austin, Texas. 48 pp., illus. U.S.$18.60.

Paleobotany and the evolution of plants. 1992. By Wilson N. Stewart and Gar W. Rothwell. 2nd edition. Cambridge University Press, New York. c500 pp., illus. cU.S.$42.50.

The visual dictionary of plants. 1992. By Dorling Kindersley. DorlingKindersley, New York. 64 pp., illus. U.S.$14.95.

Environment

After earth day: continuing the conservation effort. 1992. By Max Oelschlaeger. Texas A & M University Press, College Station. 265 pp. Cloth U.S.$24.50; paper U.S.$15.95.

An agenda of science for environment and development into the 21st century. 1992. Edited by J.C.I. Dooge, Gordon Goodman, J.W.M. La Riviere, Julia Marton-Lefevre, and Timothy O'Riordan. Cambridge University Press, New York. c300 pp., illus. Cloth cU.S.$70; paper cU.S.$34.95.

Air: the nature of the atmosphere and the climate. 1992. By Michael Allaby. Facts on File, New York. 208 pp., illus. U.S.$35; $43.95 in Canada.

The American Littoral Society handbook for the marine naturalist. 1991. By David K. Bulloch. Walker, New York. xii + 165 pp., illus. Cloth U.S.$19.95; paper U.S.$11.95.

Arctic ecosystems in a changing climate: an ecophysiological perspective. 1991. Edited by F.S. Chapin III, R.L. Jeffries, J. Svoboda, J.F. Reynolds, and G.R. Shaver. Academic Press (Harcourt, Brace, Jovanovich, San Diego). 469 pp. U.S.$95.

The balance of nature: ecological issues in the conservation of species and communities. 1992. By Stuart L. Pimm. University of Chicago Press, Chicago. xiii + 426 pp. Cloth U.S.$62; paper U.S.$26.95.

The biological century: Friday evening talks at the Marine Biological Laboratory. 1992. By Robert Barlow, John Dowling, and Gerald Weissman. Harvard University Press, Cambridge. 248 pp., illus. U.S.$45.

Confronting climate change: risks, implications, and responses. 1992. Edited by Irving Mintzer. Cambrige University Press, New York. c324 pp., illus. Cloth cU.S.$79.95; paper cU.S.$34.95.

The crystal desert: summers in Antarctica. 1992. By David Campbell. Houghton Mifflin, New York. U.S.$21.95.

***The diversity of life.** 1992. By Edward O. Wilson. Harvard University Press, Cambridge. 464 pp., illus. U.S.$29.95.

Ecological economics: the science and management of sustainability. 1991. Edited by Robert Costanza. Columbia University Press, New York. xiii + 525 pp., illus. U.S.$50.

†**Messages from earth: nature and human prospect in Alaska.** 1992. By Robert Weeden. University of Alaska Press, Fairbanks. xiv + 189 pp., illus. U.S.$16.95.

†**Naturalist's Mexico.** 1992. By Roland H. Wauer. Texas A & M University Press, College Station. xxix + 104 pp., illus. Cloth U.S.$38.50; paper U.S.$14.95.

†**The nature of southeast Alaska: a guide to plants, animals, and habitats.** 1992. By Rita M. O'Clair, Robert H. Armstrong, and Richard Garstensen. Alaska Northwest (GTE Discovery Publications, Bothwell, Washington). 254 pp., illus. U.S.$17.95; $21.95 in Canada.

***On common ground: managing human - planet relationship.** 1992. By Ranjit Kumar and Barbara Murck. Wiley, Rexdale, Ontario. 224 pp. $24.95.

The state of Canada's environment/L'etat de l'environnement au Canada. 1992. By Environment Canada. Canada Communications, Ottawa. English or French. $29.95 in Canada; U.S.$35.95 elsewhere plus shipping.

The state of nature: ecology, community, and American social thought, 1900-1950. 1992. By Gregg, Chicago. c304 pp. Cloth U.S.$58; paper U.S.$23.50.

†**Terrestrial ecosystems through time: evolutionary paleoecology of terrestrial plants and animals.** 1992. By Anna K. Behrensmeyer, John D. Damuth, William A. DiMichele, Richard Potts, Hans-Dieter Sues, and Scott L. Wing. University of Chicago Press, Chicago. xix + 568 pp., illus. U.S.$75.

The underwater naturalist: a layman's guide to the vibrant world beneath the sea. 1991. By David K. Bulloch. Lyons and Burfort, New York. 250 pp., illus. U.S.$26.95.

Valuing the environment: economic approaches to environmental evaluation. 1992. Edited by Annabel Coker and Cathy Richards. CRC Press, Boca Raton, Florida. 182 pp. U.S.$59.95 in U.S.A.; U.S.$72 elsewhere.

A view from the heart: bayou country ecology. 1991. By June C. Kennedy. Blue Heron Press, Thibodaux, Louisiana. 145 pp., illus. U.S.$16.95.

Water: its global nature. 1992. By Michael Allaby. Facts on File, New York. 208 pp., illus. U.S.$35; $43.95 in Canada.

†**Water quality in North American river systems.** 1992. Edited by C.D. Becker and D.A. Neitzel. Battelle Press, Columbus, Ohio. 328 pp. U.S.$44.95 + U.S.$3.50 postage.

*__Wildside oceans: conserving animals and plants in a changing world.__ 1992. By Nick Davies. BBC Books (McClelland and Stewart, Toronto). 64 pp., illus. $14.99.

*__Wildside rainforests: conserving animals and plants in a changing world.__ 1992. By Paul Appleby. BBC Books (McClelland and Stewart, Toronto). 64 pp., illus. $14.99.

*__Wildside rivers: conserving animals and plants in a changing world.__ 1992. By Susan McMillan. BBC Books (McClelland and Stewart, Toronto). 64 pp., illus. $14.99.

*__Wildside woodlands: conserving animals and plants in a changing world.__ 1992. By Tess Lemmon. BBC Books (McClelland and Stewart, Toronto). 64 pp., illus. $14.95.

Miscellaneous

Birder extraordinaire: the life and legacy of James L. Baillie (1904-1970). 1992. By Lise Anglin. Toronto Ornithological Club, Toronto. $12 plus $2.60 postage.

Keywords in evolutionary biology. 1992. Edited by Evelyn Fox Keller and Elisabeth A. Lloyd. Harvard University Press, Cambridge. 496 pp., illus. U.S.$45.

A naturalist in Indian territory: the journals of S.W. Woodhouse, 1849-50. Edited by John S. Tomer and Michael J. Brodhead. University of Oklahoma Press, Norman. 288 pp., illus. U.S.$29.95.

*__Nature lost? natural science and German theological traditions of the nineteenth century.__ 1992. By Frederick Gregory. Harvard University Press, Cambridge. ix + 341 pp. U.S.$39.95.

Scenes from deep time: early pictorial representations of the prehistoric world. 1992. By Martin J.S. Rudwick. University of Chicago Press, Chicago. c304 pp., illus. U.S.$45.

Young Naturalists

Ancient forests. 1991. By Alexandra Siy. Dillon Press, New York. 72 pp., illus. U.S.$13.95.

Animal opposites. 1992. By Grace Mabie. Troll Associates, Mahwah, New Jersey. 24 pp., illus. Cloth U.S.$9.95; paper U.S.$2.50.

Baby animals of the north. 1992. By Katy Main. Alaska Northwest (GTE Discovery, Bothwell, Washington). 36 pp., illus. U.S.$12.95.

Backyard scientist, series four. 1992. By Jane Hoffman. Backyard Scientist, Irvine, California. 52 pp., illus. U.S.$9.95.

Cacti and other succulents. 1992. By Wendy Madgwick. Steck-Vaughn, Austin. 46 pp., illus. U.S.$11.40.

The children's animal atlas. 1992. By David Lambert. Millbrook Press, Brookfield, Connecticut. 96 pp., illus. U.S.$18.90.

Earthwatch: earth cycles and ecosystems. 1992. By Beth Savan. Addison-Wesley, New York. 96 pp., illus. U.S.$8.95.

Grover's 10 terrific ways to help our Wonderful World. 1992. By Anna Ross. Random House, New York. 32 pp., illus. U.S.$2.25.

How a seed grows. 1992. By Helene J. Jordan. Revised edition. Harper/Trophy, New York. 32 pp., illus. U.S.$14.

How do apples grow? 1992. By Betsy Maestro. Harper Collins, New York. 32 pp., illus. U.S.$14.

Living fossils. 1992. By Cass R. Sandak. Watts, New York. 64 pp., illus. U.S.$11.90.

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Migration in the sea. 1992. By Liz Oram and R. Robin Baker. Steck-Vaughn, Austin. 46 pp., illus. U.S.$14.95.

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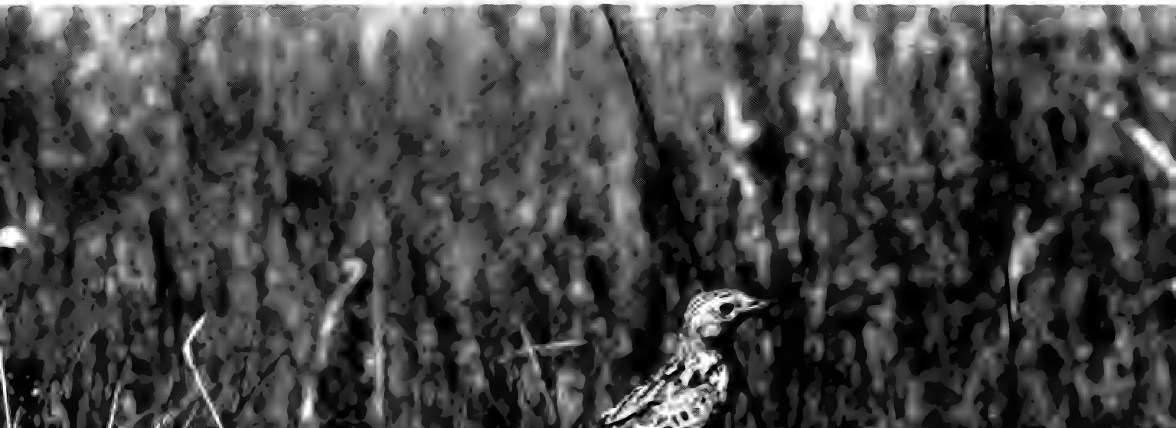
ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada



Volume 107, Number 2

April-June 1993

The Ottawa Field-Naturalists' Club

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The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

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Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue:April-June 1993 (May 1994).

Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club,* 1879-1886, and The Ottawa Naturalist, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Sprague's Pipit, *Anthus spragueii*, photographed 15 June 1991 in the Riske Creek area, British Columbia. Photograph courtesy of Anna Roberts. See note on first record of occurrence and nesting for the species in British Columbia, pages 222–223.

The Canadian Field-Naturalist

Volume 107, Number 2 April–June 1993

The Pleistocene Small Carnivores of Eastern Beringia

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Youngman, Phillip M. 1993. The Pleistocene small carnivores of eastern Beringia. Canadian Field-Naturalist 107(2): 139–163.

Twenty-six species of fissiped carnivore (four canids, 13 mustelids, one hyaenid, four felids, and four ursids) lived in Eastern Beringia during the Pleistocene. Of these species six are extinct (one canid, one ursid, two mustelids, one hyaenid, and two felids) and four (three mustelids and one felid) no longer live in the region. The status of 568 specimens, representing 17 species of small carnivores, is examined.

Key Words: Pleistocene, Beringia, Alaska, Yukon Territory, mammal, carnivore, extinction, size, Dhole, *Cuon*, Arctic Fox, *Vulpes lagopus,* Red Fox, *Vulpes vulpes,* Lynx, *Felis lynx,* Sea Otter, *Enhydra* sp., Short-faced Skunk, *Brachyprotoma obtusata,* River Otter, *Lutra canadensis,* Wolverine, *Gulo gulo,* American Pine Marten, *Martes americana*; Fisher, *Martes pennanti*, Ermine, *Mustela erminea*, Steppe Ferret, *Mustela eversmanni*, Black-footed Ferret, *Mustela nigripes,* Least Weasel, *Mustela nivalis,* American Mink, *Mustela vison,* American Badger, *Taxidea taxus.*

The broad history of Beringia is fairly well known (Hopkins 1967b, 1982). During glacial periods, beginning in the early Tertiary, and terminating with the close of the last (Wisconsinan) glaciation, a broad isthmus, in the region of the present Bering Strait, connected Asia with North America. During intervening interglacials sea level rose to form a strait. This sequence of openings and closings of the Bering Strait, and of closings and openings of an ice-free corridor between Beringia and central periglacial North America, operated as a set of valves, allowing nearly unimpeded movement of mammals from Asia (Hopkins 1967b). Some waves of immigrants to Beringia evolved into Beringian and southern periglacial vicariants (Youngman 1975).

Our understanding of the nature of the Beringian fauna is limited, partly owing to the relative lack of specimens with stratigraphic provenance, and partly to the lack of satisfactory dating techniques which would allow correlation of fossil-bearing sediments from different sites.

Many records of the carnivores of eastern Beringia are published solely in faunal lists, of which some are misidentifications, and many lack references to voucher specimens.

In this paper I document the remains of 17 species of small carnivores from eastern Beringia on the basis of all specimens of each species I have examined. I discuss pertinent biogeographical, ecological and taxonomic problems, and mention the large carnivores in the overall context of the carnivore fauna of the region.

In his seminal volume on the Bering Land Bridge, Hopkins (1967a: vii) included in Beringia "western Alaska, Northeastern Siberia, and the shallow parts of Bering and Chukchi seas." It is now recognized that a large part of the Yukon Territory, Canada, and smaller portions of adjacent Mackenzie District, Northwest Territories also belonged to this vast unglaciated refugium (Figure 1). Since 1967, new pertinent data have been published (Hopkins 1982; Kontrimavichus 1984), and thousands of Pleistocene and Holocene fossils (albeit mostly undated) have been collected in the Yukon Territory; the stratigraphy is better understood (Hughes et al. 1989; Schweger 1989b); the unglaciated regions in Canada have been approximately mapped (Dyke and Prest 1987); and palynological studies have furthered the understanding of Pleistocene vegetation and climate (Giterman et al. 1982; Matthews 1982; Ritchie and Cwynar 1982; Schweger 1982). Small carnivores from Beringia have been mentioned only recently in the literature (Péwé 1957; Péwé and Hopkins 1967; Repenning 1967; Péwé 1975; Anderson 1977; Harington 1977; Kurtén and Anderson 1980).

Materials and Methods

Most of the 567 fossil, or subfossil, specimens upon which this study is based are dated neither

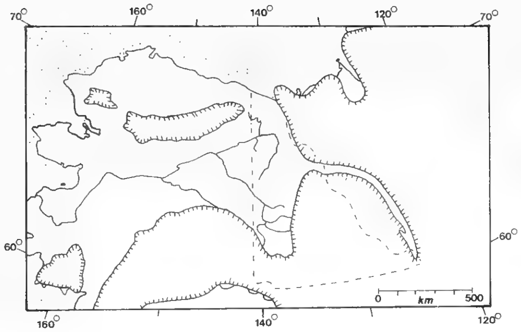

FIGURE 1. Eastern Beringian region with present political boundaries and drainage. Glacial margins at 18000 years before present. Presently submerged portion of land bridge stippled.

stratigraphically, nor isotopically, thus there is the possibility that some specimens may be late Pliocene or Holocene. Most species treated here are represented by a number of specimens from several localities. Some specimens are associated with extinct, or locally extinct, species and some are radiocarbon dated, or are bracketed by known radiocarbon dates. The most satisfactory specimens are those collected in caves or other sites of primary deposition. The least satisfactory specimens are those collected from point bars on rivers, or from other redeposited sediments.

Species accounts are preceded by a summary of each mammalian family, listed alphabetically, represented by fossils from Beringia. Species accounts, listed alphabetically, include scientific and vernacular names. A list of specimens examined by me (museum acronyms are in Acknowledgments, and Borden numbers, where applicable, are given in Appendix II), a discussion of pertinent taxonomic problems, and some life history and distributional information on modern representatives is also given. Teeth were measured with an optical micrometer; other measurements were taken with dial calipers, following the methods and terminology of Anderson (1970), except for width of dentary (lingual-buccal) at p4-m1, which was added to the measurements of ferrets.

The general localities and sources of modern comparative material are listed in Appendix I. A gazeteer of fossil localities is found in Appendix II.

Systematic Paleontology

Order CARNIVORA

Family CANIDAE

Six wild canids have been reported from the Pleistocene of Beringia: *Xenocyon* sp. [= *Cuon* sp.] (Péwé and Hopkins 1967; Repenning 1967; Irving and Harington 1973; Harington 1978; Kurtén and Anderson 1980); *Canis dirus* (Frick 1930; Péwé 1975); *Canis lupus* (Guthrie 1968a); *Canis latrans* (Guthrie 1968a); *Vulpes vulpes* (Péwé 1975; Cinq-Mars 1979; Dixon 1984), and *Vulpes lagopus* (Harington 1978; Cinq-Mars 1979; Morlan 1980a).

Frick's (1930) and Péwé's (1975) records of *Canis dirus* were listed as doubtful by Harington (1978). I have not found a Beringian specimen of that species in any collection.

Guthrie (1968a) listed the Coyote, *Canis latrans*, from Cripple Creek, near Fairbanks, Alaska, but did not record to which specimen in the Frick collection he was referring. This was the only record of that species reported from the Pleistocene of Beringia at that time. I am unable to locate a specimen of *Canis latrans* in the Frick Collection. It is probable that Guthrie's record (repeated in Harington 1978, and Kurtén and Anderson 1980) of *Canis latrans* was based on a misidentification of a specimen of *Cuon* sp. (F:AM 67180) from Cripple Creek Sump. Harington (1989) recorded *Canis latrans* from Old Crow River Loc. 11A, without reference to a specimen. I examined all canid specimens from that locality but failed to locate a specimen that can be positively identified as a Coyote. Coyotes are among the most numerous carnivores in Pleistocene localities south of Beringia, having been found in more than 100 sites (Anderson 1984). If Coyotes were part of the Pleistocene fauna of Beringia, I would expect fossils to be found in greater numbers, and at more localities. Among the unidentified canids from the Yukon, a humerus (NMC 42417) from Hunker Creek, Dawson area locality 12, is the only specimen from the Beringian region that probably belongs to that species. Radiocarbon dating of this specimen may indicate whether Coyotes were part of the Pleistocene fauna, or were postglacial immigrants as suspected by Youngman (1975).

A number of specimens of domestic dog-like canids have been reported from the Fairbanks area (Harington 1977; Olsen 1985). Ten skulls were radiocarbon dated (AMS), and none was older than 700 years (Guthrie 1990). A dentary of a domestic dog from Old Crow River Locality 11A, originally thought to be of Pleistocene age (Beebe 1980) has been radiocarbon dated (ASM) at 2110 ± 40 years ago (TO-276, W. N. Irving, personal communication 1986).

Cuon species — Dhole, Red Dog, Asiatic Wild Dog

SPECIMEN EXAMINED (1): Alaska: Cripple Creek Sump: 1 dentary (F:AM 67180).

An undated dentary (F:AM 67180) of a medium sized canid collected from Cripple Creek Sump, Alaska, by Otto Geist in 1949, was identified by M.C. McKenna as *Xenocyon* [= *Cuon*] (Péwé and Hopkins 1967). Irving and Harington (1973), and Harington (1977, 1978) also identified a partial dentary from Old Crow River, Loc. (=Locality see Appendix II) 14N, Yukon Territory (NMC 14353) as *Cuon* sp. Kurtén and Anderson (1980) referred both specimens to the extant Dhole (*Cuon alpinus*). Other North American records of *Cuon* sp. include seven specimens from San Josecito Cave, Nuevo León, Mexico, of Wisconsinan age (LACM 10984, 28081-86). *Canis texanus* from the early Irvingtonian of Rock Creek, Texas (Troxell 1915), described on the basis of a large dentary, was referred to *Cuon* sp. by Berta (1988) based on unspecified unpublished data. The talonid of m1 of this specimen is trenchant, in that respect resembling the genus *Cuon*, but this character has appeared independently in a number of canids (Van Valkenburgh 1991). The dentary is that of a bone-crusher, rather than a hypercarnivore; *Canis texanus* probably should not be referred to the genus *Cuon*.

The Cripple Creek Sump specimen is a partial right dentary (Figure 2) with p4–m2 and the alveoli of i1–p3 and m3. The m1 is fractured and incomplete. The entoconid is greatly reduced; the hypoconid is well developed; a small metaconid is present, and the talonid basin is relatively deep. A small metastylid is present as well as a small entoconulid. In occlusal view the outline of the talonid is less square than in specimens of wolf-like canids (*Canis lupus, Canis latrans* and domestic dog). The m2 is ovoid, double-rooted and the occlusal surface is relatively long (47% of the length of m1). The crown has a distinct trigonid-talonid. The metaconid is small and not widely separated from the protoconid. This tooth is more lupoid than those seen in any modern or fossil specimens of *Cuon* from Europe and Asia. The alveolus for m3 (with broken root) is relatively small.

The large size of the jaw, the presence of a double-rooted m2, and the presence of an m3 suggests that the Alaskan specimen may be more closely related to *Cuon dubius* from the Pleistocene of Europe and Asia, but the latter species has a much smaller and simpler m2. The specimens from San Josecito Cave are more robust than modern *Cuon alpinus,* have a single-rooted m2, lack an m3, and are smaller than the Beringian form. The Mexican specimens most closely resemble *Cuon priscus* of Europe. The description of new North American taxa should await the completion of studies relating North American specimens to those of Europe and Asia. Meanwhile it would be prudent to follow Adam (1959) who recognized all but *Cuon dubius* as subspecies of *Cuon alpinus*.

FIGURE 2. Right dentary of cf. *Cuon* sp. from Cripple Creek Sump, Alaska (F:AM 67180). The specimen measures 133.9 mm in length.

The specimen from Old Crow River, Locality 14N (NMC 14353), consists only of the anterior portion of a right horizontal ramus with p4 and alveoli for p2, p3, and the anterior root of m1. Harington referred this specimen to *Cuon* because the p4 did not differ from those of two modern specimens of that genus from China (except for size); "the nearly straight, rather crowded tooth row …is characteristic…of the dhole…" [as is] "…the pronounced concavity of the inferior profile of the jaw below p3…" (Harington 1977).

In comparing the dentary and p4 of NMC 14353 with the same portion of specimens of modern and Pleistocene *Cuon* from Europe and Asia, modern and Pleistocene wolves and domestic dogs, I do not believe that it is possible to distinguish among them. No diagnostic characters of the genus *Cuon* are present in the single p4 and fragment of horizontal ramus. The p4 of NMC 14353 is similar in size and morphology to that in a left dentary (c1–m1) of a small wolf from Old Crow River, Loc. 74 (NMC 32630). The distance between the anterior margin of the alveolus of p4 and the posterior margin of the mandibular symphysis of NMC 14353 is very short compared with that of other canids, indicating a comparatively short dentary and hence a crowded toothrow. The crowded nature of the toothrow is shown by the positions of the alveoli of p2 which are set obliquely in the jaw, thus the toothrow is not straight. To my knowledge, toothrows which are crowded to the extent that teeth are obliquely rooted in the dentary are not characteristic of any wild canid species. Domestic dogs often show a tendency towards this condition (Lawrence 1966). The decrease in depth of the dentary, of NMC 14353 below p3, considered diagnostic of *Cuon* by Harington (1977), is often present in other canids including wolves, Coyotes, foxes, and domestic dogs. This is the area of least depth in the horizontal ramus between the relatively deep symphysis and the much deeper posterior portion of the ramus. Therefore NMC 14353 is best referred to *Canis lupus*.

Presumably Dholes became extinct in North America at the end of the Pleistocene. The historic range of *Cuon alpinus* included the Tian-Shan and

Altai mountains and the Ussuri region of Russia, south through Mongolia, Korea, Nepal, India, Malaysia, Thailand, Java, and perhaps other parts of eastern Asia (Cohen 1978).

Modern Dholes (*C. alpinus*) are primarily predators of large mammals. Like wolves, Dholes are social animals that live in packs. Adult males weigh 15 to 20 kg, and adult females, 10 to 13 kg (Cohen 1978). The Cripple Creek Sump specimen was considerably larger than modern *C. alpinus* (Table 1).

Vulpes lagopus — Arctic Fox

SPECIMENS EXAMINED (207): Yukon Territory: Old Crow River localities: Loc. 10: 1 tibia (NMC 29299). Loc. 11: 1 tooth (NMC 45750), 3 radii (NMC 45728, 45738-39). Loc. 11A: 9 teeth (NMC 24410, 24735, 24747, 25014, 45737, 45743, 45744, 45746-47), 6 dentaries (NMC 18247, 45722, 45726, 45731, 45735-36), 2 tibiae (NMC 24912, 45725), 3 humeri (NMC 45729, 45733-34), 4 radii (NMC 45727, 45732, 45745, 45755), 7 metatarsals (NMC 24709, 24711, 24829, 24834, 24972, 45730, 45742), 1 metacarpal (NMC 45748), 1 calcaneum (NMC 18237), 2 astragali (NMC 24384, 24879). Loc. 12: 4 teeth (NMC 45740-41, 45749, 45751). Loc. 14N: 2 teeth (NMC 14798, 29404), 1 dentary (NMC 14328). Loc. 15: 1 ischium (CMC 43-13). Loc. 20: 3 teeth (NMC 19346, 28788, 31481), 1 metatarsal (NMC 18880). Loc. 22: 1 tooth (NMC 31473), 3 dentaries (NMC 14352, 24625, 26974), 1 phalanx (NMC 19212). Loc. 27: 1 tooth (NMC 28734), 2 dentaries (NMC 18627, 28668), Loc. 27W: 5 teeth (NMC 22103, 22178, 22301, 25295, 25481), 2 dentaries (NMC 22043, 31422), 2 tibiae (NMC 22410, 22415), 1 metacarpal (NMC 22312). Loc. 28: 1 maxilla (NMC 15723), 1 dentary (NMC 15579), 1 tibia (NMC 15571). Loc. 29: 2 teeth (NMC 18223, 18327), 5 dentaries (NMC 18218, 18329-31, 18510). Loc. 42: 1 dentary (NMC 32763). Loc. 44: 2 teeth (NMC 19252, 25492), 1 astragalus (NMC 15913), 1 calcaneum (NMC 15909). Loc. 65: 2 dentaries (NMC 28623, 32721), 1 ulna (NMC 20012), 1 vertebra (NMC 20010), 2 astragali (NMC 20045, 28630). Loc. 66: 1 dentary (NMC 45724). Loc. 74: 1 dentary (NMC 20858). Loc. 150: 1 dentary (NMC 32798). Loc. 155: 2 teeth (NMC 31215, 31263). Loc 300: 1 dentary (NMC 45723). Sixtymile, Loc. 5: 1 femur (NMC 47711). Dawson Area. Hunker Creek, Loc. 10: 1 dentary (NMC 29044), 1 tibia (NMC 29299). Bluefish Caves: Cave 1: 11 teeth (CMC D8-21-11, D8-24-2, D8-26-1, E7-14-5, E7-13-33, I7-G-51, I7-1-170, I9-(N)-6-2, J6-C-17, J7-4-18, T3-18-109), 2 maxillae (CMC F7-C-39, I7-1-144), 2 dentaries (CMC D8-22-1, I7-2-12), 1 ulna (CMC T1-18-4), 1 radius (CMC E7-14-35), 2 femora (CMC T1-16-5, T2-25-17), 1 tibia (CMC T3-17-72), 1 metacarpal (CMC T3-19-89), 1 caudal vertebra (CMC T2-22-101). Cave 2: 14 teeth (CMC B3-3-6, B4(N)-10-4, G4-G-57, H5-2-14, H5-3-14 (6 teeth), H5-4-3, H6-

TABLE 1. Measurements of dentaries and lower teeth of extinct *Cuon* sp., from Alaska, and modern *Cuon alpinus* from Asia.

Catalogue Number and Sex	Depth of Ramus p3-p4	m1-m2	Premolar Length p4	Length of Molar m1	m2
Fossil Specimens					
Cripple Creek, Alaska					
F:AM 67180	25.6	30.5	14.2	24.7	11.5
Recent Specimens of *Cuon alpinus*					
India					
AMNH 54544 female	18.0	21.5	11.4	20.0	7.7
AMNH 54984 female	20.4	23.8	12.8	19.9	6.5
Thailand					
AMNH 60775 ?	19.9	21.5	13.1	20.2	6.9
China					
AMNH 43144 male	20.0	21.9	12.1	20.5	5.3
Java					
AMNH 101882 male	18.3	21.7	11.8	20.5	7.6
AMNH 101773 female	17.0	19.5	10.5	20.1	6.7
AMNH 102083 female	18.0	21.1	10.1	19.5	6.4

7-18, I5-(E)-8, I5-(E)-3-10), 1 premaxilla (CMC B3-4-20), 3 maxillae (CMC B3-4-2, B4(N)-15-45, C3(E)-3-5), 6 dentaries (CMC B4(N)-15-16, C4(E)-12-5, C4(S)-12-15, C5(S)-6-10, H6-1-4, H6-7-17), 2 humeri (CMC E6-4-3, J-71-28), 1 ulna (CMC C4(N)-10-4), 3 tibiae (CMC E6-G-36, E6-5-31, H4-11-6), 2 metacarpals (CMC D4EW(W)-6-9, I5(E)-4-10), 3 metatarsals (CMC F4-3-4, I6-E-49, J7(E)-5-9). Cave 3: 9 teeth (CMC A-11-16, M-8-15, M-11-33, M-12-5, N-3-8, N-4-8, T1-D8, 85 misc.-82, 85-misc.-118), 2 maxillae (CMC M-9-17, M-11-35), 7 dentaries (CMC C-9-W, M-10-12, M-12-27, N-4-7, N-10-1, 85 misc.-98), 1 humerus (CMC C-8-11), 1 ulna (CMC T1-F-15); 5 metacarpals (CMC A-10-10, C-7-11, C-8-13, T1-E-43, T1-E-83), 2 femora (CMC S-3-20, T1-E-23), 3 metatarsals (CMC C-8-13, C-10-22, T1-1-2), 2 calcanea (CMC A-10-10, C-11-30). Alaska: Cripple Creek: 3 dentaries (F:AM 67266, 67269, 67271). Engineer Creek: 2 dentaries F:AM 67267, 70927). Ester Creek: 1 skull and mandible (F:AM 67257), 1 dentary (F:AM 67275). Fairbanks Creek: 1 dentary (F:AM 67270). Fox: 1 dentary (F:AM 67273). Gold Hill 1: 1 dentary (F:AM 70928). Upper Goldstream: 1 dentary (F:AM 30486). No. 2 Goldstrip area: 1 dentary (F:AM 67274). Porcupine River Cave 1: 1 tibia (UA 78-500-635). Teshekpuk Lake: 1 dentary, 1 maxilla, 1 tibia (USNM F9AGO22). Tofty: 1 dentary (F:AM 67268).

Previous eastern Beringian records of the Arctic Fox include specimens from a number of Old Crow River localities, two specimens from the Dawson area, Yukon Territory (Harington 1978), and a specimen from Teshepuk Lake, Alaska (Repenning 1983). None of the specimens collected thus far have been dated, but the Teshepuk Lake fauna is now thought to be about 15 000 years old (C. Repenning, personal communication 1989) which is much younger than previously estimated (Repenning 1983). My measurements (Tables 2 and 3) of a large sample of cranial and postcranial material confirm that measurements of fossil specimens fall within the range of measurements of modern western Arctic specimens as indicated by Harington (1977).

The Arctic Fox has a circumpolar distribution in Europe, Asia, and North America (including Greenland) as well as Iceland, Spitsbergen, and other islands in the Bering Sea, North Atlantic and Arctic oceans. Arctic Foxes weigh from 2.5 to 5.0 kg. Males are larger than females (Garrott and Eberhardt 1987). Arctic Foxes are predators of lemmings, Arctic Hares (*Lepus arcticus*) and ground-nesting birds.

Vulpes vulpes — Red Fox

SPECIMENS EXAMINED (150): Yukon Territory: Old Crow River localities: Loc. 11A: 3 dentaries (NMC 45720-21, 45752), 1 radius (NMC 45727), 1 vertebra (NMC 45719), 1 femur (NMC 45718). Loc. 27W: 1 humerus (NMC 22407). Loc. 37: 1 dentary (NMC 35320). Loc. 42: 1 humerus (NMC 44748). Loc. 65: 1 astragalus (NMC 20045). Loc. 115: 1 skull (NMC 28359). Bluefish Caves: Cave 1: 13 teeth (CMC D6-21-1, E6-11-1, E6-11-2, E7-16-4, E7-17-30, I6-C-6, I7-3-6, I9(N)-6-2, J7-12-31, J8-1-102, J8-1-203, K7-4-45, K7-5-30), 3 dentaries (CMC C4(S)-13-4, I9(N)-7-2, J7-2-12), 1 maxilla (CMC D8-16-6), 1 axis (CMC T3-16-34), 1 supraoccipital (CMC E7-12-31), 3 humeri (CMC D8-26-5, E7-12-24, Misc. 22), 2 ulnae (CMC misc. 22), 1 radius (CMC E7-15-8), 2 tibiae (CMC J8-2-13, L8(S)-9-6), 4 phalanges (CMC E7-15-36, J8-H-15, J9-5-6, T3-6-42), 1 calcaneum (CMC misc. 22). Cave 2: 27 teeth (CMC B3-3-6, B3-4-8, B4(N)-13-6, B4(N)-13-7, B4(N)-15-44 (2 teeth), B5(N)-9-9 (2 teeth), C3(E)-2-25, C3(E)-2-27, C3(E)-2-29, C3(E)-2-31, C3(E)-3-13, C3(E)-3-14, C3(N)-13-7, C4(S)-13-3, C5(S)-2-1, D4(S)-1-7, G4-G-54, H2-7-35, H5-2-11, H5-3-30, H5-3-32, H5-4-3, H6-G-45, I5(E)-2-4, 4-G-54), 5 maxillae (CMC B4(N)-11-7, H5-3-2, H5-3-29, H5-3-30, 4-1-F-4), 2 premaxillae, (CMC B4(N)-15-38, H5-3-17), 1 premaxilla and maxilla (CMC B4(N)-15-38), 8 dentaries (CMC B4(N)-15-26, B5(N)-9-8 (2 specimens), C3(E)-3-5, C3(E)-3-16, C4(N)-10-17, C4(S)-13-4, H6-5-38), 1 humerus (CMC E4(N)-2-6), 3 radii (CMC D4E4(W)-6-2, D4E4-6-7, H6-7-9), 1 innominate (CMC B4(N)-15-38), 1 femur (CMC E6-G-32), 1 calcaneum (CMC H6-misc. 12). Cave 3: 2 maxilla (CMC misc.-87-4, 85-misc.-96), 5 premaxillae-maxillae (CMC S-3-91, T1-E-37, T1-E-71, 85-9, 85-misc.-23, 3 humeri (CMC N-7-15, S-1-8, T1-D-23), 1 ulna (CMC T1-E-48), 2 femora (CMC T1-E-23, misc.-87-4), 1 metatarsal (CMC T1-F-88). Dawson area, Hunker Creek, Loc. 51: 1 dentary (NMC 43809). Alaska: Chicken Creek: 1 dentary (F:AM 2087). Upper Cleary, 30 feet below surface: 1 dentary (F:AM 30484). Cripple Creek: 1 skull (F:AM 67260), 2 maxillae (F:AM 67263, 67265), 5 dentaries (F:AM 67272, 67279, 67285, 67285a, 67285f), 1 femur (F:AM 68014). Dome Creek: 1 dentary (F:AM 70930). Engineer Creek: 1 maxilla (F:AM 67264), 1 dentary (F:AM 67285b). Ester Creek: 2 skulls (F:AM 67258-59), 1 maxilla (F:AM 67262), 6 dentaries (F:AM 67277, 67280, 67281, 67284, 67285d, 67285e), 1 humerus (F:AM 117086), 2 femora (F:AM 1038, 68014b). Fairbanks Creek: 1 skull (F:AM 67261a). Fish Creek: 1 tibia (F:AM 88014f). Fox: 1 skull (F:AM 67261), 1 dentary (F:AM 67282). Gilmore, 35 feet below surface: 1 dentary (F:AM 30486a). Gold Hill: 1 dentary (F:AM 70931). No. 2 Gold strip: 2 dentaries (F:AM 67278, 67285c). No. 26 strip: 1 tibia (F:AM 68014d). Upper 1 G, gravel 50 feet below surface: 1 dentary (F:AM 30485). Porcupine River Cave 1: 1 dentary (UA 78-500-39). Rosie Creek: 1 dentary (F:AM 67283). Tofty: 1 dentary (F:AM 67276), 1 ulna (F:AM

TABLE 2. Measurements of dentaries and lower teeth of fossil Arctic Foxes (*Vulpes lagopus*) from northern Yukon Territory compared with those of Recent specimens (n, $\overline{X}$ ± SD, and range) from the western Arctic.

Catalogue Number or Locality	Depth of Ramus p3-p4	m1-m2	Premolar Length p4	Length of Molar m1	m2
			Fossil Specimens		
Cave 1	—	—	—	—	6.5
	—	—	—	13.2	—
	—	—	—	—	5.6
Cave II	—	—	9.2	—	—
	10.2	12.3	—	12.9	5.5
	11.4	—	—	14.4	6.0
	10.3	—	8.4	—	—
	11.1	13.7	—	14.6	—
	—	—	—	12.9	—
O.C.R. 11A	10.2	12.3	—	12.9	5.5
	—	12.7	—	—	—
	11.2	11.2	—	12.2	—
	11.3	—	—	13.8	—
O.C.R. 29	11.1	13.7	—	13.1	—
	10.7	—	—	13.2	—
	—	12.5	—	13.6	—
	10.0	12.3	—	13.0	6.2
O.C.R. 22	—	12.2	—	13.1	—
	10.8	—	—	—	—
O.C.R. 65	11.1	—	—	—	—
O.C.R. 27	—	13.3	—	—	—
O.C.R. 74	10.1	12.3	—	13.2	—
Cripple Creek					
F:AM 67266	10.9	12.3	8.9	13.5	—
F:AM 67269	10.4	—	—	—	—
F:AM 67271	10.6	—	—	14.4	—
Tofty					
F:AM 67268	10.9	—	—	—	—
Fairbanks					
F:AM 67270	11.6	—	—	15.1	—
Ester Creek					
F:AM 67275	10.8	12.4	—	—	—
No. 2 Gold Strip Area					
F:AM 67274	10.7	13.4	—	—	—
Near Fox					
F:AM 67273	12.1	—	9.3	14.5	—
Upper-1 G					
F:AM 30486	—	—	8.9	14.4	—
Engineer Ck.					
F:AM 67267	11.2	—	—	13.8	—
F:AM 70927	11.1	—	—	14.2	—
Teshepuk Lake					
USNM uncat.	10.8	14.5	9.2	14.7	7.0
			Recent Specimens		
females (n=9)	11.69±0.66 10.7–12.7	13.39±0.88 12.3–14.9	9.10±0.57 8.3–10.2	13.89±0.80 12.9–15.6	5.89±0.38 5.4–6.5
males (n=8)	11.79±0.83 10.4–13.0	13.86±0.36 13.4–14.3	9.24±0.54 8.5–9.9	14.10±0.43 13.5–14.5	6.24±0.27 5.9–6.7

68014), 1 tibia (F:AM 68014e). Unrecorded locality: 2 dentaries (F:AM 30483, 70929e), 1 humerus (F:AM 117086).

The Holarctic Red Fox has previously been reported from Old Crow River, Locality 115 (Harington 1977; Kurtén and Anderson 1980), Porcupine River Cave 1 (Dixon 1984) and near Fairbanks (Péwé 1975). None of the specimens have

TABLE 3. Cranial Measurements of fossil Arctic Foxes (*Vulpes lagopus*) compared with those of Recent specimens ($\overline{X}$ ± SD, and range) from the western Arctic.

Catalogue Number, or Sex and/or Locality	Condylobasal length	Postorbital breadth	Length of P3	Length of P4	Breadth of M1
			Fossil Specimens		
Ester Creek					
F:AM 67257	113.0	29.0	8.7	11.0	11.3
Cave II	—	—	—	12.4	—
Cave II	—	—	—	11.9	—
O.C.R. 28	—	—	—	10.4	—
			Recent Specimens		
Females (n=9)	118.34±4.4	32.51±1.05	8.52±1.05	12.26±0.49	11.49±0.70
	110.3 - 124.6	30.4 - 33.8	13.0 - 11.7	11.7 - 13.0	10.8 - 13.1
Males (n=8)	123.89±2.75	32.75±1.80	8.46±0.52	12.46±0.47	11.69±0.41
	119.6 - 126.7	29.5 - 34.8	8.3 - 9.5	11.8 - 13.1	11.2 - 12.3

been dated, and the possibility that some specimens may be Holocene cannot be discounted.

Condylobasal lengths of specimens: 150.1 (OCR Loc. 115), 139.2 (F:AM 67260, Cripple Creek), 142.9 (F:AM 67259, Ester Creek), 133.3 (F:AM 67261A, Ester Creek) do not differ significantly from means of 150.26 (n = 10) and 111.47 (n = 4) for modern males and females, respectively, from Yukon Territory.

The earliest records for North America appear to be from Conard Fissure which is thought to be of Kansan age (Graham 1972).

The Red Fox occurs in North Africa, Europe, Asia, and most of North America, excluding Greenland. It lives in a variety of habitats ranging from from tundra (Jones and Theberge 1982; Macpherson 1964) to boreal forests, steppe (Ognev 1962), and temperate deserts (Voight 1987). Red Foxes prey on a variety of small mammals, and also scavenge on carrion.

Modern North American Red Foxes measure 100 to 110 cm and weigh between 3.5 and 7 kg. Males average 1 kg more than females (Voight 1987).

Family FELIDAE

In addition to *Felis lynx*, reported upon here, four large felids have been reported from Beringia: *Smilodon fatalis* (Guthrie 1968a; Harington 1978; Churcher, personal communication 1993) *Homotherium serum*, and *Panthera leo* (Kurtén and Anderson 1980). Harington (1977) identified a 4th premolar as belonging to *Felis concolor*, or some other large felid.

The distal end of an undated humerus from Cripple Creek, Alaska (F:AM 69214) belongs to *Felis concolor* as does a phalanx (CMC TP 1-F-63), the latter radiocarbon (AMS) dated at 18 970 ± 1490 years ago, (TO-1266) from Bluefish Cave 3.

Felis lynx — Lynx

SPECIMENS EXAMINED (6): Yukon Territory: Old Crow River localities: Loc. 11A: 1 maxilla (NMC 24966), 1 phalanx (NMC 45991). Loc. 29: 1 dentary (NMC 20322). Loc. 20: 1 phalanx (NMC 19359). Alaska: Dome Creek: 1 partial skull (F:AM 69213). Engineer Creek, Dawson Cut: 1 mummified carcass (F:AM 99925).

It has been suggested that in the last 200 000 years lynxes from Asia spread eastward into North America (Werdelin 1981). Kurtén and Rausch (1959) regarded the Nearctic and Palearctic lynxes as conspecific as did Ewer (1973), Corbet and Hill (1986) and Tumilson (1987). The differences between the two were considered to be only in size, the Palearctic form being the larger of the two. Other authors (Kurtén and Anderson 1980; Kurtén 1968; Werdelin 1981; Werdelin 1985) regarded the two forms as separate species.

Kurtén and Anderson (1980) noted that "differences in size, osteology, and external characters, as well as the absence of transitional forms in the Beringian area, indicate that the species are distinct." Size differences, either in Pleistocene or modern species are poor indicators of lack of specific distinctness. Putative differences in osteology and external characters are difficult to evaluate since the extent of these differences was not specified. The absence of transitional forms in Beringia, in my estimation, is not a significant factor, and measurements of an undated left P4 (NMC 24966), of possible "pre-late" Wisconsinan age (Harington 1977) from Old Crow River Locality 11A, fall within the range of measurements of modern specimens from the Old World. As noted by Kurtén and Rausch (1959) a bivariate plot of paracone length against length of upper carnassial effectively separates modern European and North American lynxes. A plot of these variables of the fossil specimen with lynxes from the Old World (n=27) and specimens from the Yukon Territory (n=31) places the Beringian specimen well inside the Old World cluster (Figure 3). Phalanges from Old Crow River Locs. 11A and 20 are more robust than those of a limited sample of modern Nearctic lynxes seen by me. It appears then that a transitional form existed in the Pleistocene of Beringia, and that the question of conspecificity of lynx on the two sides of the Bering Straits remains open.

Werdelin (1981) suggested that the differences in prey-size available to Palearctic and Nearctic lynxes accounts for the size difference in the two forms. The former preyed on Roe deer (*Capreolus capreolus*) while the latter was restricted to smaller prey such as the Snowshoe Hare (*Lepus americanus*). Norberg (1987) attributed the size differences between European and North American lynxes (also the difference in size between the owls, *Bubo bubo* and *Bubo virginianus*) to the differences in size between the large species of hares in Europe (*Lepus timidus*, and *Lepus europeaus*) and the smaller North American species (*Lepus americanus*).

Lynxes are Holarctic in distribution, occurring primarily in the boreal forest. Lynxes prey on a variety of mammals, including shrews, voles, lemmings, Snowshoe Hares, to young Caribou (*Rangifer tarandus*), as well as birds of a variety of sizes. The weight of males and females from Alaska average respectively 9.9 ± 1.4 kg and 8.8 ± 1.0 kg (Nava 1970). The average for males in Sweden is 17.9 kg (Haglund 1966).

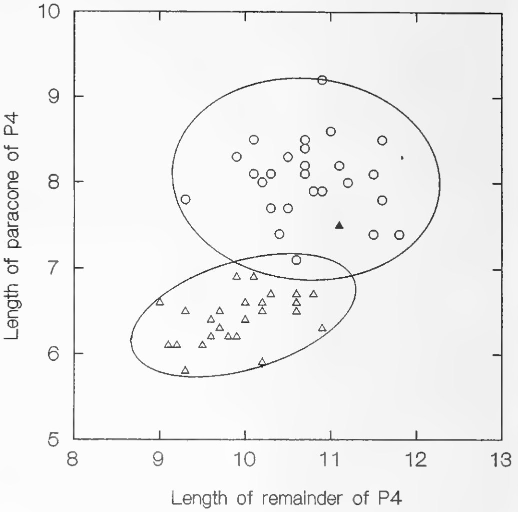

FIGURE 3. Bivariate plot of measurements of 4th upper premolar of a fossil lynx (NMC 24966), from Old Crow, Locality 11A, Yukon Territory, compared with those of modern specimens from Europe and North America. Circles = European; open triangles = North American; closed triangle = fossil.

Family MUSTELIDAE

Anderson (1977: 19) wrote:"During the late Pleistocene at least five species of mustelids inhabited an ice-free refugium in interior Alaska." Twelve terrestrial and one aquatic marine species are now known from the Pleistocene of Beringia. The recent unexpected discoveries of *Brachyprotoma obtusata* (Youngman 1986), and an, as yet, unidentified mephitine from Beringia indicate more collecting in the region would be worthwhile.

Brachyprotoma obtusata — Short-faced Skunk

SPECIMENS EXAMINED (2): Yukon Territory: Old Crow River. Loc. 44: 1 dentary (NMC 25529). Bluefish Cave 1: ?1 tooth (CMC D8-4-10).

Previously only known from six Pleistocene localities in the eastern United States, the first records of this extinct genus for Beringia, and Canada were reported by Youngman (1986).

The only mephitines living in Canada today are the large *Mephitis mephitis*, which occurrs naturally in all Provinces except Prince Edward Island and Newfoundland, and the considerably smaller *Spilogale gracilis* which has a limited distribution in southwestern British Columbia. The skull of *Brachyprotoma obtusata* can be distinguished from those of the latter species by the presence of two upper premolars, rather than three, smaller auditory bullae, smaller infraorbital foramina, shorter mandible, relatively large p4, curved tooth row, crowded lower premolars, and deep mandibular symphysis.

The age of the dentary from Old Crow River Locality 44 is not readily determinable. Harington (1978) presumed the sediments, from which the specimen was recovered, to be of Sangamonian age since previously dated fossils gave a range of from >39 000 to >54 000 years ago, but there is evidence that some of the taxa from that stratigraphic level may be Early to Middle Pleistocene (Schweger 1989b). Morlan (1984b) indicated that *Dicrostonyx* molars from Locality 44 include a wide range of morphotypes, probably indicating an assemblage of mixed age.

The dentary is heavy and deep, and the carnassial is longer and more robust than any other known specimen (Youngman 1986). The size of this dentary indicates that at least some individuals of *Brachyprotoma* from Beringia were larger than their congeners in the southern periglacial region.

Hall (1936) and Kurtén and Anderson (1980) thought that the stout dentition of *Brachyprotoma obtusata* might indicate a diet of hard-shelled insects, but Youngman (1986) theorized that the specialization might have been for carnivory or scavenging. The synchronous extinctions of isolated populations of *Brachyprotoma* in the southern periglacial region and Beringia suggest the effects of climatic change rather than human influence.

Mephitine, Undetermined Species — Extinct Skunk

SPECIMENS EXAMINED (1): Yukon Territory: Old Crow River Loc. 11A: 1 humerus (NMC 48023).

The occurrence of a second mephitine in Beringia is indicated by a left humerus (NMC 48023) that does not appear to be attributable to any known taxon, living or extinct. Measurements of this specimen are: Total Length: 50.6, Breadth Proximal: 12.1, Least Shaft Breadth: 5.0, and Breadth Distal: 14.5. This undated bone (Figure 4) is much larger than the only known humerus of *Brachyprotoma obtusata* (Carnegie Museum, uncatalogued: TL 32.8, BP 8.3, BD 10.3, LSB 3.0), and does not resemble the humerus of that species. NMC 48023 is within the size range of *Mephitis mephitis* but differs from that species in that the deltoid tuberosity is less than half the total length, rather than longer than half the total length. Also in *Mephitis* the tuberosity for the teres minor is larger. The apex of this bone in *Mephitis mephitis* occupies a position approximately one quarter of the total length of the shaft distally from the head of the humerus, and the tuberosity is plainly visible in cranial view. In NMC 48023 that tuberosity is very small (the apex is less than one fifth of the total length of the bone distally from the head of the humerus). The tuberosity is not plainly visible in cranial view, and does not impinge on the outline of the deltoid tuberosity. Other differences can be seen in the curvature of the tricipital line, and in the proportions of the greater and lesser tubercles. A comparison of size and morphology also rules out the genus *Conepatus*. The only Pleistocene mephitine from North America for which there are no known humeri is the taxon *Osmotherium spelaeum*, all specimens of which were collected from Port Kennedy Cave, Pennsylvania, and which may be conspecific with *Mephitis mephitis*. NMC 48023 either represents *O. spelaeum*, or an undescribed mephitine.

FIGURE 4. Anterior view (upper) and posterior view (lower) of fossil humerus of undescribed skunk (NMC 48023) from Old Crow, locality 11A, Yukon Territory. The total length of the bone is 50.6 mm.

Enhydra sp. — Sea Otter

SPECIMEN (1): Alaska: Gubik Formation, Skull Cliff, 19.2 km S Arctic Research Laboratory, Barrow. Left braincase with frontals (California Academy of Science 34558) not seen by me.

The age of the only specimen from Beringia is unknown (Repenning, personal communication 1985). It appears more primitive than *Enhydra lutris* according to Repenning (personal communication 1985). Other Pleistocene specimens of the genus *Enhydra* are known from Cape Blanco, Oregon, Moonstone Beach, near Eureka, California, and from the Timms Point silt Member of the San Pedro Formation, San Pedro, California (Repenning 1976). The age of the latter specimen has been estimated at 2.0 ± 1 X 10^6 years ago (Repenning 1976).

The historical range of the North Pacific Sea Otter (*Enhydra lutris*) is along the Baja California coast, Mexico, north to Alaska and westward to Kamchatka, and south to northern Japan (Wilson et al. 1991). Sea Otters usually occur in coastal waters less than 35 m deep, but have been found in waters up to 97 m deep. Sea Otters are the largest living mustelids. Adult females usually weigh from 18 to 25 kg and adult males from 27 to 39 kg (Garshelis 1987). Sea Otters primarily feed on invertebrates including molluscs, crabs, and sea stars (Calkins 1978).

Gulo gulo — Wolverine

SPECIMENS EXAMINED (75): Yukon Territory: Old Crow River localities: Loc. 11: 1 ulna (NMC 47767). Loc. 11A: 5 teeth (NMC 13603, 23056, 24363, 24580, 47753), 25 dentaries (NMC 13578, 13584, 13587, 18255, 18259, 24706, 24903, 28777, 45757, 47754-62, 47765, 47768-69, 48430, 48626, 48642, 48647, 49996), 1 humerus (NMC 47764), 1 innominate (NMC 47763), 1 tibia (NMC 47766). Loc. 12: 1 dentary (NMC 48650), 1 tooth (NMC 48700). Loc. 14N: 2 teeth (NMC 47771, 48700), 2 dentaries (NMC 21063, 47771), 1 ulna (NMC 16803), 1 femur (NMC 16711), 1 metatarsal. Loc. 20: 3 teeth (NMC 18867, 26766, 26778), 1 dentary (NMC 20746), 1 maxilla (NMC 20747). Loc. 22: 1 skull (NMC 14582), 1 tooth (NMC 24639), 3 dentaries (NMC 24236, 24661, 36143), 1 astragalus (NMC 24063). Loc. 22E: 1 dentary (NMC 24717). Loc. 27: 1 maxilla (NMC 28708). Loc. 29: 2 teeth (NMC 18324, 20321), 5 dentaries (NMC 18332-34, 20320, 31749). Loc. 44: 1 tooth (NMC 15905), 1 dentary (NMC 20742). Loc. 45: 1 tibia (NMC 31698). Loc. 63: 1 humerus (NMC 19285). Loc. 65: 1 maxilla (NMC 16321), 2 teeth (NMC 19279, 28609), 2 dentaries (NMC 20008, 33471), 1 tibia (NMC 19479). Loc. 66: 3 dentaries (NMC 24214, 48635, 48648). Loc. 77: 1 dentary (NMC 28849).

Loc. 81: 1 dentary (NMC 25078). Loc 83: 1 tooth (NMC 24641), 1 femur (NMC 27800). Loc. 125: 1 humerus (NMC 27793). Sixty mile, Loc. 3: 2 dentaries (NMC 42492, 46447). Dawson area, Hunker Creek, Loc. 37: 1 skull (NMC 36419). Alaska: Cripple Creek: 1 skull (F:AM 30799), 3 dentaries (F:AM 30808-09, 30811). Engineer Creek: 1 dentary (F:AM 30810). Ester Creek: 1 skull (F:AM 30796), 1 premaxilla-maxilla (F:AM 30800), 1 humerus (F:AM 117088), 1 radius (F:AM 117887). Old Eva Creek: 1 skull and mandible (F:AM 30798). Fairbanks Creek: 1 dentary (F:AM 30805), 1 ulna (F:AM 117093), 1 femur (F:AM 117092). Gold Hill: 1 maxilla and dentary (F:AM 68003), 1 dentary (F:AM 68005). Goldstream: 1 skull (F:AM 30795). No. 2 Goldstream stripping area: 1 dentary (F:AM 30806). 21 Goldstream, top of gravel 40 feet below original surface: 2 dentaries (F:AM 30797, 30807). Lost Chicken Creek: 1 skull (USNM 262627).

The only radiocarbon age for this species from Beringia is on a specimen from Sixtymile, Yukon Territory, AMS dated at 41 420±1100 years ago (TO-2701) (C.R. Harington, personal communication).

The earliest North American record of *Gulo*, from Cumberland Cave, Maryland, was referred to *Gulo schlosseri* by Kurtén and Anderson (1980), a form said to differ from the Recent species by its smaller size and slight differences in the dentition. Bryant (1987) questioned the assignment of mid-Pleistocene *Gulo* to a separate chronospecies because of known fluctuations in size and morphology in the species during the Quaternary. These fluctuations have been adequately documented for North America and Eurasia (Bryant 1987; Harington 1977; Kurtén 1973; Sotnikova 1982).

Harington (1977) and Bryant (1987) found that lower teeth of Wolverines of possible Sangamonian to Wisconsinanan age from the Old Crow Basin were smaller than modern Yukon specimens. Wolverine specimens from the Late Pleistocene of the Fairbanks region are especially large (Anderson 1977). This trend was also reported by Kurtén who found that the mean dimensions of Late Pleistocene *Gulo* of Europe greatly exceeded those of Recent populations (Kurtén 1973). Bryant (1987: 654) summed up the size fluctuations in *Gulo* by saying, "Old Crow wolverines conform to the general trend of increasing size and broadening of certain teeth especially P4, from the mid-Pleistocene appearance of *Gulo* in Europe and North America to the end of the Wisconsinan".

Wolverines have a circumboreal distribution. They eat a great variety of food, mammals, birds, carrion, fishes, fruits, and berries. Adult males weigh from 14 to 27.5 kg, and adult females from 7 to 14 kg (Hash 1987).

Lutra canadensis — River Otter

SPECIMENS EXAMINED (2): Yukon Territory: Old Crow River localities: Loc. 11A: 1 femur (NMC 45708). Loc. 29: 1 dentary (NMC 20329).

The River Otter has been reported from Pleistocene localities in Arkansas, Florida, Georgia, Iowa, Missouri, Pennsylvania, Tennessee, and Virginia (Kurtén and Anderson 1980; Anderson 1984). Harington (1977) reported the first Pleistocene specimen from Beringia. The measurements of that specimen (NMC 20329) fall within the range of modern individuals (Table 4). The largest River Otters occur on Prince of Wales and adjacent islands in southeastern Alaska, while there is a clinal decrease in size to the south (van Zyll de Jong 1972). The historic distribution of otters included much of North America except for the central High Arctic and parts of the southwest (Hall 1981).

Otters are primarily piscivores, but also feed on molluscs, crustaceans, insects, birds, amphibians, reptiles, and mammals (Toweill and Tabor 1982).

Martes americana — American Pine Marten

SPECIMENS EXAMINED (18): Yukon Territory: Old Crow River localities: Loc. 11A: 1 skull (NMC 45709), 1 dentary (NMC 24360), 1 humerus (NMC 24733). Loc. 14N: 1 tooth (NMC 45753). Loc. 27W: 1 tooth (NMC 22128), 1 dentary (NMC 22153), 1 calcaneum (NMC 22311). Loc. 28: 1 dentary (NMC 19098). Loc. 65: 1 dentary (NMC 32699), 1 humerus (NMC 28605). Bluefish caves: Cave 1: 1 tooth (CMC B6(N1/2)-L-5), 1 ilium (CMC T1-20-9). Cave 2: 2 teeth (CMC G4-G-49, GT-G-34). Cave 3: 3 teeth (CMC S-3-55, T1-D-8, 85 misc. 118). Eureka Creek, Dawson Loc. 65: 1 skull (NMC 47039).

Fossil specimens of *Martes americana* have been recorded, from Old Crow River Loc. 11A (Harington 1977), and I identified specimens from the Bluefish Caves (Harington 1989). Harington (1977) referred two dentaries (NMC 24360 and 19098) as well as a humerus (NMC 28605) to the supposedly extinct *Martes nobilis*, and Kurtén and Anderson (1980) referred unspecified specimens (undoubtedly NMC 24360 and 28605) from Old Crow locality 11A to that species. Harington (1977) referred the two dentaries to *M. nobilis* because measurements of m1 length and m1 trigonid length of these specimens fall within the range of *M. nobilis* in a bivariate graph which Anderson (1970) thought to be diagnostic. Actually both specimens fall within the range of measurements of modern *M. americana* from the Yukon. A humerus (NMC 28605) from OCR Loc. 65 measures 2.2 mm longer than the largest of six modern humeri from the Yukon Territory. Youngman and Schueler (1991) showed that specimens which have been referred to *Martes nobilis* are large Pleistocene chronomorphs of *M. americana* (*caurina* subspecies group), similar to specimens of *Martes foina* and *Martes martes* from Europe, which also showed gigantism during the Pleistocene (Anderson 1970). There has been con-

TABLE 4. Measurements of the dentary and lower teeth of a fossil River Otter (*Lutra canadensis*) from Yukon Territory compared with those of Recent specimens.

Catalogue Number and Sex	Depth of Ramus at m1-m2	Width of m1 Middle	Trigonid Length of m1
	Fossil Specimen		
NMC 20329	13.5	6.5	8.3
	Recent specimens		
	Yukon Territory		
NMC 31814 male	13.7	7.6	9.6
NMC 31744 male	12.7	7.6	9.0
NMC 1969 male	14.5	7.7	9.5
NMC 36292 female	12.8	7.3	9.0
	British Columbia		
NMC 29261 female	12.9	6.6	8.6
NMC 29265 female	12.6	6.9	8.9
NMC 29269 female	13.1	8.0	9.6

jecture that *Martes americana* might be conspecific with *M. martes*, *M. melampus*, and *M. zibellina* (Anderson 1970; Corbet 1978), however there is no supporting evidence.

Martens occur primarily in wooded areas from Alaska east across Canada, and into mountains of the western United States. Martens feed on small mammals, birds, insects, fruit, and carrion (Strickland et al. 1982). There have been few published records of weights and measurements of Martens from western North America. In Ontario, males measured 513 to 659 mm, total length, and females measured 465 to 572 mm. Males weighed 563 to 990 g, and females 400 to 605 g (Strickland et al. 1982).

Martes pennanti — Fisher

SPECIMENS EXAMINED (7): Yukon Territory: Old Crow River localities: Loc. 11: 1 humerus (NMC 46394). Loc. 11-1: 1 humerus (NMC 46393). Loc. 11A: 1 humerus (NMC 24368). Loc. 27W: 1 calcaneum (NMC 22322). Loc. 28: 1 calcaneum (NMC 15673). Loc. 42: 1 dentary (NMC 33249). Alaska: Fairbanks Creek: 1 humerus (F:AM 117091).

Youngman (1975), on the basis of modern distribution and ecology, suggested that the Fisher was a postglacial immigrant to Beringia; however, Pleistocene specimens of the Nearctic Fisher have since been reported from the Yukon Territory (Harington 1977; Jopling et al. 1981). This report records specimens from four new localities for the Yukon Territory, and the first specimen from Alaska.

Jopling et al. (1981) suggested that a specimen from the 10 M level from Unit 2 at Old Crow River Locality 11 (NMC 46394) and associated specimens, were of Sangamonian age, but R.E. Morlan (personal communication, 1992), suggests that specimens from this site may be much older than previously thought.

Measurements of the few fragmentary specimens from Beringia suggest that Pleistocene Fishers were larger than modern animals. The distal breadth of a humerus, from Old Crow River Locality 11 (NMC 46394), measures 28.1 mm. The largest of 12 modern male specimens from several localities in eastern and western North America measures 25.0 mm. The total length of the calcaneum, from Old Crow River Loc. 27W (NMC 25076), measures 30.2 mm. The largest of 11 modern calcanea from several localities is 28.4 mm.

Fishers presently occur across North America in coniferous and mixed forests in the Canadian and Transition zones proposed by Merriam (1898). Pleistocene fossils are known from localities as far south as Georgia, Alabama, and Arkansas (Kurtén and Anderson 1980). A nominal Pleistocene Fisher, *M. diluviana*, known only from Port Kennedy Cave, Cumberland Cave, Conard Fissure, and Strait Canyon Fissure, shows minor size differences from *M. pennanti* and in my estimation is probably a chronomorph of that species.

Fishers are the largest living members of the genus *Martes*. The body length of males averages 20% larger than that of females (Douglas and Strickland 1987). Adult males usually weigh between 3.5 and 5.5 kg and adult females between 2.0 and 2.5 kg (Powell 1981).

Fishers are opportunistic in their feeding habits. Prey includes shrews, voles, mice, Snowshoe Hares (*Lepus americanus*), squirrels, Porcupines (*Erethizon dorsatum*), birds, amphibians, reptiles, fish, insects, fruit, fungi, nuts, and carrion. In the Yukon Territory, Fishers are currently at their ecological limit and local extinctions have been reported (B. Slough, personal communication 1988).

Mustela erminea — Ermine

SPECIMENS EXAMINED (31): Yukon Territory: Old Crow River localities: Loc. 11A: 1 dentary (NMC 45717). Loc. 15: 1 dentary (CMC 59-8). Loc. 20: 1 dentary (NMC 28782). Loc. 27W: 1 dentary (NMC 25076), 1 ulna (NMC 25320). Bluefish Caves: Cave 1: 1 tooth (CMC T2-16-86), 1 premaxilla-maxilla (CMC Misc.-23), 2 dentaries (CMC G7/8-6-6, K7-4-1), 4 humeri (CMC D6-16-7, T2-15-41, T2-15-99, T2-16-69), 2 radii (CMC K6-2-32, T2-15-37), 1 innominate (CMC I7-G-69), 2 femora (CMC T3-7-40, T3-18-102), 4 tibiae (CMC T1-17-4, T2-15-20, T2-21-53, T3-14-46), 1 fibula (CMC T1-21-27), 1 axis (CMC T2-18-33), 2 vertebrae (CMC T2-19-67, T2-20-21), 1 phalanx (CMC T1-20-29). Cave 2: 1 femur (CMC B4-(S)-13-2). Cave 3: 1 dentary (CMC C-4-3). Alaska: Fairbanks area: 4 dentaries (F:AM 49340-41, 49348-49).

In North America the Holarctic Ermine has been found in many southern periglacial Wisconsinan sites but has previously been unequivocally recorded from only a few eastern Beringian sites such as Old Crow locality 27W, the first Pleistocene records for Canada (Harington 1977). Dixon (1984) reported specimens from Porcupine River Cave 1, Alaska, as either Mink or Ermine, however I have not been able to locate specimens of either species in his collection. The size of a small percentage of postcranial elements of a few fossil ermines from Eastern Beringia slightly exceed in size the same elements from modern specimens of the largest North American subspecies, *Mustela erminea arctica* from Alaska, Yukon Territory and the Northwest Territories; however, most specimens are within the size-range of modern populations (Table 5). Macpherson (1965), Youngman (1975), and Eger (1990) concluded that *Mustela erminea arctica* owes its distinctiveness to past isolation in the Beringian refugium. Eger (1990) found that skull size, in *M. erminea*, varies with environmental factors, whereas skull shape is more likely to reflect refugial origins. In Europe, robust specimens of *M. erminea* dating from the last Eemian interglacial have been found in the northern Carpathians and Alps (Kratochvíl 1977).

In North America, and Asia, body size in *Mustela erminea* increases with latitude (Hall 1951; Rosenzweig 1968; Ralls and Harvey 1985), whereas in Europe the situation is less clear. Reichstein (1957) describes a reversal of Bergmann's Rule, for *M. erminea*, in which specimens decrease in size with increasing latitude, and Kratochvíl (1977) indicates a size increase with decreasing longitude. In North America males range from 22 to 34 cm in total length, while females range from 19 to 29 cm. Males weigh between 70 to 206 g, and females weigh between 28 and 85 g (Fagerstone 1987).

Ermines are currently found thoroughout much of North America from the Canadian Arctic islands to about 35° N. Their diet includes small mammals, birds, amphibians, reptiles and insects. In Beringia,

TABLE 5. Measurements of the dentary and lower teeth of fossil *Mustela erminea* compared with those of Recent specimens ($\bar{X}$ ± SD, and range) from Alaska and the Yukon Territory.

Catalogue Number, Sex, and/or Locality	Depth of Ramus at		Premolar Length	Length of Molar
	Dp3-p4	Dm1-m2	p4	m1
			Fossils	
O.C.R. 20				
NMC 28782	4.1	4.5	2.6	5.1
Cave I	4.6	5.0	3.2	6.3
Cave I	—	—	2.6	5.4
O.C.R. 44	—	—	—	4.7
O.C.R. 27W	—	5.1	—	5.6
Loc. 11A	4.6	4.5	—	—
			Fairbanks area	
F:AM 49340	3.0	3.0	2.2	4.6
F:AM 49341	3.2	2.9	2.2	4.7
F:AM 49348	—	—	2.3	4.5
F:AM 49349	—	—	2.3	—
			Recent Specimens	
Males (n=20)	3.78 ± 0.43	4.4 ± 0.40	2.84 ± 0.17	5.57 ± 0.28
	3.0 - 4.5	3.5 - 5.2	2.5 - 3.2	5.1 - 6.1
USNM 290396 female	3.3	3.2	2.3	4.5
USNM 305063 female	3.8	5.0	3.2	4.0

Ermines probably preyed on shrews, Pikas (*Ochotona collaris*), young Arctic Hares, voles, lemmings, Arctic Ground Squirrels (*Spermophilus parryi*), birds and insects.

Mustela eversmanni — Steppe Ferret

SPECIMENS EXAMINED (14): Yukon Territory: Old Crow River: Loc. 83, 1 dentary (NMC 25079); Loc. 65, 1 dentary (NMC 16323). Bluefish Cave 2: 1 dentary (CMC C4(N)10-15). Bluefish Cave 3: 8 dentaries (CMC M-9-4, M-9-28, N-4-7, 85-18, 85-29, 85-139a, 85-139b, 85-misc. 97), 1 skull (CMC M-9-66). Alaska: Ester Creek: 1 skull (F:AM 49336). Cripple Creek: 2 dentaries (F:AM 49337, 30822).

In Eurasia the polecats or ferrets (subgenus *Putorius*) are represented by the Forest Polecat, *Mustela putorius*, and the Steppe Ferret, *M. eversmanni* (Youngman 1982). In North America the vicariant of *M. eversmanni*, the Black-footed Ferret, *M. nigripes*, may have immigrated from Asia to North America during the Illinoian glacial period. In historic times it occupied a portion of the Great Plains and intermontane basins. Because of morphological similarities it has been assumed, by most authors, that *M. eversmanni* and *M. nigripes* are sister taxa, and that both species migrated to North America via the Beringian Isthmus during the Pleistocene. Some authors have suggested on morphological grounds that the two forms may be conspecific (Hensel 1881; Kostron 1948; Rempe 1970), but morphometric and molecular studies suggest specific distinctness (Anderson 1977; O'Brien et al. 1989).

Anderson (1973) tentatively identified a partial skull and two dentaries of a large Pleistocene ferret from Alaska as *Mustela eversmanni* (Anderson 1973). She conjectured that this species had reached North America by way of the Bering Land Bridge. Subsequently she described the fossils as *Mustela eversmanni beringiae* (Anderson 1977).

Other specimens of large ferrets have been collected in Beringia since Anderson's initial discovery, including eight dentaries and a partial skull from the Bluefish Caves and one dentary from Old Crow River Loc. 83 (Tables 6 and 7). A dentary from Old Crow River, Loc. 65, referred by Kurtén and Anderson to *M. nigripes* is here referred to *M. eversmanni*. Recently two mummified carcasses of *M. nigripes* were found in the Dawson region of Yukon Territory. The radiocarbon date (AMS) of one of the large jaws of *M. eversmanni* (CMC 85-139a) from Bluefish Cave 3 of 33 550 ± 350 years ago (TO-1196) is encompassed by the dates of the two mummified specimens of *M. nigripes* from the more southern localities in the Yukon of 39560 ± 490 years ago (TO-214) and 30 370 ± 550 years ago (Beta-23347; ETH 3537). This suggests that *M. nigripes* and *M. eversmanni* may have occurred allopatrically in Beringia during the late Pleistocene.

The Steppe Ferret preys primarily on mammals such as ground squirrels, and other rodents (Novikov

TABLE 6. Measurements of crania of fossil ferrets from Beringia compared with those of Recent *Mustela nigripes* and *Mustela eversmanni* ($\overline{X}$ ± SD, and range) from Alaska and the Yukon Territory.

Catalogue Number or Locality	Rostral Breadth	Bimolar Breadth	Postorbital Breadth	Postorbital Constriction Breadth	Maxillary Tooth Row Length	Premolar Length P4
			Fossil Specimens			
FAM 49336	21.5	27.8	26.3*	14.9	22.1	8.5
Cave III	20.8	26.8	27.6	14.7	21.9	8.0
			Recent *M. eversmanni* males (n=5)			
	20.2±0.7	26.3±0.6	23.8±1.4	13.7±0.6	21.7±0.3	8.5±0.2
	19.5 - 21.2	25.6 - 26.9	22.0 - 25.9	12.9 - 14.5	21.3 - 22.0	8.3 - 8.7
			Recent *M. eversmanni*, females (n=8)			
	17.1±0.9	23.5±1.1	24.0±1.9	12.1±0.6	19.8±0.4	7.5±0.4
	15.5 - 18.2	22.0 - 25.0	21.7 - 26.8	11.2 - 12.9	18.8 - 21.0	7.1 - 8.1
			Recent *M. nigripes*, males (n=24)			
	17.7±0.7	24.6±0.7	21.6±1.2	12.7±1.8	20.2±1.2	7.5±0.2
	19.2 - 16.7	25.8 - 23.2	23.7 - 19.7	19.8 - 10.7	21.5 - 15.4	8.1 - 7.1
			Recent *M. nigripes*, females (n=14)			
	16.3±0.7	23.4±0.7	20.3±0.8	12.1±2.3	19.0±0.6	7.2±0.1
	14.9 - 17.2	22.0 - 24.2	18.8 - 21.5	10.3 - 4.0	18.0 - 20.2	7.0 - 7.4

*Maximum measurement of damaged specimen.

TABLE 7. Measurements of dentaries of fossil ferrets from Beringia compared with Recent specimens ($\overline{X}$ ± SD, and range) of *Mustela nigripes* from North America, and *Mustela eversmanni* from the Soviet Union.

Ramus Depth at		Width of Dentary	Length Posterior	Length
p3-p4	m1-m2	p4-m1	Margin C-m1	m1
Fossils from Cripple Creek, Bluefish caves, and O.C.R. Loc. 83, here assigned to *M. eversmanni* (n=14).				
10.2±0.8	9.4±0.6	5.0±0.4	20.1±0.8	9.1±0.4
9.1 - 11.9	8.4 - 10.0	4.4 - 5.9	18.7 - 20.9	8.5 - 9.8
Recent Specimens				
M. eversmanni, males (n=7)				
10.4±0.5	10.0±0.6	5.1±0.4	19.9±0.6	9.4±0.4
9.9 - 11.4	8.8 - 10.6	4.7 - 5.6	19.3 - 21.0	8.9 - 10.0
M. eversmanni, females (n=9)				
9.3±0.5	9.0±0.8	4.5±0.3	18.3±0.9	8.5±0.5
8.6 - 10.3	8.1 - 10.2	4.2 - 4.9	17.2 - 19.9	7.5 - 9.3
M. nigripes, males (n=21)				
8.7±0.4	8.8±0.5	4.2±0.2	18.8±0.6	8.6±0.3
7.9 - 9.4	7.9 - 9.9	3.8 - 4.6	17.8 - 20.7	8.1 - 9.1
M. nigripes, females (n=14)				
8.1±0.4	8.1±0.4	3.8±0.2	17.8±0.8	8.2±0.2
7.1 - 8.5	7.3 - 8.7	3.4 - 4.1	16.2 - 19.5	7.7 - 8.5

1956). The maximum weights of males and females from Siberia are 2050 g, and 1350 g, respectively (Stroganov 1969).

Mustela nigripes — Black-footed Ferret

SPECIMENS EXAMINED (2): Yukon Territory: Sixtymile, Loc. 3: 1 mummified carcass (NMC 43786). Dawson area, Hunker Creek, Loc. 12: 1 mummified carcass (NMC 44305).

The earliest record of a ferret in North America is of Irvingtonian age from Porcupine Cave in Colorado with the co-occurrence of *Pitymys meadensis, Microtus* cf. *paroperarius, Ondatra* cf. *annectens*, and *Synaptomys* cf. *meltoni* (Barnosky and Rasmussen 1987), and paleomagnetic dates of between 400 000 and 850 00 years ago (E. Anderson, personal communication 1989).

An electrophoretic study of isozymes (O'Brien et al. 1989) suggests that the Black-footed Ferret, *M. nigripes,* and the Old World Steppe Ferret, *M. eversmanni* may have separated from a common ancestor at 0.5-2.0 x10^6 years ago.

For many years the existence of *Mustela nigripes* in the Pleistocene of Beringia rested inconclusively with two dentaries (NMC 25079 and 16323). Both were referred to *M. eversmanni* by Harington (1977), but NMC 25079 was referred to *M. nigripes* by Kurtén and Anderson (1980).

In 1984, miners collected a mummified Black-footed Ferret near the known paleontological site at Sixtymile River (Loc. 3), Yukon Territory (Youngman 1987). The mummy, a young adult male, is in an excellent state of preservation, missing only a foot and the tail. The legs, left anterior and ventral portions of the body have a considerable amount of fur present. The black mask is visible on one side of the head, and the fur on the feet and legs is still black and glossy. Collagen from bone from this specimen (NMC 43786) was AMS dated at 39560 ± 490 years ago (TO-214). A second, less complete, partly mummified specimen (NMC 44305), AMS dated at 30 370 ± 560 years ago (Beta-23347; ETH 3537), was collected by J. Fraser and C.R. Harington at Hunker Creek (Loc. 12), Yukon Territory in 1987.

The allopatric occurrence of two species of ferrets in Eastern Beringia may represent two proximate migrations into Beringia, one perhaps late Wisconsinan from Eurasia, and the other, a Boutellier interval reentry, from the grasslands of North America (Schweger et al. 1982).

All ferrets are extinct in Alaska and the Yukon, and the Black-footed Ferret is now almost extinct in its historical range, due primarily to the elimination of its primary prey species by man. Black-footed Ferrets prey on prairie dogs (*Cynomys*) and use burrows of the latter for shelter. Historically the ranges of Black-footed Ferrets and sciurids of the genus *Cynomys* coincided closely. Anderson et al. (1986) argued for an obligate relationship between Black-footed Ferrets and prairie dogs. However, there is no evidence for the existence of the genus *Cynomys* in the Pleistocene of Beringia, so Beringian ferrets probably preyed on ground squirrels, lagomorphs, voles, and birds.

A North-South cline in size in modern populations agrees with Bergmann's rule (Anderson et al. 1986). Mean weights of live-trapped adult males and females from Meeteetse, Wyoming, were respectively: (n = 13) 1034.3 ± 60.18 g and (n = 31) 703.5 ± 128.36 g (Anderson et al. 1986).

Mustela nivalis — Least Weasel

SPECIMENS EXAMINED (17): Yukon Territory: Bluefish caves: Cave 1: 3 dentaries (CMC T2-16-95, T2-24-138, T2-24-139), 1 scapula (CMC T3-18-140), 5 humeri (CMC E7-17-36, I6-G-28, J7-G-33, T2-24-129, T2-24-180), 6 femora (CMC T1-9-4, T1-10-9, T-2-17-34, T2-18-58, T2-24-109, T3-15-271), 1 tibia (CMC T1-13-12). Cave 2: 1 humerus (CMC E5-H-85).

Although currently found in Alaska, Yukon Territory, part of the Northwest Territories, and much of the remainder of boreal North America, the first records of fossil *Mustela nivalis* from the Beringian Pleistocene were identified from the Bluefish caves by me in 1985 (Harington 1989).

The taxonomy of this weasel of Europe, Asia, and North America is confusing (Youngman 1975; Corbet 1978). Several names applied to this diminutive carnivore are still in use by various authors for populations in Eurasia and North America. The questions, essentially, are whether *Mustela nivalis* Linnaeus, 1766 (type locality: Vasterbotten, Sweden) and *Mustela rixosa* (Bangs), 1896 (type locality: Osler, Saskatchewan) are conspecific, and if not, what are the ranges of the two species?

Hall (1951) used the name *Mustela rixosa* for the Least Weasel, or Stoat, in North America and Eurasia. Others (Siivonen 1967; Kurtén 1968; Kurtén and Anderson 1980), noting the occurrence of two allopatric pigment forms in Scandinavia, referred them to *M. nivalis* and *M. rixosa*. Stolt (1979) concluded that the two forms were subspecies of *M. nivalis*. Breeding experiments with these two forms show that the two types of pigmentation are the result of two alleles of a single gene (Frank 1985). In the absence of evidence to the contrary, the name *M. nivalis* should be used for the Palearctic Least Weasel or Stoat. In North America, contemporary taxonomists have generally followed Reichstein (1957) who considered the two forms to be conspecific. Youngman (1975) suggested that the short-tailed form in Alaska, the Yukon, and part of the Northwest Territories, might belong to *M. nivalis*, and that populations of the long-tailed form occupying the remainder of North America might belong to *M. rixosa*; however, this may rather indicate that the short-tailed form is a Beringian relict.

Wisconsinan fossils from Beringia do not differ in size from their modern counterparts from the Arctic (Tables 8 and 9). The Least Weasel, in Eurasia, may demonstrate a reversal of Bergmann's Rule (Zimmermann 1940; Frank 1985); however, the specific status of some of the large forms now included in this species is in need of clarification. For instance the weasel from Corsica may be *M. erminea* rather than *M. nivalis* (Reumer 1988). A latitudinal cline in size has not been demonstrated in North America (Ralls and Harvey 1985).

The Least Weasel is found in a variety of habitats including tundra, boreal forest, marshes, and grasslands. Unlike the Short-tailed and Long-tailed

TABLE 8. Measurements of dentaries and lower teeth of fossil *Mustela nivalis* compared with those of Recent specimens from Alaska, and Yukon Territory.

Catalogue Number or Locality	Mandible Length	Depth of Ramus p3-p4	Depth of Ramus m1-m2	Premolar length p4	Length of m1
	Fossil Specimens				
Bluefish I	15.7	3.25	3.08	—	4.00
Bluefish I	15.7	2.89	3.14	1.80	3.83
Bluefish I	—	—	—	1.84	3.70
	Recent Specimens from Alaska, and Yukon Territory				
USNM 170138 male	17.3	3.19	3.43	2.03	4.07
USNM 38181 male	16.9	2.71	3.31	2.08	3.89
USNM 210282 female	14.6	2.47	2.54	1.88	3.49
USNM 225628 female	15.7	1.93	2.51	1.70	3.42
USNM 107591 female	14.1	2.11	2.35	1.68	3.15
USNM 39044 unknown sex	14.7	2.08	2.49	1.80	3.75
NMC 39761 male	20.3	—	—	—	—

TABLE 9. Measurements of fossil humeri of *Mustela nivalis* from Beringia compared with those of Recent specimens.

Catalogue Number or Locality	Greatest Length Proximal	Breadth Proximal	Breadth Distal	Smallest breadth Diaphysis
		Fossil Specimens		
Bluefish I	19.4	4.0	4.3	1.5
Bluefish I	18.3	—	4.2	1.4
Bluefish I	19.0	4.0	4.7	1.6
Bluefish I	17.8	3.5	4.1	1.2
		Recent specimens		
NMC 30622 male	17.0	3.4	3.8	1.2
NMC 37303 female	15.7	3.0	3.4	1.0
NMC 34110 unkown sex	16.5	3.0	3.4	1.2
NMC 39761 unknown sex	20.3	—	—	—

weasels, the Least Weasel does not have delayed implantation, and breeds throughout the year. The Least Weasel preys primarily on small rodents, but also may eat shrews, birds and insects.

An adult male from the northern Yukon Territory weighed 51.3 g (Youngman 1975). An adult female from the northern part of the Seward Peninsula (USNM 506882), and a young female from Umiat (Bee and Hall 1956) weighed 24.7 g and 33 g respectively.

Mustela vison — American Mink

SPECIMENS EXAMINED (1): Alaska: Fairbanks Creek: 1 dentary (F:AM 30821).

The only known fossil mink from Beringia is from Fairbanks Creek, Alaska. This specimen does not differ from the mink occurring today in Alaska and the Yukon Territory (Anderson 1977). Dixon (1984) reported a specimen from Porcupine River Cave 1, Alaska as either mink or Ermine, however I have not found specimens of either species in this collection.

The largest subspecies of mink, *M. vison ingens*, is found in Alaska, Yukon Territory and the Northwest Territories. Youngman (1975) proposed that this subspecies owed its distinctive characters to former isolation in Beringia. Phenetic, karyological and immunological evidence shows that the American Mink and European Mink (*Mustela lutreola*) belong to different subgenera (Youngman 1982).

Minks are restricted to wetland habitat where they feed on a variety of animals including mammals, fish, frogs, birds, and arthropods (Linscombe et al. 1982). Adult male minks weigh from 0.9 to 1.6 kg, and adult females weigh 0.7 to 1.1 kg (Linscombe et al. 1982).

Taxidea taxus — American Badger

SPECIMENS EXAMINED (25): Yukon Territory: Old Crow River Loc. 11A: 1 tooth (NMC 24856). Dawson area, Gold run Creek, Loc. 32: 1 humerus (NMC 13486). Dominion Creek, Loc. 28: 1 skull (NMC 17260), Hunker Creek, Loc. 37: 1 humerus (NMC 35319). Alaska: Cleary: 1 dentary (F:AM 30789). Cripple Creek : 2 skulls (F:AM 30835-36), 1 maxilla (F:AM 30834), 6 dentaries (F:AM 30826, 30830-32, 30840, 50828). Cripple Creek Sump: 1 mandible (F:AM 117100). Engineer Creek: 1 dentary (F:AM 117099); 1 humerus (F:AM uncatalogued). Ester Creek: 2 dentaries (F:AM 30827, 30829). Fairbanks Creek: 1 dentary (F:AM 30839), 1 humerus (F:AM 117091), 1 ulna (F:AM 18733). Gold Hill: 1 dentary (F:AM 117098). Goldstream: 2 dentaries (F:AM 30788, 30790). Fairbanks area: 1 skull (F:AM 30786).

Flint (1957) was the first to report the presence of Nearctic *Taxidea taxus* from the Pleistocene of Beringia (Fairbanks). Anderson (1977) listed skulls and dentaries from Alaska, and Harington and Clulow (1973) added records from central Yukon Territory. The present account adds identifications of postcranial material from Alaska and the Yukon Territory. Long (1972) and Anderson (1977) suggested that the presence of badgers in the Pleistocene of eastern Beringia indicated the existence of a milder climate than that of today. Guthrie (1984) however, convincingly argued that badgers were present in Beringia not because of the milder climate, but because sufficient food was available throughout the year.

The Saiga (*Saiga tatarica*), Black-footed Ferret (*Mustela nigripes*), and badger have been cited as indicators of steppe conditions during the mid-to-late Wisconsinan (Bannikov et al. 1961; Sher 1968; Harington 1981; Matthews 1982; Guthrie 1982).

The large size of Beringian badgers was mentioned by Anderson (1977) who advocated the subspecific recognition of Late Rancholabrean populations. A comparison of measurements of fossil

Beringian skulls with specimens of the largest modern subspecies, *Taxidea taxus jeffersonii* from the state of Washington, shows that the Pleistocene specimens are indeed large, but not disproportionally, considering that American Badgers conform to Bergmann's Rule (Tables 10 and 11).

The distribution of modern American Badgers is from western Canada to Ontario, and from the Pacific Ocean through the mountains and prairies eastward to Ohio, Indiana, Illinois and Missouri, and southward into Mexico. Long and Killingley (1983) reported the existence of a small living population in southwestern Yukon Territory; however, there is no substantiating evidence (Youngman 1975; Brian G. Slough, personal communication 1988).

The total length of seven male badgers, *Taxidea taxus jeffersoni*, from Wyoming averaged 787.6 mm (753 to 820 mm), while six females averaged 699.2 mm (670 to 740 mm). A male weighed 12.03 kg and two females weighed 6.4 and 5.9 kg, respectively (Long and Killingley 1983).

Badgers are opportunistic in their food habits, feeding on vertebrates, invertebrates, and carrion (Long and Killingley 1983). In Beringia badgers probably preyed mostly on Arctic ground squirrels, voles, hares, and ground nesting birds.

Discussion

The lack of stratigraphically correlated or radiocarbon dated specimens from Beringia makes it difficult to reach definite conclusions concerning the temporal associations of the carnivores. It would be impossible, for instance, to estimate the components of mammalian predator guilds during any part of the Beringian Pleistocene. There are no early and late dates for Beringian taxa, and many species are represented by incomplete cranial material.

Specimens of a hyaenid *Chasmaporthetes* sp. (a left m1, NMC 38053, and a right p4, NMC 24958) from Old Crow River locality 11A, as well as specimens of *Homotherium serum* from that locality (Harington 1989), may be the oldest (perhaps Blancan or Irvingtonian) terrestrial carnivore fossils from Beringia.

Deposits previously considered to be of Illinoian age, but which may be much older, have yielded specimens of *Canis lupus*, *Vulpes lagopus*, and *Cuon* sp. Sediments previously thought to be Sangamon, but which may be much older, have produced specimens of *Canis lupus*, *Vulpes lagopus, Martes pennanti, Gulo gulo*, and *Brachyprotoma obtusata*. The remaining specimens are from various parts of the Wisconsinan.

Of the 23 species of terrestrial carnivores recorded from eastern Beringia during the Pleistocene, six species became extinct (*Cuon* sp., *Arctodus simus, Brachyprotoma obtusata, Homotherium serum, Smilodon fatalis*, and an unidentified mephitine), and four species became locally extinct (*Mustela nigripes, Mustela eversmanni, Taxidea taxus*, and *Panthera leo*). *Mustela nigripes* and *Taxidea taxus* are now found on the Great Plains of North America, and the entire range of *Mustela eversmanni* is in Eurasia. *Panthera leo*, now restricted to parts of Africa and India, formerly ranged through southeastern Europe, and southwest Asia. The remaining species have now either a Holarctic distribution (*Vulpes lagopus, V. vulpes, Mustela erminea,*

TABLE 10. Cranial measurements of fossil badgers (*Taxidea taxus*) from Yukon Territory compared with those of Recent male *T. t. jeffersonni* from the state of Washington ($\overline{X}$, SD, and range).

Catalogue Number and Locality	Condylobasal Length	Palatal Length	Zygomatic Breadth	Mastoidal Breadth	Cranial Height
			Fossil Specimens		
Ester Creek					
F:AM 30837	139.5*	71.9	—	91.0	58.6
F:AM 308308	—	75.4	—	—	—
Cripple Creek					
F:AM 30836	—	79.1	—	—	—
Goldstream					
F:AM 30787	138.1	73.8	—	89.8	—
Dominion Creek					
NMC 17620	134.1	72.4	—	86.3	—
Fairbanks					
F:AM 30786	—	73.2	90.5	—	—
			Recent Specimens		
males (n=14)	130.67* ± 2.82	67.43 ± 3.21	85.64 ± 1.94	81.56 ± 1.92	55.57 ± 1.61
	126.2 - 136.4	58.2 - 71.5	83.1 - 88.1	79.3 - 85.6	53.2 - 58.7
females (n=19)	123.67 ± 3.26	64.63 ± 2.06	78.62 ± 3.71	76.95 ± 3.02	52.49 ± 1.59
	118.9 - 130.7	61.5 - 69.7	71.8 - 87.5	70.7 - 82.6	48.0 - 54.7

* Maximum measurement of a damaged specimen.

TABLE 11. Measurements of dentaries of fossil badgers *(Taxidea taxus)* from Alaska and the Yukon Territory compared with those of Recent male specimens of *T. t. jeffersonni* from the state of Washington (n, $\overline{X}$ tSD, and range).

Specimens	Measurements				
Catalogue Number and Locality	Mandible Length	Depth of Ramus m1—m2	Mandibular Tooth—Row Length	Width of Dentary m1—m2	Length of m1
			Fossil Specimens		
Cripple Creek					
F:AM 30828	—	22.2	41.5	9.8	—
F:AM 30831	—	20.4	41.5	8.7	—
F:AM 30832	109.7	25.7	43.8	10.9	—
F:AM 30826	97.1	19.6	42.5	8.6	—
F:AM 30830	—	22.1	43.7	8.3	15.1
Ester Creek					
F:AM 30827	93.7	19.4	42.2	8.0	—
Goldstream					
F:AM 30788	95.6	21.1	38. 2	8.8	15.2
F:AM 30790	—	22.8	43.6	9.6	—
Cripple Sump					
F:AM 117100	—	21.2	2.2	8.5	—
Engineer Creek					
F:AM 117099	102.3	24.4	41.7	10.1	—
Gold Hill					
F:AM 117098	—	24.0	44.3	10.0	—
Fairbanks Creek					
F:AM 30839	97.8	21.8	42.2	9.9	15.1
Fairbanks area					
F:AM 30786	95.5	21.3	41.3	8.8	15.1
Cleary					
F:AM 30789	—	22.6	42.5	8.2	—
			Recent Specimens (n=14)		
	91.06 ± 1.72	19.44 ± 0.82	39.78 ± 1.26	8.06 ± 0.44	13.71 ± 0.73 (10)
	88.5 - 93.6	18.2 - 20.7	38.4 - 41.7	7.4 - 8.9	12.4 - 15.4

Mustela nivalis, Gulo gulo, and *Felis lynx*, or a Nearctic distribution (*Martes americana, Martes pennanti, Mustela vison*, and *Lutra canadensis*). There are no carnivores currently occurring in eastern Neoberingia (that area of present North America that was formerly part of the Beringian refugium) that were not present in eastern Beringia during the Pleistocene, with the exception of *Canis latrans*.

Most of the extinct species are large hypercarnivores at the top of the food chain. Their demise was probably linked to the reduction of the large ungulate fauna, as was the local extinction of *Panthera leo*. The local extinctions of *Mustela nigripes, M. eversmanni*, and *Taxidea taxus* probably resulted from climatic change which virtually eliminated the steppe from the Beringian region. The reasons for the extinctions of *Brachyprotoma obtusata* and the unidentified skunk are enigmatic. Populations of the former species became extinct both in Beringia and in the southern periglacial region, perhaps indicating that this was a highly specialized form whose extinction was somehow associated with the demise of the megafauna, or with post-Wisconsinan climatic change.

Kurtén (1968) showed that most mammals changed in size during the Pleistocene. The large size of Beringian specimens of *Mustela erminea, M. eversmanni, Brachyprotoma obtusata, Taxidea taxus*, and *Cuon* sp., and the variation in size of specimens of *Gulo gulo*, are evidence of these size changes.

The study of vertebrates from the Pleistocene of Beringia is in its infancy, and this infancy is apt to be prolonged by the expense of collecting, by the lack of accurate dating methods for specimens over 40 000 years old, by the paucity of specimens collected *in situ*, and by the incompleteness of our knowledge of the morphology, and therefore systematics, of the taxa involved. Because of Beringia's position as one of the pathways between North America and Eurasia future collecting of fossil vertebrates from the Beringian region is obviously of great importance to the understanding of Quaternary paleontology. Only when there is a firm understanding of the composition of the Beringian fauna, with first dates of appearance and last dates of occurrence, will there be more reliable understanding of the Pleistocene fauna of the remainder of the continent.

It is still useful to collect from areas in Neoberingia where there is no stratigraphy because so many taxa are known only from fragmentary material. Future collecting should however, concentrate on excavating in caves or other undisturbed sediment, such as the Bluefish caves, which can be dated with greater confidence.

Acknowledgments

This paper is dedicated to my late mentors, Ralph M. Wetzel, E. Raymond Hall, and Björn Kurtén. I am especially grateful to J. Cinq-Mars (Canadian Museum of Civilization, Ottawa), for inviting me to dig at the Archaeological Survey of Canada site at Bluefish caves, and for graciously making the material from that locality available to me. For loans of specimens, or permission to examine specimens in their care, I am indebted to R. Tedford, and J. Alexander, Frick Collection (F:AM), American Museum of Natural History; G. Musser, American Museum of Natural History (AMNH); E. J. Dixon, and R. Eshelman, University of Alaska, Fairbanks (UA); the late W. N. Irving, University of Toronto, (TO); O. Rossolimo, Moscow State University (MSU); D. Wilson, and R. Fisher, National Museum of Natural History, Washington, D.C. (USNM); J. Cinq-Mars, Archaeological Survey of Canada, Canadian Museum of Civilization, Ottawa (CMC). Fossil specimens designated NMC are in the collection of the Paleobiology unit, Canadian Museum of Nature, Ottawa. Recent specimens designated NMC are in the Recent mammal collection of that museum formerly under the curatorship of S. van Zyll de Jong. I appreciate comments on an earlier draft of this paper by E. Anderson, C. R. Harington, R. E. Morlan, C. Pirozynski, F. W. Schueler, R. Tedford, and two anonymous reviewers. C. R. Harington provided me with considerable information on paleontological sites.

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Recieved 24 July 1992
Accepted 20 September 1993

Appendix I. Recent Comparative Specimens Examined

Species names are followed by the acronym of the museum where the specimens are housed, followed by the political region(s) where the specimen(s) were collected, and the number of specimens examined. Specimens listed in Tables by acronym, catalogue number and locality, are not duplicated here.

Vulpes lagopus (NMC): Northwest Territories: Baker Lake, 14. *Vulpes vulpes* (NMC): Northwest Territories: Baker Lake, 11; Cornwallis Island, 3; Banks Island, 1. Yukon Territory: Stewart River region, 12; Henderson Creek, 2. *Martes pennanti*: U.S.A. (USNM), California, 1; Maine: 1; Minnesota, 1. Canada: British Columbia: Hudsons Hope, 2 (AMNH); Quebec: Lake Edward, 1 (NMC); Wakefield, 2 (NMC); Godbout, 3 (USNM). *Mustela erminea* Alaska: Anaktuvuk Pass, 6 (USNM); Anuk Lake, 2 (USNM); Chandler Lake, 1 (USNM); John River, 2 (USNM); Kidluit Bay, 5 (NMC); Lake Peters, 2 (USNM); Narvak Lake, 1 (USNM); Nutuvuki Lake, 2 (USNM); Umiat, 3 (USNM). *Mustela eversmanni* (MSU): U.S.S.R.: Altai, 2; Borzinskiy Region, 2; Chita Oblast, 2; Kazakstan, 1; Kirgizkaya Republic, 3; Za-Baikal, 6 (USNM). China, 6. *Mustela nigripes* (USNM): Arizona, 2; Colorado, 2; Kansas, 21; Montana, 10; North Dakota, 1; New Mexico, 1; South Dakota, 7; Texas, 1. *Mustela nivalis* (NMC): Alaska: Beaver Mountains, 1; Cook Inlet, 1; St. Michaels, 1; Toklat River, 1; Yukon River, 2. Yukon Territory: Firth River, 1; Herschel Island, 1; Porcupine River, 1; Summit Lake, 1. *Taxidea taxus* (USNM): Washington: Plymouth, 1; Trinidad, 1; Wallula, 3; Rattlesnake Hills, 2; Anatone, 1; Peach, 1; Keller, 1; Bluestem, 2; Opportunity, 2.

Appendix II. Gazetteer and Bibliography of Localities

Localities listed here were taken from specimens, from catalogues, or are thought to be synonyms of preceding locality names. Coordinates following locality names are to be taken as approximate. Details on localities, often including radiocarbon dates, and stratigraphy, can be found in the references following the locality names. For a map of many Beringian localities *see* Harington (1978).

Alaska, U.S.A.

Fairbanks Region

Most of the specimens from this area were collected between 1937 and 1944 by Otto W. Geist who had little or no stratigraphic control for the collection of specimens, many of which he picked out of the gold dredges (Anderson 1977; W. Pruitt, personal communication 1990).

No. 26 Strip

Cleary. Harington 1978. Upper Cleary. Lower Cleary Creek, Kurtén and Anderson 1980.

Cripple Creek (64°49′N, 148°01′W). Guthrie 1968*a*, 1968b; Kurtén and Anderson 1980; Pewe 1975; Péwé and Hopkins 1967. Cripple Creek Sump. Name of the former placer operation south of Ester Island in Sec 8, T. 1S., R.2 W, approximately 16 km N Fairbanks. Harington 1989; Hopkins 1967, 1982; Péwé 1952, 1975; Péwé and Hopkins 1967.

Dome Creek. Harington 1978; Péwé 1975.

Engineer Creek (64°57′N, 147°38′W). Guthrie 1968a, 1968b; Harington 1978.

Engineer Creek, Dawson Cut. Guthrie 1968b.

Ester Creek. Péwé 1975.

Eva Creek. 16 km west of Fairbanks. Guthrie 1968b; Harington 1978; Hopkins 1982; Matthews 1968, 1970, 1983; Morgan et al. 1983; Péwé 1952, 1975; Porter 1988.

Eva Bench (64°51′12″N,148°00′18″W). Hopkins and Smith 1981.

Fairbanks Creek (65°04′N, 147°10′W). Guthrie 1968a; Harington 1978; Hopkins and Smith 1981; Péwé 1975.

Fox. North of Fairbanks.

Gilmour Creek. About 18 km NE Fairbanks. Harington 1981; Péwé 1975.

Gold Hill (64°51′N, 147°59′W). On a bench of Cripple Creek. Kurtén and Anderson 1980; Péwé 1975; Guthrie 1968*a*; Harington 1978, 1981; Westgate et al. 1990. An important site with a long undisturbed depositional record being excavated by R. D. Guthrie (Guthrie, personal communication 1991).

Upper Goldstream. A creek approximately 10 km N Fairbanks. Péwé 1975. 21 Goldstream. No. 2 Goldstream. Upper 1 G (=Goldstream?).

Rosie Creek. About 5 miles N Fairbanks. Flows into the Tanana River.

North Slope, Lower Gubik Formation

Teshekpuk Lake. North of the lake, about 139 km ESE Point Barrow longitude 153°6′W. Repenning 1983.

East-Central Alaska

Lost Chicken Creek (64°3.2′N, 141°52.6′W). A highly fossiliferous site with some specimens in place Harington 1978; Hopkins and Smith 1981; Porter 1988; Whitmore and Foster 1967.

Chicken Creek. Adjacent to Lost Chicken Creek. Whitmore and Foster 1967.

Central Alaska

Tofty Placer District (65°05′N, 150°52′W). Harington 1977, 1978; Hopkins and Smith 1981; Kurtén and Anderson 1980; Péwé 1975; Repenning et al. 1964.

Yukon Territory, Canada

For a map of many Yukon localities *see* Harington 1989.

Old Crow Basin

For maps of OCR localities *see* Clarke and Harington 1978; Bryant 1987, Fitzgerald 1978 Morlan 1980a. For discussions of stratigraphy *see* Hughes et al. 1989; Morlan 1980a; Irving et al. 1989 Harington 1977, 1986; Jopling et al. 1981; Schweger 1989a, 1989b.

OCR 11 (67°49′N, 139°50′W) Harington 1977; Jopling et al. 1981; Morlan 1980a; Schweger 1989b.

OCR 11-1. Important because many late Wisconsin fossils were discovered in place. Harington 1977, 1989.

OCR 11A (67°49.2′N, 139°54.3′W). Point bars with redeposited bone of Early Pleistocene to Late Wisconsinan and Holocene age. Fitzgerald 1978, 1980; Harington

1971, 1977, 1978; Jopling et al. 1981; Kurtén and Anderson 1980; Morlan 1980a; Schweger 1989b. OCR 14N (67°51′N, 139°51.1′W). Bonnichen 1979; Fitzgerald 1980; Harington 1970, 1975; Irving and Harington 1973; Jopling et al. 1981; Kurtén and Anderson 1980; Morlan 1980a,b; Morlan et al. 1990.

OCR 12 Harington 1977; Irving et al. 1989.

OCR 15 (67°51′30″N, 139°48′40″). Mid-late Wisconsinan. Cumbaa et al. 1981; Harington 1977; Morlan 1980a, 1980b; Morlan et al. 1990. The Borden number for this locality is MlVl-2.

OCR 27 (68°10′N, 139°56′W). Harington 1977; Morlan 1980a.

OCR 29 (68°10.4′N, 139°57.1′W). Compares with OCR 14N. Fitzgerald 1980; Harington 1977; Morlan 1980a.

OCR 44, Unit 2 (68°12.6′N, 140°00′W). A richly fossiliferous site for both invertebrates and vertebrates, thought possibly to be of Sangamon age, >54,000 years old. Clarke and Harington 1978; Fitzgerald 1980; Harington 1971, 1977, 1978, 1990; Kurtén and Anderson 1980; Lichti-Federovich 1973; Matthews 1975; Morlan 1980a; Schweger 1989b; Youngman 1986.

OCR 65. "…a river terrace bluff about 7.6 m high on the right limit of the river." Fitzgerald 1978: 1887; Morlan 1980a.

OCR 77 (68°1.5′N, 139°33.6′W). "a gravel bar". Fitzgerald 1980: 1594.

OLD CROW RIVER LOCALITIES, 10, 20, 22, 22E, 27W, 28, 42, 63, 66, 67, 74, 81, 83 (Morlan 1980a); and 115 are mostly gravel bars yielding specimens of mixed age.

BLUEFISH CAVES

Caves 1, 2, and 3 (67°8′N, 140°47′35″W). 24 000–12 000 years BP. Cinq-Mars 1979; Harington 1989; Hopkins 1982; Morlan 1989; Morlan and Cinq-Mars 1982; Ritchie et al. 1982; Youngman 1986. Borden numbers for the caves are MgVo 1, 2, and 3.

WEST-CENTRAL YUKON

SIXTYMILE Loc. 3 (64°00′N, 140°47′W). Mummified black-footed ferret, 39 560 ± 490 years ago. (Youngman 1987). A mummified Arctic ground squirrel dated at 47 500 ± 1900 years ago was found at Locality 4, "a few km away [from locality 3]" (Harington 1989).

DAWSON AREA

DOMINION CREEK, Loc. 28. Site on Upper Dominion Creek. Harington 1969, 1977, 1980.

EUREKA CREEK, Loc. 65. Site on Eureka Creek a few miles below road crossing. (C. R. Harington, personal communication 1991).

HUNKER CREEK, Loc. 10, 80 Pup. Harington 1977, 1978, 1980, 1987a, 1989.

HUNKER CREEK, Loc. 12 (63°58′N, 138°59′W). Harington 1977. Mummified black-footed ferret ASM dated at 30,370 ± 560 years ago.

HUNKER CREEK, Loc. 37. Harington 1977.

HUNKER CREEK, Loc. 51. Harington 1977.

GOLD RUN CREEK, Loc. 32 (63°43.5′N, 138°41′W). Late Wisconsinian. Harington 1977, 1978, 1989; Harington and Clulow 1973; Kurtén and Anderson 1980.

Mortality of Seabirds Assessed from Beached-bird Surveys in Southern British Columbia

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Burger, Alan E. 1993. Mortality of seabirds assessed from beached-bird surveys in southern British Columbia. Canadian Field-Naturalist 107(2): 164–176.

Results are reported from 738 monthly beached-bird surveys, performed between October 1989 and March 1993, and covering 1468 km at 38 sites in British Columbia. The mean density of beached carcasses was 0.42 km^{-1}, with marked differences between sites. Carcass deposition was highest in autumn and winter in most sites, and this was attributed to high densities of wintering birds, increased mortality among juveniles and post-breeding adults, and possibly wind and oceanic factors. A total of 823 water birds from 53 species was reported. Common Murres, *Uria aalge* (21%), Glaucous-winged Gulls, *Larus glaucescens* (20%), and Rhinoceros Auklets, *Cerorhinca monocerata* (7%), were the only species to exceed 5% of the total count. At least 6 % of the beached-birds were oiled, but the mean density of oiled birds (0.02 km^{-1}) was among the lowest reported from beach surveys around the world.

Key Words: Beached-bird surveys, seabird mortality, British Columbia, oiled seabirds, pollution.

The coastal waters of British Columbia support some of the highest densities of seabirds, waterfowl and shorebirds in the eastern North Pacific. These seas are also used by thousands of vessels, including oil-bearing tankers and barges. Marine shipments of crude oil and refined petroleum products in southern British Columbia exceed 40 million cubic metres (>250 million barrels) every year (Shaffer and Associates 1990). There is clearly a high risk that spills might affect large numbers of seabirds. These risks became reality with the *Nestucca* spill in the winter of 1988/89 and the sinking of the *Tenyo Maru* in the summer of 1991. Both events created extensive oil slicks off British Columbia and northern Washington and killed thousands of seabirds (Rodway et al. 1989; Ford et al. 1991; Burger 1992, 1993). Birds are also affected by hundreds of smaller spills of petroleum and vegetable oils (Vermeer and Vermeer 1975; McKelvey et al. 1980; Burger 1992; Burger and Fry 1993). The cumulative mortality of seabirds due to such chronic oiling can, in some situations, exceed the more publicized deaths which follow large, catastrophic spills (Piatt et al. 1985; Camphuysen 1989; Chardine et al. 1990).

The risk of oiling and the paucity of baseline information on chronic oiling and natural mortality patterns of seabirds prompted the initiation of systematic beached-bird surveys in British Columbia. Surveys were started at several beaches in 1989, under the auspices of the Royal British Columbia Museum and the Emergency Services Branch of B.C. Environment, and has grown to include regular surveys at 38 beaches. The primary aims of the program are to provide baseline information on the rates of mortality of seabirds through the seasons and in a variety of coastal regions, and to monitor oiling from both large catastrophic and small-scale chronic spills. This report analyzes the data available from surveys made in southern British Columbia between October 1989 and March 1993.

Materials and Methods

Surveys were made by volunteer naturalists on foot, once a month at approximately the same date each month at each beach, following Ainley et al. (1980). Details on all dead or incapacitated birds were recorded on standardized field sheets. Carcasses not retained for identification or museum purposes were thrown well above the tideline to avoid them being counted twice. Identification of carcasses was sometimes difficult, but was aided by the use of a field guide to beached-birds (Ainley et al. 1980) and through comparisons with museum specimens. Surveyors reported the presence of any oiled birds, oil on the beaches, storms or other relevant phenomena.

Data were stored on two databases (Microsoft Excel): one summarising each beach survey, and one for information on each bird found. Data on about 35 beached carcasses found outside systematic surveys were also included in the latter database, but were not included in calculations of carcass densities. Copies of the databases have been archived at the Biological Collections, Royal British Columbia Museum. Victoria, B.C.

Surveys were grouped into four regions:

i) The west coast of Vancouver Island (WCVI), between Tofino and Port Renfrew, encompasses beaches facing the open Pacific. Virtually all of the beaches were predominantly sandy, with occasional rocky shelves or boulders, and exposed to high energy waves.

ii) Southern Vancouver Island (SVI), between China Beach and Sidney, faces the Strait of Juan de Fuca and Haro Strait. Tidal currents in this region are strong, but most beaches are exposed to low wave action except during storms.

iii) Strait of Georgia and the Gulf Islands (SGGI), includes beaches on both sides of the strait, from Campbell River and Powell River southwards, including the Gulf Islands in the south of the strait. These marine areas are very sheltered but are sometimes exposed to strong tidal currents. Wave action is usually very light.

iv) White Rock and Boundary Bay (WRBB) lies just north of the U.S. border. These surveys were made along the shores at White Rock, in Mud Bay and on the west of Boundary Bay. Beaches are sandy or muddy, are often covered in dense eelgrass wrack and are exposed to moderate to light wave action.

Results

Carcass density

Data from 738 monthly surveys covering 1468 km at 38 sites are summarized in Table 1. The mean carcass density (giving each site equal weighting regardless of the frequency of surveys) was 0.42 carcasses km^{-1}.

There were striking differences in carcass densities between the four major regions (Table 1). An analysis of variance using the mean carcass density per beach, indicated that the variation among beaches within each region was less than the variation among regions ($F_{3,34} = 6.466$, $P<0.01$). The average density was highest on the west coast of Vancouver Island and the White Rock-Boundary Bay regions (0.67 and 0.87 birds km^{-1}, respectively), relatively low on the south of Vancouver Island (0.31), and very low (0.08) in the Strait of Georgia and Gulf Islands where no carcasses at all were found at two-thirds of the sites in 99 surveys.

Data from sites which had one or more years of continuous coverage were selected to show monthly variations (Figure 1). The west coast of Vancouver Island showed a strong, seasonal trend, with 76% of carcasses found in a four-month period in late summer and autumn (August through November). There was high mortality during this period in all other areas too, although the pattern was less striking. Very few carcasses were found during late spring through mid-summer (May through July).

Species composition

Information was obtained on 840 beached-birds, of which 17 were terrestrial or domesticated birds and were not considered further. The 823 water birds included 53 species, dominated by waterfowl (21% of the carcasses), gulls (31%) and alcids (34%) (Table 2; see Appendix for species list). The Common Murre, *Uria aalge* (21%), Glaucous-winged Gull, *Larus glaucescens* (20%) and Rhinoceros Auklet, *Cerorhinca monocerata* (7%) were the most common species, and the only species to exceed 5% of the total count .

There were striking differences among the four regions, reflecting the differences in marine habitat (Table 2). Tube-nosed seabirds made up 7% of the carcasses from the west coast of Vancouver Island, where beaches face the open Pacific, but were insignificant elsewhere. Conversely, waterfowl (ducks and geese) made up only 2% of the carcasses on the WCVI beaches, but 17–47% in other regions with more sheltered water. Gulls were common in all regions (28–52%). Alcids were the most common birds found on the west coast of Vancouver Island (54%) and southern Vancouver Island (44%), but were rare elsewhere.

There was insufficient material to detect seasonal trends among most species, but trends in families were often obvious. Loons and grebes, which winter in coastal waters, were found only between September and May (Figure 2). All three species of cormorants are resident in British Columbia, although their numbers are supplemented in winter by northward movements from the United States Most cormorants appear to die in summer or autumn (Figure 2). The vast majority of waterfowl use the coastal waters only as wintering grounds and this is reflected in the strong seasonal pattern found in all areas. The peak of mortality in January is partly due to an unseasonably cold period in 1993, when much of the fresh water was frozen and many starved dabbling ducks were found in the White Rock-Boundary Bay region.

Glaucous-winged Gulls are common breeding residents in most coastal areas, but the bulk of carcasses (70%) were found in autumn and winter (September through January) and very few during the breeding season (Figure 3). First-year (22%) and immature gulls (16%, including some first-years) occurred disproportionately more often among the carcasses, particularly in autumn.

Dead Common Murres, Cassin's Auklets, *Ptychoramphus aleuticus,* and Rhinoceros Auklets were most common in late summer through early winter (Figure 4). This pattern was partially due to the seasonal presence of these species off the west coast of Vancouver Island, although large numbers of murres and Cassin's Auklets tend to remain there through the winter. This pattern also reflected high mortality among newly-fledged juveniles. The age of 125 Common Murres was reported, and 61 (49%) were partly-grown juveniles found dead in August through October. Forty-six (85%) of the 54 Rhinoceros Auklets were juveniles found between August and November. Few Cassin's Auklets were reliably aged.

TABLE 1. Summary of carcass densities reported from beached bird surveys in southern British Columbia (October 1989 through March 1993) . In each region, the beaches are arranged in sequence from north to south, except for southern Vancouver Island (arranged west to east).

Region and beach site	No. of surveys	Total carcasses	Total distance (km)	Mean birds per km	No. of person-days
1. West coast Vancouver Island (WCVI)					
Chesterman's Beach, Tofino*	37	45	70.3	0.64	41
Cox Bay, Tofino *	34	32	34.0	0.94	36
Schooner Cove, Tofino *	29	22	20.5	1.07	34
Long Beach, Ucluelet *	24	149	164.4	0.91	41
First Beach, Bamfield	4	1	6.0	0.17	8
Pachena Beach, Bamfield *	56	112	67.2	1.67	82
Dead End Beach, Pachena Point	8	3	3.2	0.94	12
Mile Half Beach, Pachena Point	9	3	9.0	0.33	12
Michigan Creek Beach	8	1	8.0	0.13	10
Carmanah Crib Creek *	16	15	40.0	0.38	21
Carmanah Creek *	16	5	21.0	0.24	20
Total for WCVI:	241	388	443.6	0.87	317
(Unweighted mean, N = 11 sites)				[0.67]	
2. Southern Vancouver Island (SVI)					
China Beach *	27	4	28.5	0.14	29
French Beach *	12	1	16.0	0.06	17
Gordon's Beach	10	1	5.8	0.17	13
Whiffin Spit Inner, Sooke *	21	31	29.4	1.05	27
Whiffin Spit Outer, Sooke *	21	11	21.0	0.52	28
Witty's Lagoon/Taylor Point *	11	5	11.0	0.45	17
Chatham & Discovery Islands *	26	0	26.0	0.00	27
Cordova Bay Central *	22	4	22.0	0.18	22
Cordova Bay North *	25	7	40.0	0.18	25
Bazan Bay, Sidney *	34	14	85.0	0.16	34
Island View, Sidney *	21	19	42.0	0.45	20
Total for SVI:	230	97	326.7	0.30	259
(Unweighted mean, N = 11 sites)				[0.31]	
3. Strait of Georgia & Gulf Islands (SGGI)					
Storries Beach, Campbell River *	14	0	21.5	0.00	26
Palm Beach, Powell River *	18	0	16.6	0.00	18
Mission Point, Sechelt *	23	8	23.0	0.35	43
Sergeant's Bay, Sechelt *	26	24	78.0	0.31	24
Wace Creek, Mill Bay *	11	4	22.0	0.18	46
Fulford Harbour, Saltspring Island	4	0	10.0	0.00	5
Menhinick, Saltspring Island *	25	0	50.0	0.00	25
North Beach, Saltspring Island *	29	1	42.4	0.02	29
Hamilton Beach, Pender Island	10	0	5.0	0.00	18
Medicine Beach, Pender Island *	18	0	14.4	0.00	28
East Point, Saturna Island	10	0	10.0	0.00	12
Total for SGGI:	188	37	292.9	0.13	274
(Unweighted mean, N = 11 sites)				[0.08]	
4. White Rock and Boundary Bay (WRBB)					
Boundary Bay West	3	18	12.0	1.50	3
White Rock Area 6 (Mud Bay)*	21	107	61.7	1.73	52
White Rock Area 4 *	25	58	75.0	0.77	28
White Rock Area 2*	20	56	199.4	0.28	35
White Rock Area 1*	10	4	57.0	0.07	20
Total for WRBB:	79	243	405.1	0.60	138
(Unweighted mean, N = 5 sites)				[0.87]	
TOTAL (All sites)	738	765	1468.3	0.52	988
(Unweighted mean, N = 38 sites)				[0.42]	

*Data from these beaches were used for seasonal analyses (Figure 1).

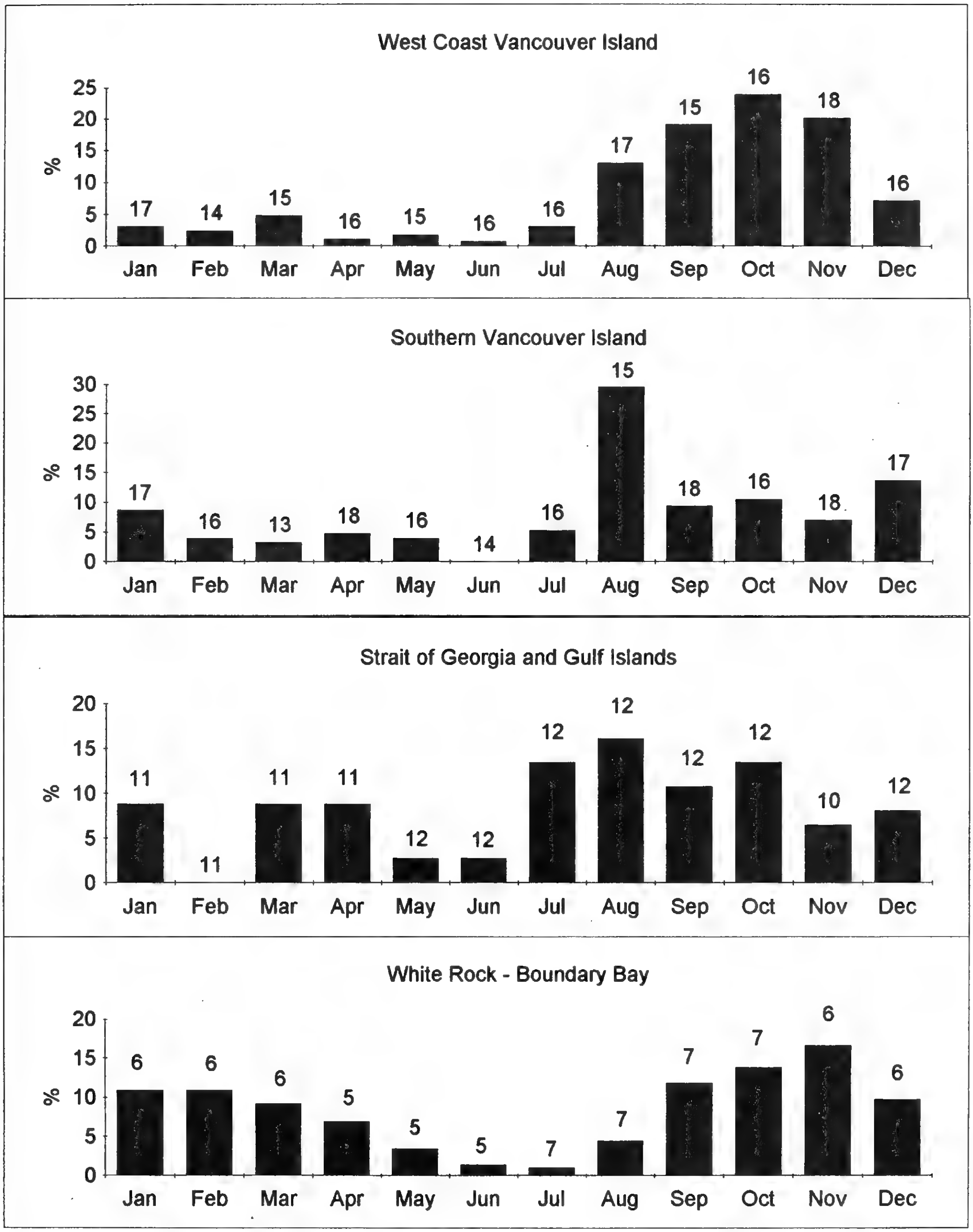

FIGURE 1. The monthly percentage of the total carcass count found in each region during beached-bird surveys in British Columbia. Sample sizes show numbers of surveys per month.

Causes of mortality

Many of the beached-birds were either decomposed or partially eaten by scavengers, making assessment of the causes of death difficult. Furthermore, most causes of mortality, such as disease, starvation, internal injuries, and poisoning were not apparent from external examination. Surveyors were asked to estimate the state of decomposition and time since death. They estimated that 29% were fresh (average five days since death), 34 slightly

TABLE 2. Numbers (and percentages in parentheses) of carcasses of each family found in beached-bird surveys on the West Coast of Vancouver Island (WCVI), southern Vancouver Island (SVI), the Strait of Georgia and Gulf Islands (SGGI), and the White Rock - Boundary Bay area (WRBB) in British Columbia. See the appendix for species composition.

Families	WCVI	SVI	SGGI	WRBB	Total
Loons (Gaviidae)	4 (1.0)	2 (1.8)	0	9 (3.2)	15 (1.8)
Grebes (Podicipedidae)	4 (1.0)	3 (2.8)	1 (3.0)	23 (8.0)	31 (3.8)
Tube-noses (Procellariidae and Hydrobatidae)	28 (7.1)	1 (0.9)	0	0	29 (3.5)
Cormorants (Phalacrocoracidae)	20 (5.0)	3 (2.8)	0	1 (0.4)	24 (2.9)
Herons (Ardeidae)	1 (0.3)	1 (0.9)	1 (3.0)	3 (1.1)	6 (0.7)
Waterfowl (Anatidae)	8 (2.0)	18 (16.7)	13 (39.4)	133 (46.7)	172 (20.9)
Shorebirds (Charadriidae and Scolopacidae)	5 (1.3)	0	0	7 (2.5)	12 (1.5)
Gulls and jaegers (Laridae and Stercorariidae)	112 (28.2)	33 (30.6)	17 (51.5)	94 (33.0)	256 (31.1)
Alcids (Alcidae)	215 (54.2)	47 (43.5)	1 (3.0)	15 (5.3)	278 (33.8)
Total for all water birds	397	108	33	285	823

decomposed (average 13 days dead) and 37% very decomposed (average 21 days dead).

Causes of death were assumed for only 118 carcasses (Table 3). Natural causes, primarily starvation, were assigned to 25% , and oiling (30%) and shooting (35%) were the most frequent human-induced causes. Oiling was most frequent on the west coast of Vancouver Island, and shooting was most common on southern Vancouver Island and at White Rock.

Thirteen species were included in the 35 oiled birds, of which 28 came from the west coast of Vancouver Island (Table 4). Glaucous-winged Gulls (9) and Common Murres (9) were the most common oiled birds. Oiled birds were found in most months, with no apparent seasonal peak. Most were covered with relatively little oil: 66% of the birds had 10% or less of their plumage affected, and only three (9%) were nearly completely covered in oil (Table 4). The oiled birds included 12 affected by thick bunker or crude oil, two by light fuel oil and two by creosote from pilings.

The oiled birds represented 4.3 % of the 823 water birds found. However, at least 241 carcasses were known to be too decomposed or eaten to allow oiling to be detected, and there were undoubtedly additional carcasses in similar states which were not reported. At least 6.0% of the carcasses (35 out of 582) were therefore oiled. Broken down into regions this represents 10.2% (28/275) on the west coast of Vancouver Island, 4.4% (3/68) on southern Vancouver Island, 13.3% (4/30) in the Strait of Georgia and Gulf Islands, but none (0/209) at White Rock-Boundary Bay.

The mean density of oiled carcasses per km of beach was 0.06 on the WCVI, 0.01 on SVI, 0.01 in the SGGI area, 0 for the WRBB area, and 0.02 for all surveys pooled together. In the 22 surveys that reported oiled birds, only six (27%) reported other types of oil (usually small tar-balls) on the beach at the same time. The sample period overlapped with the Tenyo Maru oil spill of July and August 1991, but very little of the spilled oil and fewer than 20 oiled birds (none in routine beach surveys) were reported ashore in Canada.

Discussion

Comparisons with other beached-bird surveys

Beached-bird surveys have been conducted in several countries and regions (Table 5). The mean density of carcasses in British Columbia (0.42 km^{-1}) is among the lowest recorded anywhere. Only the inland waters of Washington State (Puget Sound and the San Juan Islands) had a lower density (0.26 km^{-1}) which was very similar to the adjacent areas in British Columbia; i.e., southern Vancouver Island (0.31 km^{-1}) and the Strait of Georgia and Gulf Islands (0.08 km^{-1}). The west coast of Vancouver Island (0.67 carcasses km^{-1}) had lower densities than comparable exposed beaches in California, Oregon and Washington (Table 5). This low rate of carcass deposition in British Columbia is surprising because the marine bird populations are comparable to, if not higher than, those off most of the lower United States (Atlantic and Pacific). Several reasons can be advanced to explain the low rates, including: low wave action in sheltered waters resulting in few dead birds being washed ashore; large amounts of beached debris, including huge piles of logs or kelp typical on more exposed beaches which make it more difficult to locate carcasses; high densities of scavenging birds (eagles, gulls, ravens, crows) and mammals (bears, wolves, coyotes, raccoons, dogs) which eat or remove beached carcasses. Other topographical and physical factors, such as the slope of the beach, local currents and wind directions, all are likely to influence deposition rates and require further investigation.

Seasonal and geographical variations

The highest carcass densities were reported during late summer through early winter, particularly on the

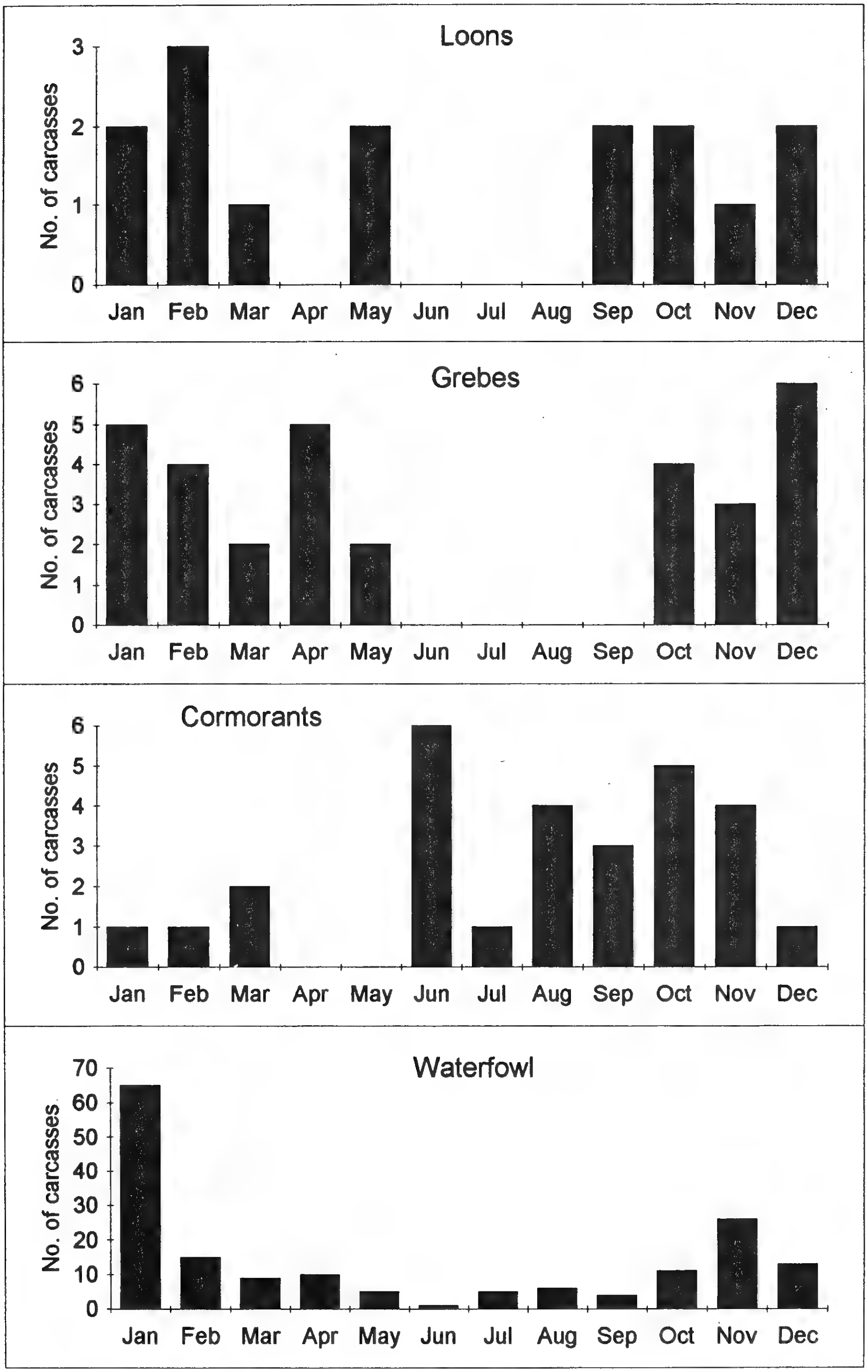

FIGURE 2. Monthly frequencies of loons, grebes, cormorants and waterfowl found in beached-bird surveys in all areas in British Columbia.

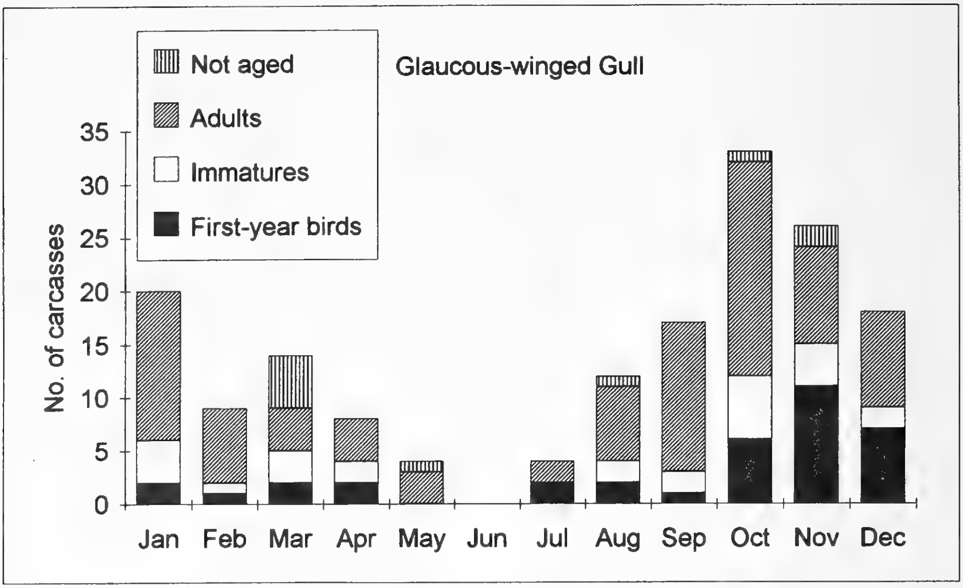

FIGURE 3. Age composition of Glaucous-winged Gulls found in each month in beached-bird surveys. The immature category includes 2- and 3-year olds, as well as some incompletely classified first-year birds. Some birds classified as adults might have been 3-year olds.

west coast of Vancouver Island and in the White Rock-Boundary Bay area, which had the highest overall densities. There are several reasons for the seasonal peak in beached-bird depositions.

First, all of the coastal areas sampled here experience a massive influx of birds in late summer and fall. Many, such as shorebirds or California Gulls, *Larus californicus*, move away as winter sets in, but huge populations of loons, grebes and waterfowl overwinter in British Columbia's coastal waters (Vermeer et al. 1983, 1992; Vermeer and Butler 1989; Campbell et al. 1990). This cannot explain all of the fall and winter mortality, however. Some species, such as Glaucous-winged Gulls, Common Murres, Cassin's Auklets, and Rhinoceros Auklets are present year-round and population densities at sea are not necessarily highest in fall and winter (Morgan et al. 1991). A second reason for the seasonal peak is that high mortality of newly-fledged juveniles occurs at this time and, in the case of the gulls, murres and Rhinoceros Auklets, contributes substantially to the peak. Adult birds, which might be stressed after breeding or while moulting, are more likely to die at this time too.

A third reason for the fall-winter peak is that carcasses are more likely to be deposited on beaches by storms in those seasons than in spring or summer. Again this doesn't fully explain the pattern because days on which many carcasses were found did not always follow stormy weather, and conversely, many intense storms did not bring carcasses ashore. The low wave action and sheltered waters of the Strait of Georgia and Gulf Islands, and at several of the beaches on southern Vancouver Island are obviously major reasons for low carcass deposition there, because many of these sites are adjacent to important feeding grounds of water birds. On the west coast of Vancouver Island, the prevailing winds are more likely to bring carcasses ashore in winter than in summer. The winter winds tend to be from the south or south-west (Thomson et al. 1989), which, in combination with the clock-wise Coriolis forces, will bring floating objects closer to shore. Summer winds tend to be from the northwest and hence have the opposite effect.

There are clearly a variety of topographical, physical and biological processes underlying the marked seasonal and geographical variation in carcass deposition within the areas sampled. This study has demonstrated the importance of some of these, but a longer series of surveys is needed for more rigorous analysis.

Causes of mortality and the impact of chronic oiling

The causes of death could be assumed for very few of the beached-birds. A thorough study will require detailed (and expensive) autopsies, toxicological sampling and microscopic investigations. The effects of industrial effluents, such as dioxins, which are known to affect herons in the Strait of Georgia (Whitehead 1989), could be monitored using fresh material from beached-birds.

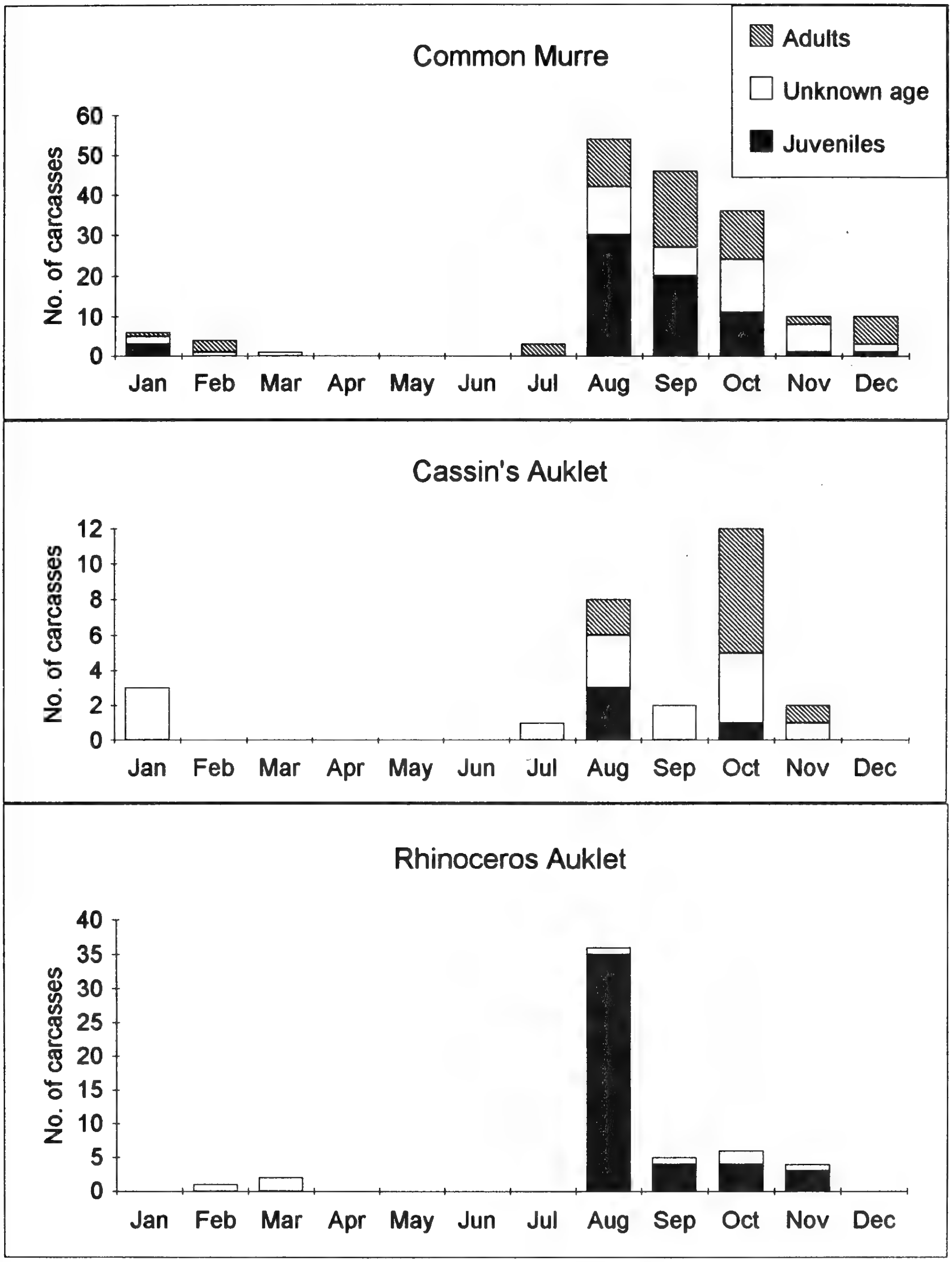

FIGURE 4. Age composition of three species of alcids found in each month in beached-bird surveys.

TABLE 3. Assumed causes of death for beached birds in southern British Columbia. The numbers of birds are shown for each category.

	Area within British Columbia					
Assumed cause of death	WCVI	SVI	SGGI	WRBB	Total No.	Total %
Natural causes						
Storms	2				2	1.7
Starvation	10	2		1	13	11.0
Predators	3	1		5	9	7.6
Broken wing	1		3		4	3.4
Choked on food				1	1	0.8
Human-related causes						
Oiling	28	3	4		35	29.7
Tangled in net or line	1	2	1	5	9	7.6
Shot	2	13	2	24	41	34.7
Injured by dog			3		3	2.5
Possible poisoning			1		1	0.8
Total	47	21	14	36	118	100

Oiling was a conspicuous cause of death among the beached-birds, and most of the victims were killed by small amounts of oil fouling their plumage. Oiling occurred year-round and affected many types of water bird. The overall estimate that 6% of mortality was due to oiling is clearly a minimum value, and the true value may be several times higher. Small amounts of oil on carcasses could easily be overlooked, particularly since the majority of carcasses were scavenged or partly disintegrated.

The 6% estimate of oiled birds is similar to estimates obtained from beach surveys in Washington, the Atlantic U.S., Shetland and Portugal, but lower than estimates from California, Newfoundland, Britain, the Netherlands and Belgium (Table 5). These comparisons are problematic, however, because some reports refer only to birds with known causes of death, whereas others refer to all carcasses found. The mean density of oiled birds per km of beach in British Columbia (0.02) is clearly very low relative to other parts of the world (Table 5). At face value this indicates that mortality due to chronic oiling is less serious in British Columbia than elsewhere. The problem certainly appears less serious here than in Newfoundland or the North Sea, where high shipping volumes, frequent spills and deliberate tank-flushing or bilge-pumping continue to be significant problems (Chardine et al. 1990; Chardine 1991; Camphuysen and Franeker 1991).

TABLE 4. Numbers of birds of each species found oiled, and the percentage of their plumage covered with oil.

	Percentage of plumage oiled					
Species	1 - 5	6 - 10	11 - 50	51 - 90	>90	Total oiled
Pacific Loon			1		1	2
Western Grebe			1			1
Sooty Shearwater		1				1
Cormorant sp.		1				1
Red-breasted Merganser		1				1
California Gull		1				1
Glaucous-winged Gull	3	4	1	1		9
Gull sp.		1				1
Common Murre		4	3	2		9
Pigeon Guillemot		1				1
Cassin's Auklet	2					2
Ancient Murrelet					1	1
Tufted Puffin	1	1				2
Rhinoceros Auklet	2					2
Auklet sp.					1	1
Total	8	15	6	3	3	35

TABLE 5. Summary of beached-bird surveys around the world.

Country or region	Years of coverage (#)	Mean distance per year (km)	Mean corpses per km	Proportion oiled corpses (%)	Approx. oiled corpses per km	References
British Columbia	1989-1993 (4)	367	0.42	6	0.02	This study
California	1971-1985 (14)	(91 beaches)	2.72	83% of known causes	–	Stenzel et al. (1988)
Oregon	1978-1984 (7)	(1 beach)	2.4-7.5	Not known	–	R. Loeffel, *quoted in* Speich and Wahl (1986)
Washington (Inland marine)	1978-1979 (2)	48	0.26	<1	<0.01	Speich and Wahl (1986)
Washington (Open shores)	1981-1984 (4)	Not known	6.64	4.5	0.30	Speich and Wahl (1986)
Atlantic U.S.	1975-1983 (8)	202	1.17	6.6	0.08	Simons 1985
Newfoundland	1980 -1984 (4)	68	7.1	52	3.68	Piatt et al. (1985)
Newfoundland	1984 -1988 (5)	144	4.7	23	0.57	Chardine et al. (1990)
New Zealand	1960-1990 (30)	4347	3.1	Not known	–	Powlesland and Imber (1988); Powlesland (1989)
South Africa	1978-1990 (12)	1678	1.45	Not analyzed	–	Avery (1983, personal communication)
Britain	1971 - 1979 (8) (autumn and winter only)	8890	0.57	47	0.27	Stowe (1982)
Shetland, U.K.	1979-1990 (10)	618	4.24	9.1	0.39	Heubeck (1987, personal communication)
Netherlands	1969-1990 (21)	1282	4.5	68.4	3.08	Camphuysen (1989, personal communication)
Belgium	1962-1977 (15)	63	3.7	70	2.59	Kuyken (1978)
Portugal	1982-1990 (9)	1359	2.4	7.8	0.19	(Teixeira 1986, personal communication)

It is not clear, however, whether the low density of oiled birds is due to the overall low rate of carcass deposition due to the factors outlined above. Experiments with bird-sized drift blocks off the west coast of Vancouver Island in summer and winter showed that only half the blocks released 1-2 km offshore were found on beaches, and only 10% of those launched 35-116 km off were found (Hlady and Burger 1993). Many oiled birds which die at sea are never found on beaches. This obviously also applies to other parts of the world, but there is insufficient information to judge whether oiled birds off British Columbia are more or less likely to be found on beaches than elsewhere.

About 10% of the surveys reported some oil on the beaches, with beaches on the west coast of Vancouver Island having a higher incidence (19%, Burger unpublished data). This suggests that there is a continual low level of small-scale oil pollution in British Columbia waters. Most of the reports referred to relatively small volumes of small tar-balls or oily sheens, but it is certain that the majority of such oil is overlooked on British Columbia beaches, which tend to be littered with large volumes of kelp, logs and other debris. No oil was reported on beaches in 72% of the surveys in which oiled birds were found, confirming that monitoring of seabird carcasses is essential for detecting evidence of the many slicks which do not come ashore (Piatt et al. 1985; Chardine 1991; Camphuysen 1989).

Chronic oiling on beaches and marine ecosystems in British Columbia may be less severe than in highly polluted waters elsewhere. Likewise, the impact of chronic oiling on seabirds off British Columbia might be less severe than that of a major spill, such as the *Nestucca* event, which killed about 56 000 seabirds (Ford et al. 1991). Nevertheless, the presence of oiled birds and oil on the beaches are indicators of a continuing problem which requires attention.

Acknowledgments

This study was funded by B.C. Environment (Emergency Services Branch) and the Royal British Columbia Museum. The advice and support of John Bones, Debbi Hlady, Don Howse and Ken Lozoway of B.C. Environment is appreciated. I thank John Chardine for useful comments on the manuscript. The program depends upon the enthusiasm, goodwill and commitment of the many volunteer surveyors who walk the beaches, pick over smelly carcasses and send in the data. I am extremely grateful to them all.

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Received 27 April 1992
Accepted 21 September 1993

APPENDIX. Species composition of carcasses found in beached bird surveys on the West Coast of Vancouver Island (WCVI), southern Vancouver Island (SVI), the Strait of Georgia and Gulf Islands (SGGI), and the White Rock-Boundary Bay area (WRBB) in British Columbia.

Species	WCVI	SVI	SGGI	WRBB	Total
Red-throated Loon, *Gavia stellata*				2	2
Common Loon, *Gavia immer*	1	2		6	9
Pacific Loon, *Gavia pacifica*	3			1	4
Horned Grebe, *Podiceps auritus*		1	1	7	9
Red-necked Grebe, *Podiceps grisegena*	1	1		2	4
Eared Grebe, *Podiceps nigricollis*		1			1
Western Grebe, *Aechmophorus occidentalis*	3			13	16
Grebe sp.				1	1
Northern Fulmar, *Fulmarus glacialis*	22	1			23
Sooty Shearwater, *Puffinus griseus*	4				4
Short-tailed Shearwater, *Puffinus tenuirostris*	1				1
Fork-tailed Storm-petrel, *Oceanodroma furcata*	1				1
Double-crested Cormorant, *Phalacrocorax auritus*	1	1		1	3
Brandt's Cormorant, *Phalacrocorax penicillatus*	9	1			10
Pelagic Cormorant, *Phalacrocorax pelagicus*	6	1			7
Unidentified Cormorant	4				4
Great Blue Heron, *Ardea herodias*	1	1	1	3	6
Trumpeter Swan, *Cygnus buccinator*	1				1
Canada Goose, *Branta canadensis*		1	4	1	6
Green-winged Teal, *Anas crecca*				40	40
Mallard, *Anas platyrhynchos*		1	6	17	24
Northern Pintail, *Anas acuta*				30	30
American Wigeon, *Anas americana*		1		4	5
Greater Scaup, *Aythya marila*				5	5
Lesser Scaup, *Aythya affinis*				1	1
Scaup sp.				1	1
Surf Scoter, *Melanitta perspicillata*	3			5	8
White-winged Scoter, *Melanitta fusca*	1	3	1	12	17
Scoter sp.		1		5	6
Goldeneye sp., *Bucephala* sp.		1		1	2
Bufflehead, *Bucephala albeola*	1	6		8	15
Common Merganser, *Mergus merganser*				1	1
Red-breasted Merganser, *Mergus serrator*		2			2
Ruddy Duck, *Oxyura jamaicensis*				1	1
Unidentified duck	2	2	2	1	7
Black-bellied Plover, *Pluvialis squatarola*				2	2
Surfbird, *Aphriza virgata*	2				2
Dunlin, *Calidris alpina*				3	3
Semi-palmated Sandpiper, *Calidris pusilla*				1	1
Long-billed Dowitcher, *Limnodromus scolopaceus*				1	1
Red-necked Phalarope, *Phalaropus lobatus*	1				1
Red Phalarope, *Phalaropus fulicaria*	1				1
Unidentified Shorebird	1				1
Parasitic Jaeger, *Stercorarius parasiticus*	1				1
Heerman's Gull, *Larus heermanni*	1				1
Mew Gull, *Larus canus*	2	1		1	4

APPENDIX: *CONTINUED*

Species	WCVI	SVI	SGGI	WRBB	Total
Ring-billed Gull, *Larus delawarensis*	1			4	5
California Gull, *Larus californicus*	30	2			32
Herring Gull, *Larus argentatus*	5			1	6
Thayer's Gull, *Larus thayeri*			2	2	4
Western Gull, *Larus occidentalis*	1				1
Glaucous-winged Gull, *Larus glaucescens*	45	27	10	79	161
GWGU x WEGU hybrid				2	2
Black-legged Kittiwake, *Rissa tridactyla*	2				2
Unidentified Gull	24	3	5	5	37
Common Murre, *Uria aalge*	127	34	1	13	175
Pigeon Guillemot, *Cepphus columba*		3		1	4
Marbled Murrelet, *Brachyramphus marmoratus*	4	1			5
Ancient Murrelet, *Synthliboramphus antiquus*	2				2
Cassin's Auklet, *Ptychoramphus aleuticus*	28				28
Rhinoceros Auklet, *Cerorhinca monocerata*	44	9		1	54
Tufted Puffin, *Fratercula cirrhata*	4				4
Unidentified auklet	4				4
Unidentified alcid	2				2
TOTAL ALL WATER BIRDS	**397**	**108**	**33**	**285**	**823**

Prédation exercée par le Coyote, *Canis latrans*, sur le Cerf de Virginie, *Odocoileus virginianus*, dans un ravage en déclin de l'Est du Québec

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Poulle, M. L., M. Crête, J. Huot, et R. Lemieux. 1993. Prédation excercée par le Coyote, *Canis latrans,* sur le cerf de Virginie, *Odocoileus virginianus,* dans un ravage en déclin de l'Est du Québec. Canadian Field-Naturalist 107(2): 177–185.

La prédation exercée par le coyote (*Canis latrans*) sur le cerf de Virginie (*Odocoileus virginianus*) a été étudiée dans un ravage en déclin de l'est du Québec, au cours d'un hiver particulièrement clément. L'analyse des 319 fèces de coyote récoltées a permis de constater que le régime alimentaire des coyotes présents dans le ravage était à 98% composé de cerfs. Entre le 16 janvier et le 31 mars 1992, durant 33 jours de présence sur le terrain, 32 carcasses de cerfs victimes des coyotes ont été découvertes. Dans cet échantillon, le rapport des sexes était en faveur des mâles. Les faons étaient très sous-représentés dans les proies des coyotes, que ce soit par comparaison avec la récolte de chasse ou par rapport à la structure d'âge décrite dans des études similaires. L'inverse s'est produit pour les animaux âgés de six ans et plus, qui ont constitué la majorité des captures. Par ailleurs, les animaux abattus étaient très majoritairement en bonne condition physique. Bien que l'hiver ait été clément, les coyotes semblent donc avoir exercé une prédation intensive sur les cerfs en raison, vraisemblablement, d'un rapport coyotes-cerfs très élevé.

Mots Clés: Coyote, *Canis latrans*, cerf de Virginie, *Odocoileus virginianus*, régime alimentaire, sélection des proies.

Coyote predation was studied on White-tailed Deer (*Odocoileus virginianus*) in a declining wintering area of eastern Québec during a mild winter. Remains of deer occurred in 98% of the scats (n = 319) collected in the area. From 16 January to 31 March 1992, 32 Coyote-killed deer were found during 33 days of field work. Among these, sex ratio favored bucks. Proportion of fawns in this sample differed markedly from that in hunter-killed deer and from that observed in similar studies. They were underepresented. Old deer (more than six years old) dominated among the preys. Most deer killed by Coyote were in good physical condition. A high Coyote-deer ratio seemed to be responsible for the heavy predation observed on deer despite a mild winter.

Key Words: Coyote, *Canis latrans*, White-tailed Deer, *Odocoileus virginianus*, diet, prey selection.

A l'arrivée des colons européens en Amérique du nord, la distribution du coyote (*Canis latrans*) se limitait aux grandes plaines du centre du continent (Young et Jackson 1951; Nowak 1978). Le déboisement extensif pratiqué depuis le début du siècle, associé à la disparition progressive du loup qui est un compétiteur du coyote (Fuller et Keith 1981; Dekker 1989; Paquet 1991), ont fourni des conditions favorables à l'extension de l'aire de répartition de ce canidé (Young et Jackson 1951; Larivière et Crête 1992). Entre les années 1900-1920 et 1980, le coyote a ainsi progressivement colonisé le nord-est des États-Unis (Richens et Hugie 1974; Hilton 1978) puis les provinces de l'est du Canada: Ontario, Québec, et les Provinces Maritimes (Young et Jackson 1951; Lord 1961; Cartwright 1975; Georges 1976; O'Brien 1983; Moore et Millar 1986; Thomas et Dibblee 1986). Il a été signalé pour la première fois au Québec en 1944 (Young et Jackson 1951).

Dans l'est, en milieu forestier, le cerf de Virginie (*Odocoileus virginianus*) constitue, avec le lièvre d'Amérique (*Lepus americanus*), la base du régime alimentaire hivernal des coyotes (Messier et al. 1986; Moore et Millar 1986; Parker 1986; Dibello et al. 1990). La viande de cerf consommée par les coyotes peut provenir de carcasses d'animaux morts de façon naturelle, de malnutrition ou à la suite de blessures (Nellis et Keith 1976; Berg et Chessness 1978; Haroldson 1981; Parker 1986). Cependant, elle peut également résulter de la prédation exercée par les coyotes sur les faons au printemps (Cook et al. 1971; Garner et al. 1976; Messier et al. 1986) ou sur les cerfs adultes en hiver (Richens et Hugie 1974; Hilton 1978; Perry et Hilton 1980; Messier et al. 1986; Dibello et al. 1990).

Au Québec, le cerf de Virginie se trouve à l'extrême limite nord-est de son aire de répartition (Huot 1973). Il doit affronter des conditions hivernales souvent très rigoureuses. Ses déplacements, et donc sa recherche de nourriture, sont rendus difficiles par la neige épaisse. Dispersés dans tous les habitats disponibles au cours de l'été, les cerfs, à l'approche de l'hiver, se regroupent dans des milieux particuliers pour passer la mauvaise saison. Ces lieux de confinement hivernal portent le nom de "ravages". Ils sont aisément repérables à leur réseau dense de sentiers régulièrement entretenus par le passage des animaux. Cette grande disponibilité de sentiers permet notamment aux cerfs d'échapper plus facilement aux attaques de leurs prédateurs et, ainsi, la concentration des cerfs dans les quartiers d'hiver réduit le risque d'être tués (Messier et Barrette 1985).

La Gaspésie, située complètement à l'est de la province, est la région du Québec qui présente les conditions d'enneigement les plus difficiles pour le cerf (Potvin et Breton 1986). Elle a, de plus, subi une succession d'hivers très rigoureux, de 1989 à 1991 (Breton 1991). Depuis 1988, la récolte sportive y a diminué de façon draconnienne pour atteindre, en 1991, le niveau le plus bas jamais enregistré (Potvin 1991; Lamontagne et al. 1992). Cette baisse très forte de la récolte est vraisemblablement le reflet de la tendance démographique des populations de cerfs de la région, car tous les ravages ont régressé depuis 1988, certains ont même d'ores et déjà disparu (J. Lamoureux, communication personnelle).

Notre objectif était de décrire la relation cerf de Virginie-coyote dans un ravage représentatif de la Gaspésie, région caractérisée par des hivers très rigoureux et par un déclin prononcé des populations de cerfs. L'étude a été effectuée du début de janvier à fin la de mars 1992. Le régime alimentaire hivernal du coyote ainsi que l'âge, le sexe et la condition physique des cerfs victimes de prédation ont été déterminés.

Terrain d'étude

La Gaspésie est caractérisée par des vallées très encaissées. Les ravages de cerfs de Virginie sont limités au bas et au versant des vallées. Les cerfs se cantonnent sur le bord des rivières et ne fréquentent généralement pas les plateaux (J. Lamoureux, communication personnelle).

L'étude a été entreprise dans le ravage de cerfs de Bonaventure, qui était représentatif de l'ensemble des ravages de Gaspésie. En effet, il correspondait à une bande relativement étroite (1 à 4 km) s'étendant de part et d'autre de la rivière Bonaventure et de ses affluents, dans une vallée très encaissée (Figure 1). Le lit de la rivière est situé à environ 100 m au dessus du niveau de la mer alors que les plateaux adjacents, non compris dans l'aire d'hivernage, dépassent souvent les 350 m. En hiver, le ravage n'est accessible que par deux pistes de motoneige.

La couverture forestière est à dominante résineuse: sapin baumier (*Abies balsamea*), épinette blanche (*Picea glauca*), thuya occidental (*Thuja occidentalis*). En moyenne, il tombe 608 cm de neige durant l'hiver, la température minimale est en dessous de −18°C durant 13 jours par année et l'épaisseur de neige dépasse le seuil critique des 50 cm (Severinghaus 1947) durant 92 jours (Potvin et Breton 1986). En 1992, le nombre de jours-enfoncement (qui est l'indice le mieux relié au taux de mortalité hivernal des cerfs: Potvin et Breton 1986) a révélé que cet hiver fut particulièrement clément: 4641 j-cm d'enfoncement, comparativement à une normale de 5926 j-cm pour la période 1976 à 1992. En revanche, l'hiver 1991 fut extrêmement rigoureux car il a totalisé 9756 j-cm d'enfoncement (Breton 1992).

La cartographie du ravage, toujours effectuée durant les mois de février par relevé aérien de pistes, a permis d'estimer la superficie à 121 km^2 en 1987, à 83 km^2 en 1990 et à 48 km^2 en 1992, soit un déclin d'environ 60% en cinq ans (G. Landry et C. Pelletier, communication personnelle). Néanmoins, ce ravage représentait, en 1992, la plus grande aire d'hivernement du Cerf en Gaspésie (G. Landry, communication personnelle) et c'est pourquoi il a été choisi comme site d'étude. L'effectif de la population de cerfs du ravage a été estimé pour la première fois, en février 1992, par la technique du double inventaire aérien (Potvin et al. 1991), sur une superficie échantillonnée de 212 km^2 (Figure 1). Il était de 409 individus ± 159% ($\alpha = 0.05$, $n = 45$ parcelles de 30 ha, 1.9 cerfs /km^2). Le grand intervalle de confiance de l'estimation s'explique en majeure partie par la très faible densité rencontrée, la petite taille de l'échantillon et l'absence de stratification (Crête et al. 1986). Bien que très imprécise, cette estimation s'avère néanmoins plausible car le relevé de traces au sol et par voie aérienne laissait croire effectivement à une très faible densité.

Les traces notées lors des déplacements au sol ont permis de constater la présence de rares orignaux (*Alces alces*) dans le ravage. La densité de lièvres d'Amérique (*Lepus americanus*) semblait très faible. Quelques pistes de renards roux (*Vulpes vulpes*), de lynx (*Lynx canadensis*), de pékans (*Martes pennanti*) et de martres d'Amérique (*Martes americana*) ont également été observées. Les traces de carnivores les plus abondantes étaient cependant, de loin, celles de coyotes.

Méthodes

Une équipe de deux personnes a effectué trois séjours sur le terrain entre le 16 janvier et le 31 mars 1992, pour un total de 33 jours de présence. Ces personnes circulaient dans le ravage en motoneige, parcourant quotidiennement une cinquantaine de kilomètres sur les pistes, les rivières gelées et les sentiers secondaires. L'ensemble des voies accessibles du ravage était parcouru en trois jours, le tour complet du ravage a donc été effectué à 11 reprises au cours de l'hiver. La vallée comprise à l'intérieur des limites du ravage a été parcourue en totalité ainsi qu'une partie des plateaux adjacents.

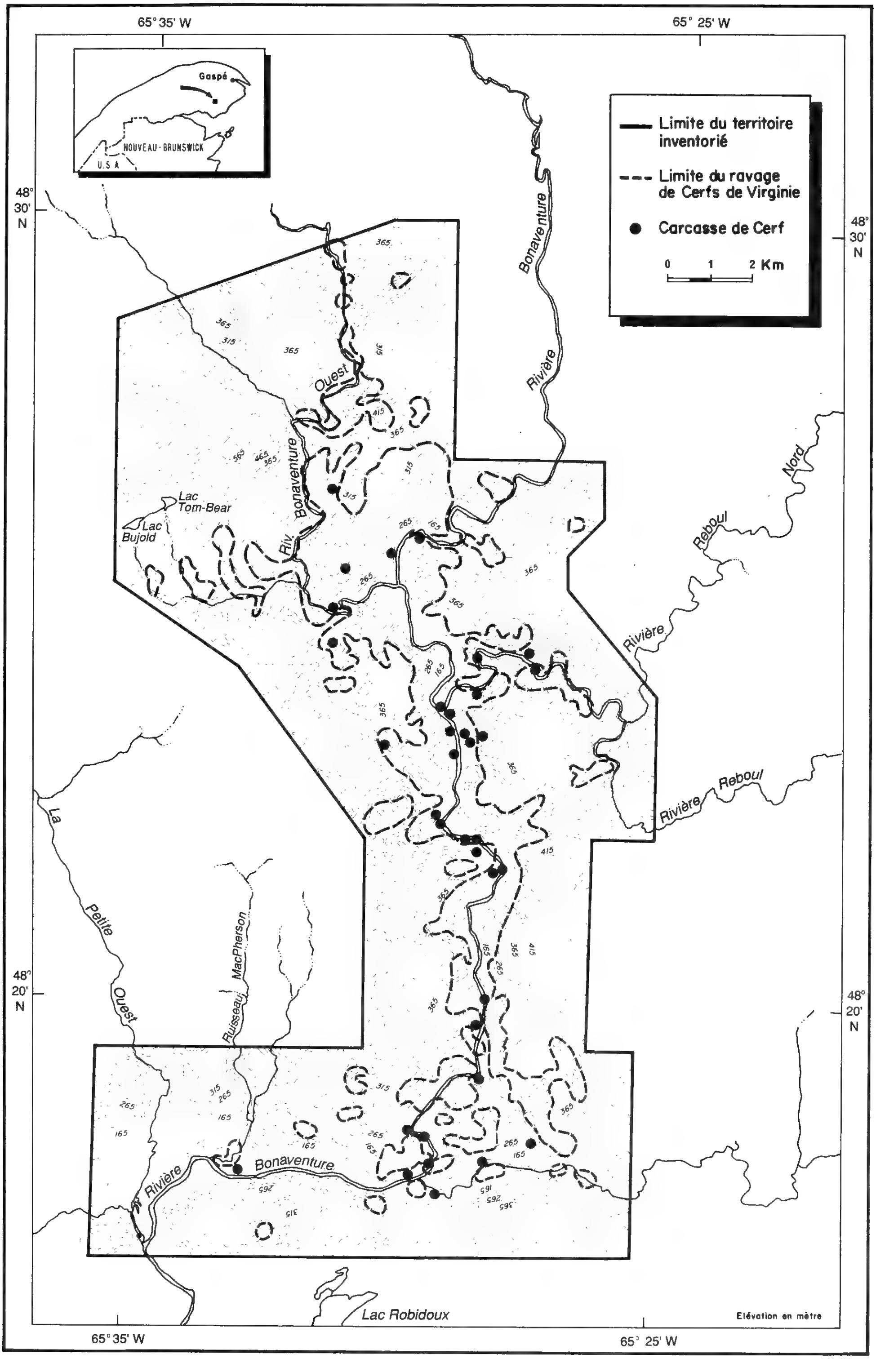

FIGURE 1. Situation du ravage de Bonaventure en Gaspésie, limites du territoire inventorié lors de l'estimation de la densité de cerfs, limites du ravage et localisation des carcasses de cerfs trouvées du 16 janvier au 31 mars 1992.

Toutes les fèces de coyote vues au cours de ces déplacements ont été récoltées; d'autres ont également été ramassées à proximité de carcasses de cerfs qui étaient régulièrement découvertes. L'ensemble de ces fèces a permis la détermination du régime alimentaire par l'examen des restes non digérés qu'elles contenaient. Chacune a été identifiée individuellement à l'aide d'une étiquette portant sa localisation, la date de déposition et la date de récolte. Les fèces ont été congelées jusqu'à leur analyse en laboratoire où elles ont alors été séchées à l'étuve, à 70°C, durant 24 h, pour être ensuite lavées sous l'eau courante dans un tamis à mailles de 2 mm. L'identification spécifique des restes non digérés (dents, griffes, plumes, poils, fragments d'os ou de végétaux) a été faite par examen macroscopique à la loupe binoculaire, en effectuant des comparaisons avec une collection de référence. Les poils ont été identifiés par l'examen de leur coloration, de leur diamètre et de la forme de leurs ondulations. En cas de doute, la structure de la médulla, observée au microscope à un grossissement de 100x, permettait de différencier les poils de cervidés des poils de rongeurs ou de carnivores. La distinction entre les poils de cerfs de Virginie et les poils d'autres cervidés se faisait par l'examen microscopique de la forme des écailles et par la détermination du nombre d'ondulations au 25 mm sur des poils dégraissés et imprégnés dans du tampon de glaçage contenant de la résine. Les résultats ont été exprimés en fréquences d'apparition.

La recherche des carcasses de cerfs a fait l'objet d'une attention particulière. Elle s'effectuait au cours des déplacements quotidiens, à partir du relevé d'indices indirects tels le vol de corbeaux (*Corvux corax*), la convergence de plusieurs pistes de coyotes ou la présence de gouttes de sang ou de touffes de poils sur la neige. La présence du contenu du rumen, qui n'a jamais été déplacé par les animaux venus se nourrir sur les carcasses, indiquait le lieu précis de la mort du (ou des) cerf(s). Des traces de coyotes étaient présentes dans tous les cas à proximité des carcasses. Lorsque la mort était récente, l'examen des pistes dans la neige permettait d'en déterminer la cause. Les signes évidents d'une poursuite ainsi que la présence de sang ou de touffes de poils dans la piste, permettaient de conclure à une mise à mort par les coyotes. Le relevé de tels indices n'a pu être effectué pour les carcasses trop anciennes. Nous ne présenterons que les données concernant les carcasses pour lesquelles la cause de la mort a pu être déterminée.

Le sexe des cerfs dont nous retrouvions la carcasse a été déterminé par la recherche des bases d'implantation des bois sur le crâne. L'âge a été évalué par la méthode de décompte des couches de cément déposées sur la racine des incisives (Ouellet 1977). Le pourcentage de gras de la portion centrale des fémurs, déterminé en utilisant la méthode de séchage de Neiland (1970), nous a servi d'indice de la condition physique des animaux. Lorsque le fémur n'a pas été trouvé, et que le tibia était disponible, ce dernier a été récolté. L'évaluation du pourcentage de gras du fémur (Y) à partir du pourcentage de gras du tibia (X) a été faite par application de la droite de régression calculée par Jolicoeur (1978):

$$Y = 0{,}89\ X - 4{,}96\ (r = 0{,}94;\ n = 50)$$

Résultats

Au cours de l'hiver, 218 fèces ont été trouvées sur les pistes et rivières, et 101 à proximité des carcasses de cerfs. Toutes les fèces trouvées à proximité des carcasses contenaient des restes de cerfs; il en allait de même pour 211 des 218 trouvées ailleurs. C'est pourquoi les deux échantillons ont pu être regroupés pour la détermination du régime alimentaire. Le cerf de Virginie a occupé une place prépondérante dans le régime alimentaire hivernal des coyotes fréquentant le ravage de Bonaventure en 1992. Il est apparu effectivement dans 98% des fèces analysées et, de janvier à mars, cette espèce a véritablement constitué la base du régime alimentaire des coyotes (Tableau 1). En raison de cette omniprésence, aucune tendance saisonnière n'est véritablement apparue. Les lièvres, gélinottes huppées (*Bonasa umbellus*), et petits rongeurs ont constitué des proies secondaires très occasionnelles; une fèces contenait exclusivement des restes de porc-épic (*Erethizon dorsatum*) alors qu'une autre contenait en partie les restes de la

TABLEAU 1. Fréquence d'apparition (en pourcentage par rapport au nombre total de fèces analysées) des éléments du régime alimentaire dans les fèces de coyotes récoltées dans le ravage de Bonaventure au cours de l'hiver 1992.

Période	Nombre de fèces analysées	Fréquence d'apparition des éléments du régime alimentaire						
		Cerf	Lièvre	Gélinotte	Porc-épic	Petit rongeur	Animal de ferme	Graminée
16 au 31 janvier	159	96 %	2 %	3 %	< 1 %	2 %	0 %	6 %
19 au 25 février	43	100 %	0 %	0 %	0 %	0 %	0 %	5 %
9 au 16 mars	82	100 %	4 %	1 %	0 %	0 %	1 %	5 %
31 mars au 1er avril	35	100 %	3 %	0 %	0 %	0 %	0 %	3 %
TOTAL	319	98 %	2 %	2 %	< 1 %	< 1 %	< 1 %	5 %

TABLEAU 2. Répartition, selon l'âge et le sexe, des cas de prédation exercés par les coyotes sur les cerfs dans le ravage de Bonaventure, au cours de l'hiver 1992.

	< 1 an	1 à 5 ans	6 ans et plus	Indéterminé	Total
Mâles	0	2	9	1	12
Femelles	0	4	4	0	8
Indéterminés	2	2	0	8	12
TOTAL	2	8	13	9	32

carcasse d'un animal domestique. Des graminées, vraisemblablement ingérées accidentellement, en consommant une proie, ou volontairement, pour se purger, ont été trouvées chaque mois, mais peu de fèces en contenaient.

Trente sept carcasses de cerfs ont été découvertes au cours des 33 jours de présence sur le terrain. Comme toutes les voies accessibles du ravage ont été parcourues, et comme les personnes présentes sur le terrain ont consacré l'essentiel de leur temps et leur énergie à cette recherche, il est possible de dire que la totalité, ou la quasi totalité des carcasses qui étaient présentes dans le ravage durant ces 33 jours, a été découverte. Les causes de la mort ont pu être établies pour 32 carcasses (les cinq autres étant trop anciennes pour que cette détermination puisse être effectuée), et il s'agissait dans tous les cas de prédation par les coyotes. Les mâles représentaient 60% des 23 cerfs pour lesquels le sexe a pu être établi (Tableau 2). Le ratio des captures ne différait pas significativement du rapport 100 mâles: 100 femelles ($\chi^2 = 0{,}8$; 1 ddl; $p > 0{,}05$).

La structure d'âge des 23 animaux abattus pour lesquels l'âge a pu être déterminé, a été analysée en fonction de trois groupes pour lesquels la vulnérabilité à la prédation est différente (Pimlott et al. 1969, Mech et Frenzel 1971): "jeunes de l'année (moins d'un an)", "adultes (1 à 5 ans)", "animaux âgés (6 ans et plus)" (Tableau 2). La proportion de faons était de beaucoup inférieure à celle de la dernière récolte de chasse sportive non sélective de 1973 (Bouchard et al. 1974, Tableau 3, $\chi^2 = 24{,}3$; 1 ddl; $p < 0{,}05$). Contrairement à ce qui avait été observé dans le ravage d'Amstrong au cours des hivers 1976-1977 et 1977-1978 (Messier et Barrette 1979), la prédation s'est exercée sur les adultes et non sur les faons (Tableau 3; $\chi^2 = 138$; 1 ddl; $p < 0{,}01$). La proportion d'adultes par rapport aux animaux âgés différait fortement de celle de la récolte de chasse de 1973 ($\chi^2 = 237$; 1 ddl; $p < 0{,}01$); en revanche elle ne différait pas significativement de celle des cerfs abattus à Amstrong ($\chi^2 = 1{,}44$; 1 ddl; $p > 0{,}05$). A Bonaventure comme à Amstrong, parmi les cerfs de plus d'un an abattus par les coyotes, la prédation s'est exercée de façon sélective sur les animaux âgés.

Le pourcentage de gras de la moelle du fémur a été déterminée pour 21 des 32 carcasses de cerfs morts par prédation (Tableau 4). Selon les critères établis par Cheatum (1949), tous les cerfs dont la carcasse a été retrouvée en janvier et février étaient en bonne condition physique (% gras de la moelle > 50%), de même que sept des animaux abattus en mars. En revanche, un mâle et une femelle adultes victimes de prédation en mars commencaient à être dans un état de malnutrition (25% < % gras de la moelle < 50%) et deux mâles adultes avaient utilisé la presque totalité de leurs réserves (% gras de la moelle < 25%). Globalement, les cerfs abattus par les coyotes étaient en bonne condition physique avec un pourcentage moyen de gras de 69 ± 6 (écart-type) %.

TABLEAU 3. Structure d'âge des cerfs victimes de prédation ou de la chasse, exprimée en nombre de victimes pour 100 cerfs (comparaison faons-adultes) et en nombre de victimes pour 100 cerfs adultes (comparaison "1 à 5 ans" avec "6 ans et plus").

		Pour 100 cerfs		Pour 100 adultes	
	Effectif de l'échantillon	Faons (< 1 an)	Adultes	1 à 5 ans	6 ans et plus
Prédation par les coyotes dans le ravage de Bonaventure (présente étude)	23	9	91	38	62
Prédation par les coyotes dans le ravage d'Amstrong (Messier et Barrette 1979)	40	65	35	44	56
Récolte de chasse non sélective de 1973 (Bouchard et al. 1974)	142	32	68	88	12

TABLEAU 4. Pourcentage moyen de gras (± écart type de la moyenne) de la moelle des cerfs tués par les coyotes dans le ravage de Bonaventure durant l'hiver 1992.

Période	% moyen de gras	Nombre de cerfs avec 25% < % de gras < 50%	Nombre de cerfs avec % de gras < 25%
92-01-16 au 92-01-31	86 ± 4,5 (n = 8)	0	0
92-02-19 au 92-02-25	76 ± 13,5 (n = 2)	0	0
92-03-09 au 92-03-16	53 ± 8,9 (n = 10)	2	2
92-03-31 au 92-04-01	88 (n = 1)	0	0
TOTAL	69 ± 5,8 (n = 21)	2	2

Discussion

Dans le ravage de Bonaventure, à l'est du Québec, la fréquence d'apparition du cerf dans les fèces de coyotes était de 98% au cours de l'hiver 1992. C'est la plus forte occurence relevée, à date, dans la littérature. Les fortes consommations de cerfs par les coyotes sont d'ordinaire associées aux hivers rigoureux (Ozoga et Harger 1966; Richens et Hugie 1974; Hilton 1978; Messier et Barrette 1979; Todd 1985; Dibello et al. 1990). Or la présente étude a été effectuée lors d'un hiver particulièrement clément. En raison du faible enneigement, les cerfs ont bénéficié de bonnes conditions pour se déplacer et trouver de la nourriture, et il est probable que peu d'entre eux aient eu à souffrir de malnutrition au cours de l'hiver. La majorité des cerfs abattus par les coyotes étaient, d'ailleurs, en bonne condition physique, même en fin d'hiver. L'omniprésence du cerf dans le régime alimentaire des coyotes ne peut donc pas être attribuée à une forte exploitation, par ces animaux, de carcasses de cerfs morts de malnutrition. Nos données laissent penser, au contraire, que la prédation a représenté le principal facteur de mortalité des cerfs de Virginie présents dans le ravage de Bonaventure durant l'hiver 1992.

Les coyotes furent capables de capturer des cerfs adultes, en bonne condition physique, durant un hiver facile, comme cela avait déjà été observé pour les loups (Potvin et al. 1988) et les coyotes (Messier et Barrette 1979; Lavigne, communication présentée au Symposium sur le coyote de l'est, Nouveau Brunswick, 7–8 novembre 1991). Conformément à ce qui a été rapporté pour le Maine (Lavigne *op. cité*), ils n'ont pas exercé de prédation sélective sur l'un ou l'autre des sexes. Nous avons, cependant, supposé que le ratio au sein de la population de cerfs était de 100 mâles: 100 femelles. Or, comme l'espérance de vie des femelles de cerfs est généralement supérieure à celle des males (Nelson et Mech 1986), il est vraisemblable que le rapport réel des sexes ait été déséquilibré en faveur des femelles. Cela serait d'autant plus vraisemblable qu'en Gaspésie, depuis 1974 et à l'exception des années 1981, 1985, 1986, et 1987, seul le prélèvement des mâles par la chasse est autorisé. Dans ces conditions, s'il y avait plus de femelles que de mâles dans la population alors que les deux sexes se retrouvaient en même proportion dans l'échantillon des animaux victimes de prédation, les coyotes auraient eu une légère tendance à sélectionner les mâles.

De plus, les coyotes ont exercé une prédation sélective sur les animaux âgés, ce qui est conforme à ce qui a été observé dans le ravage d'Amstrong (Messier et Barrette 1979). Cependant, contrairement à ce qui a été observé dans ce ravage, et contrairement à ce qui a été couramment rapporté dans la littérature (Hilton 1978; Cook et al. 1971; Messier et Barrette 1985; Parker et Maxwell 1989), très peu de carcasses de juvéniles ont été trouvées. Les travaux de Verme (1969, 1977) ont montré que les hivers très rigoureux peuvent entraîner, en raison de la mauvaise condition physique des femelles, une faible productivité de ces dernières, suivie d'une forte mortalité printannière et estivale des faons. Ainsi, comme l'hiver 1991 a été extrêmement rigoureux, il est probable que peu de faons soient nés au printemps 1991 et que peu de juvéniles aient survécu jusqu'à l'hiver 1992 dans le ravage de Bonaventure. La très faible proportion d'animaux de ce groupe d'âge dans l'échantillon des animaux victimes de prédation (seulement 2 sur 32 carcasses, soit 6%) serait alors le reflet de la structure d'âge de la population de cerfs de Bonaventure, qui aurait été composée essentiellement d'adultes au cours de l'hiver 1992.

Par ailleurs, si l'on ne tient compte que des animaux abattus entre le premier et le dernier jour de présence sur le terrain, c'est-à-dire en ne tenant pas compte des six carcasses retrouvées en début de séjour mais dont la mort remontait à début janvier, les coyotes ont tué au moins 26 cerfs sur une période de 77 jours (16 janvier-31 mars), soit 0,34 cerfs / jours. En extrapolant cette donnée, ont peut considérer que, sur un hiver de 110 jours, au moins 37 cerfs ont pu être abattus par les coyotes dans le ravage. De plus, comme, au cours de l'hiver, nous étions absents du terrain durant deux à trois semaines entre deux périodes successives, il est très vraisemblable que, entre deux séjours, des cerfs aient été abattus et que leurs carcasses aient été consommées sans qu'il n'en reste aucune trace à notre retour. Ceci est d'autant plus plausible, que les carcasses pouvaient être utilisées à 100% en seulement trois à quatre jours (Poulle et al. 1992). C'est pourquoi, il est plus que probable que seule une partie des carcasses de cerfs tués par les coyotes entre le 16 janvier et le 31 mars ait été retrouvée. Une estimation du nombre de coyotes présents dans le ravage et de leur besoins énergétiques permet d'évaluer plus précisemment le nombre total de cerfs abattus au cours de l'hiver.

Au lendemain d'une chute de neige, un relevé de traces de coyotes a été effectué sur la moitié de la longueur totale des pistes parcourues en motoneige dans le ravage. La distance entre les traces, la trajectoire prise par les animaux et la taille des empreintes permettaient de distinguer les traces d'individus différents. Ce relevé a laissé soupçonner la présence d'au moins 18 coyotes différents sur seulement la moitié du ravage. Ce résultat a pu être extrapolé à l'ensemble de la superficie du ravage car les fèces de coyotes récoltées étaient réparties sur l'ensemble des pistes du ravage et leur répartition ne laissaient donc pas supposer qu'une partie de ce dernier ait été plus fréquentée qu'une autre par les coyotes. Une bonne trentaine de coyotes auraient donc fréquenté le ravage durant l'hiver 1992. Le fait qu'un grand nombre de fèces aient été récoltées (n = 319), sans pourtant qu'un effort particulier ait été consacré à cette tâche, tend à confirmer cette estimation. De plus, un piégeage intensif effectué à l'intérieur du ravage au cours de l'hiver 1992-1993 a conduit à la capture de 24 individus (G. Landry, communication personnelle) et tous les coyotes présents dans le ravage durant cet hiver n'ont pas été piégés car des traces fraîches de coyotes ont encore été observées après la fin de la période de piégeage. Finalement, à partir de cette information, du décompte effectué, du nombre de traces observées et du nombre de fèces récoltées tout au long de l'hiver 1992, il est possible d'estimer, avec une assez faible marge d'erreur, qu'au moins une vingtaine, et plus vraisemblablement une trentaine, de coyotes étaient présents dans le ravage durant la période d'étude.

Chaque cerf adulte fournit, en moyenne, 36 kg de viande (Potvin 1986) et chaque coyote a besoin d'environ 2.3 kg de viande par jour (Messier et Barrette 1979). Comme le cerf constituait 98% du régime alimentaire des coyotes présents dans le ravage, il fallait donc, pour 20 coyotes (estimation minimale), 46 kg de viande de cerfs quotidiennement, soit 5060 kg (140 cerfs) pour un hiver de 110 jours. La population de cerfs a été estimée à 409 individus en février 1992, mais cette estimation était imprécise. Le taux de prédation par les coyotes aurait donc atteint environ 35% si l'on se fie à la moyenne (140/409), il aurait été d'au moins 13% si l'on considère l'intervalle de confiance supérieur de l'estimation (1059 individus). Un taux minimal de prédation par les coyotes de 20% peut donc être avancé avec un faible risque d'erreur. Cette estimation qui fait état d'une pression de prédation élevée exercée sur les cerfs dans le ravage de Bonaventure au cours de l'hiver 1992, est d'autant plus vraisemblable qu'au cours de l'hiver suivant (1993), la superficie du ravage n'était plus que de 7,4 km^2, soit six fois moins qu'en 1992.

En résumé, dans le ravage de Bonaventure, au cours de l'hiver 1992, la densité de cerfs était très basse, le taux de recrutement était apparemment faible car les faons étaient rares, et le nombre de coyotes présents (au moins 20) était élevé compte tenu des dimensions restreintes du ravage (48 km^2). La situation décrite correspondait donc à celle pour laquelle des conditions environnementales (une succession d'hivers rigoureux en l'occurence) ont provoqué une diminution de la population de proies, tandis que la population de prédateurs s'accroissait dans le même temps, pour arriver rapidement à un rapport prédateur-proie probablement élevé. Ce type de situation est identifiée comme étant celui pour lequel un prédateur peut avoir un impact majeur sur une population proie (Pimlott 1967; Connolly 1978; Erlinge et al. 1984). Par ailleurs, comme la densité de cerfs était faible, le réseau de sentier du ravage de Bonaventure n'était ni dense, ni bien entretenu, ce qui augmentait d'autant plus la vulnérabilité des cerfs (Messier et Barette 1985).

La Gaspésie présente des conditions hivernales généralement rigoureuses. Elle ne constitue donc pas une région très favorable à l'établissement et au maintien d'importantes populations de cerfs car celles-ci, même en l'absence de prédation, peuvent subir des taux de mortalité allant jusqu'à 40 % lors d'hiver rigoureux (Potvin et al. 1981). Les hivers catastrophiques des années 1989 à 1991 ont vraisemblablement permis aux coyotes de profiter d'une abondance de carcasses ainsi que d'une hausse de la vulnérabilité des cerfs. Des coyotes piégés au cours de l'hiver 1990-1991 à proximité de ravages de cerfs, dans la Baie des Chaleurs, avaient d'ailleurs un important pourcentage de gras, laissant penser qu'ils étaient bien nourris (Poulle et al. en préparation). Comme tous les ravages de Gaspésie ont subi, entre 1987 et 1992, une diminution de leur superficie tout au moins aussi importante que celui de Bonaventure, la situation décrite dans ce ravage peut être généralisée à l'ensemble de la région. Elle fait état d'une prédation importante exercée par les coyotes, au cours de l'hiver 1992, sur une population de cerfs affaiblie par la rigueur des hivers précédents. Cette situation est toutefois très dynamique et les tendances démographiques des deux espèces peuvent se renverser rapidement. Le conditions climatiques et les interventions humaines devraient avoir une influence déterminante sur l'avenir du système cerfs/coyotes en Gaspésie.

Remerciements

Nous tenons à remercier le personnel du Service de l'aménagement et de l'exploitation de la faune du Ministère Loisir Chasse et Pêche à New-Richmond et à Rimouski, et en particulier Gilles Landry et Claudel Pelletier pour les précieuses informations qu'ils nous ont fournies. Nos remerciements s'adressent également à Jean Lamoureux qui nous a communiqué ses données relatives au plan de redressement du Cerf de Virginie en Gaspésie ainsi qu'à Laurier Breton pour avoir mis à notre disposition les données concernant l'enneigement. Cette étude a été financée par le ministère du Loisir, de la Chasse et de la Pêche, par le Fond mondial de la nature, par Outdoor Canada/The sportmen's Shows, par le Service Canadien de la faune et par le CRSNG.

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Received 25 September 1992
Accepted 18 October 1993

Distribution of the Long-tailed Weasel, *Mustela frenata longicauda*, in Alberta as Determined by Questionnaires and Interviews

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Proulx, Gilbert, and Randal K. Drescher. 1993. Distribution of the Long-tailed Weasel, *Mustela frenata longicauda*, in Alberta as determined by questionnaires and interviews. Canadian Field-Naturalist 107(2):186–191.

A study of the distribution of the Long-tailed Weasel (*Mustela frenata longicauda*) in Alberta was conducted in July 1991 through 798 questionnaires and 120 interviews with landowners, resident trappers, and government employees. Five hundred and four responses were received. The presence of Long-tailed Weasel was confirmed in 48 locations on the basis of roadkills, captures and multiple observations. The majority of the confirmed locations delimited a corridor overlapping the black soil zone of the province and the distribution of Northern Pocket Gopher (*Thomomys talpoides*) reported by other researchers. Results of this survey indicate that the Long-tailed Weasel is present in the central and southern regions of Alberta.

Key Words: Long-tailed Weasel, *Mustela frenata*, Northern Pocket Gopher, *Thomomys talpoides*, black soils, Alberta, distribution, threatened species.

The Long-tailed Weasel (*Mustela frenata*) occurs from southern Canada throughout all of the United States and Mexico, southward through all of Central America and into northern South America (Svendsen 1982). It is found in forests, open woodlands, prairies and alpine habitats (Fagerstone 1987) and is considered to be a generalist predator preying upon a variety of small mammals and bird species (Dearborn 1932; Hamilton 1933; Polderboer et al. 1941; Quick 1951; Simms 1979; Gamble 1981). In Alberta, the sub-species *M. f. longicauda* is documented to have occurred in the central and southern parts of the province, including the eastern slopes of the Rocky Mountains (Rand 1948; Soper 1964). In general, the northern distribution of the Long-tailed Weasel is the transition zone between Aspen (*Populus* spp.) parkland and the boreal forest (Soper 1970; Fagerstone 1987), but extralimital records have been previously noted in northern Alberta (Gamble 1981).

Until recently, the species was considered threatened (i.e., is likely to become endangered in Canada if the factors affecting its vulnerability do not change) in Manitoba, Saskatchewan and Alberta by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This status was assigned on the basis of Gamble's (1982) report suggesting that population declines resulted from habitat loss (particularly the aspen parklands) and increased use of agricultural pesticides.

In July 1991, a study was conducted to determine the distribution of this species in Alberta through questionnaires and personal interviews with landowners, resident trappers, and government employees. This paper presents the results of the survey.

Study Area

The study area was determined according to previous Long-tailed Weasel distributions reported by Hall and Kelson (1959) and Banfield (1974). The survey was carried out in central and southern Alberta, in regions south of the 54th North parallel.

Methods

During July 1991, questionnaires were mailed to 330 rural residents randomly selected near 11 communities (30 residents/community) based on delineation of the extent of the Long-tailed Weasel distribution reported in literature. Questionnaires were also mailed to 300 trappers (150 with traplines in Registered Fur Management Areas and 150 trapping on privately-owned and public lands not part of the registered areas) randomly selected from the Alberta Fish and Wildlife Division computer outputs. Finally, 168 questionnaires were sent to government employees (biologists, agriculturalists, park rangers, pest controllers) (Figure 1). Many government employees mailed an unknown number of photocopies to colleagues. All questionnaires were sent with a covering letter explaining the purpose of the Long-tailed Weasel survey and with an addressed postage-paid envelope for their return.

During the month of July, we also visited six regions and interviewed 20 randomly selected rural residents in each region. The content of the interview was identical to that of the mail questionnaires.

Scale reproductions of the Long-tailed Weasel, the Short-tailed Weasel (*Mustela erminea*), and the Least Weasel (*Mustela nivalis*) were provided with real dimensions at the top of the questionnaires. The questionnaires were developed according to one developed by Groves (1988). They asked respon-

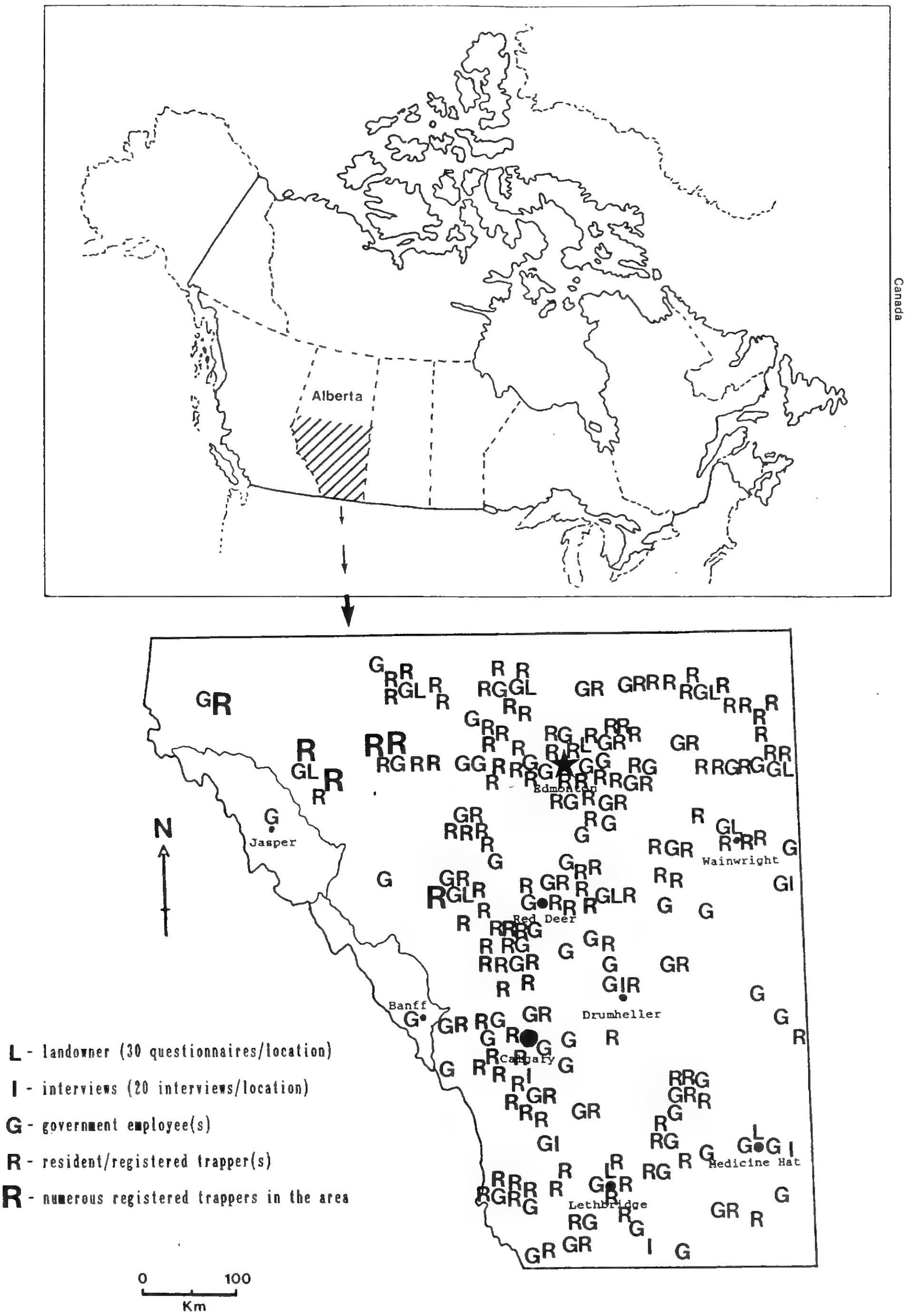

FIGURE 1. Distribution of Long-tailed Weasel questionnaires and interviews in Alberta. The star indicates the position of Edmonton, dots are other major settlements as labelled.

dents to provide information on the date, location (place name, county, township-range-section), habitat type, and type and certainty of observations (seen, roadkill, tracks) they had made, if any, during the last five years. Government employees were asked to provide the number of colleagues they had contacted to answer their own questionnaire. Trappers were also asked to indicate their general trapping area, and the number of Long-tailed Weasels they had captured in the last five years.

Confirmed Long-tailed Weasel reports consisted of a trapper's capture or a carcass properly identified by a government employee. Reports based on tracks alone were discarded because of the difficulty in differentiating between the tracks of the Long-tailed Weasel and the Short-tailed Weasel. Reports based on sightings alone were retained if, for the same location, they were made by at least two respondents of different category (i.e., government, trapper or landowner). In the case of personal interviews, the presence of Long-tailed Weasel in a region was confirmed if at least 25% of the respondents reported a sighting. If a respondent lacked confidence in his/her observation, poorly described the animal, or provided fallacious information, the report was discarded. The confirmed locations were mapped and the outermost point joined up to enclose the area of distribution of the species. This technique was based on Dalke's (1942) home range minimum area method.

Results and Discussion

A total of 384 of 798 mailed questionnaires were received for a return rate of nearly 50% (Table 1). With the 120 personal interviews carried out in six communities, the total number of received questionnaires was 504 (Table 1). The 103 government respondents contacted at least 180 other coworkers before answering their questionnaire. The 384 questionnaires corresponded to 132 independent locations.

The survey resulted in a total of 184 (36.5%) positive responses (Table 1) suggesting the presence of the Long-tailed Weasel in 96 distinct locations. However, the presence of the species was confirmed in only 48 locations on the basis of roadkills, captures, and multiple observations (Figure 2). In 33 (68.8%) of the confirmed locations, Long-tailed Weasels were captures or roadkills (Figure 2).

TABLE 1. Summary of questionnaires/interviews and positive responses on the distribution of Long-tailed Weasel in Alberta, July 1991.

	Number of Questionnaires		Number of Positive
Category	Mailed	Returned (%)	Responses (%)
Government	168[*]	103 (61.3%)	63 (61.2%)
Trappers	300	118 (39.3%)	49 (41.5%)
Landowners	330	163 (49.4%)	50 (30.7%)
Total	798[*]	384 (48.1%)	162 (42.2%)
Interviews	120	120 (100.0%)	22 (18.3%)
GRAND TOTAL	918[*]	504 (54.9%)	184 (36.5%)

[*] Some government offices mailed an unknown number of photocopied questionnaires to their employees.

The majority of the confirmed locations were part of a north-south corridor extending from the 49th to the 54th north parallels (Figure 2). To the west, the Long-tailed Weasel distribution was limited to the Rocky Mountains but two extralimital locations were recorded north of Jasper. To the east of the corridor, a few observations were recorded near Drumheller. Most eastern confirmations occurred in Brooks, Medicine Hat and Cypress Hills Provincial Park (Figure 2).

Respondents observed or captured Long-tailed Weasels in a large variety of habitats: forests, fields, wetlands, roadsides, ditches, creeks, lakeshores, and farmyards. However, most of the confirmed reports were found within the black soil zone of the province (Figure 3a). The remaining confirmations occurred in the brown and grey soil zones, and at the edge of the mountain range (Figure 3a). The distribution of the Long-tailed Weasel overlapped that of the Northern Pocket Gopher (*Thomomys talpoides*) reported by Nietfeld and Roy (1992) (Figure 3b).

It is not always easy to determine where weasels live because they are not evenly distributed in all habitats and their population density fluctuates considerably from year to year (King 1990). Of course, the accuracy of this survey depends on the respondents' ability to recall correctly their observations or to identify the species properly. Fortunately, landowners' observations were often corroborated by the reports of government employees and trappers. Government employees had records of weasels that died and a few specimens were given to the provincial museum. Trappers also referred to their records on the type, time and location of their captures over the years. The large number of answers suggesting multiple observations and captures in similar locations give credibility to this survey.

The confirmed locations of this survey led to the determination of a minimum area of distribution for the Long-tailed Weasel in Alberta. The patchy distribution of questionnaires and interviews contributed to the clustering of observations. The species may be present in other adjacent areas that were not surveyed in this study or where the Long-tailed Weasel was not common enough to be seen by trappers and landowners. Although results of this survey offer little aid in estimating Long-tailed Weasel populations in Alberta, they suggest that this species is still present in the central and southern regions of Alberta, as was reported many decades ago by Rand (1948) and Hall and Kelson (1959). Our study identified northern marginal and extralimital records similar to those

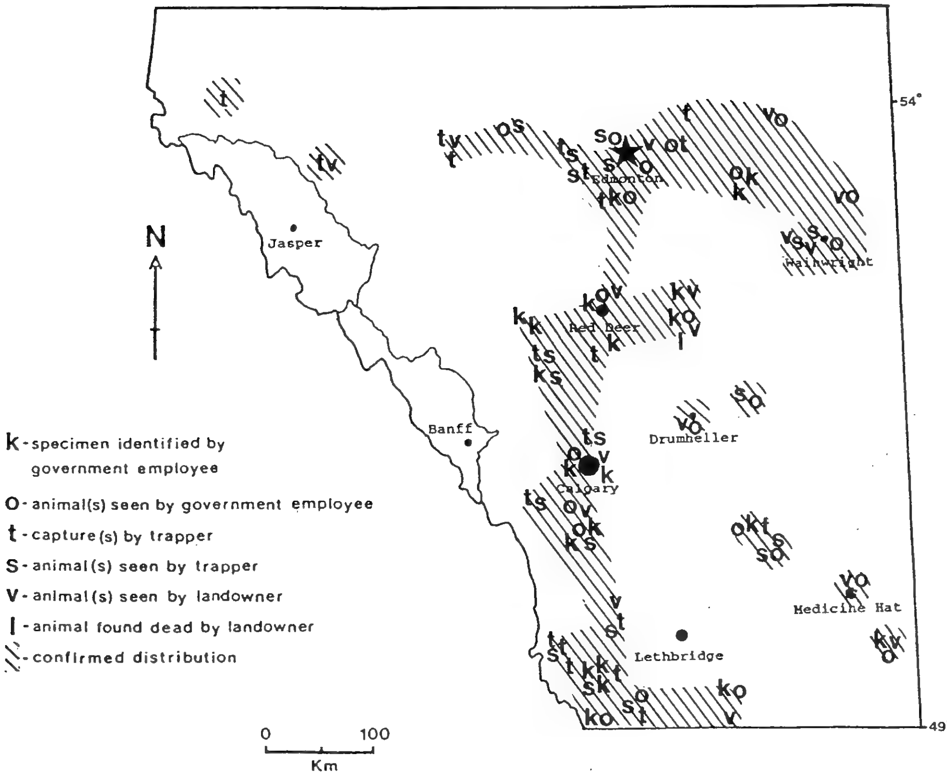

Figure 2. Distribution of the Long-tailed Weasel in Alberta based on questionnaires and interviews, July 1991.

reported by Hall (1951), Soper (1964) and Gamble (1981). Our confirmed locations in Waterton Park were in agreement with Soper (1973). Our patchy distribution in southeast Alberta also corroborated previous findings (Soper 1946; Williams 1946, Smith 1981). On the basis of our findings, and those of other researchers, Johnson et al. (1992) concluded that the Long-tailed Weasel is still common throughout the prairies and recommended to COSEWIC that its status of threatened species be changed to a non-status designation.

The corridor of distribution of the Long-tailed Weasel in Alberta is located in the parklands where open grasslands alternate with groves, drought is not as prevalent as in the prairies, and soils are dark brown in the southern parts and black in the northern parts (Looman and Best 1987). Of course, the parklands offer the most suitable soils for agriculture. Gamble (1982) suggested that, because these soils were heavily transformed by agricultural practices in the western provinces, the Long-tailed Weasel distribution had suffered from a severe reduction in habitat. On the other hand, one must recognize that the transformation of native range into crops may not have been totally detrimental to the Long-tailed Weasel. For example, in Iowa, Polderboer et al. (1941) found that Long-tailed Weasels preferred areas where the dens of Plains Pocket Gopher (*Geomys bursarius*), Franklin's Ground Squirrel (*Spermophilus franklini*), and other burrowing mammals were numerous and close to cover. Alfalfa fields, because of the amount and quality of succulent food they produce, support more Northern Pocket Gophers than any other type of field (Turner et al. 1973). In Alberta, these fields have contributed to the range expansion of the Northern Pocket Gopher populations which now appear to be beyond effective control (Nietfeld and Roy 1992) and may have provided Long-tailed Weasel with valuable habitats. According to Gamble (1982), the Long-tailed Weasel is an ecotonal species which lives in close proximity to free-standing water. The actual mosaic of rangelands, crops and potholes found in central and southern Alberta may therefore be beneficial to the Long-tailed Weasel.

Our study is the first to demonstrate that the distribution of the Long-tailed Weasel in Alberta may be intimately related with that of the Northern Pocket Gopher. While Long-tailed Weasels will den in the burrows of fossorial mammals (Polderboer et al.

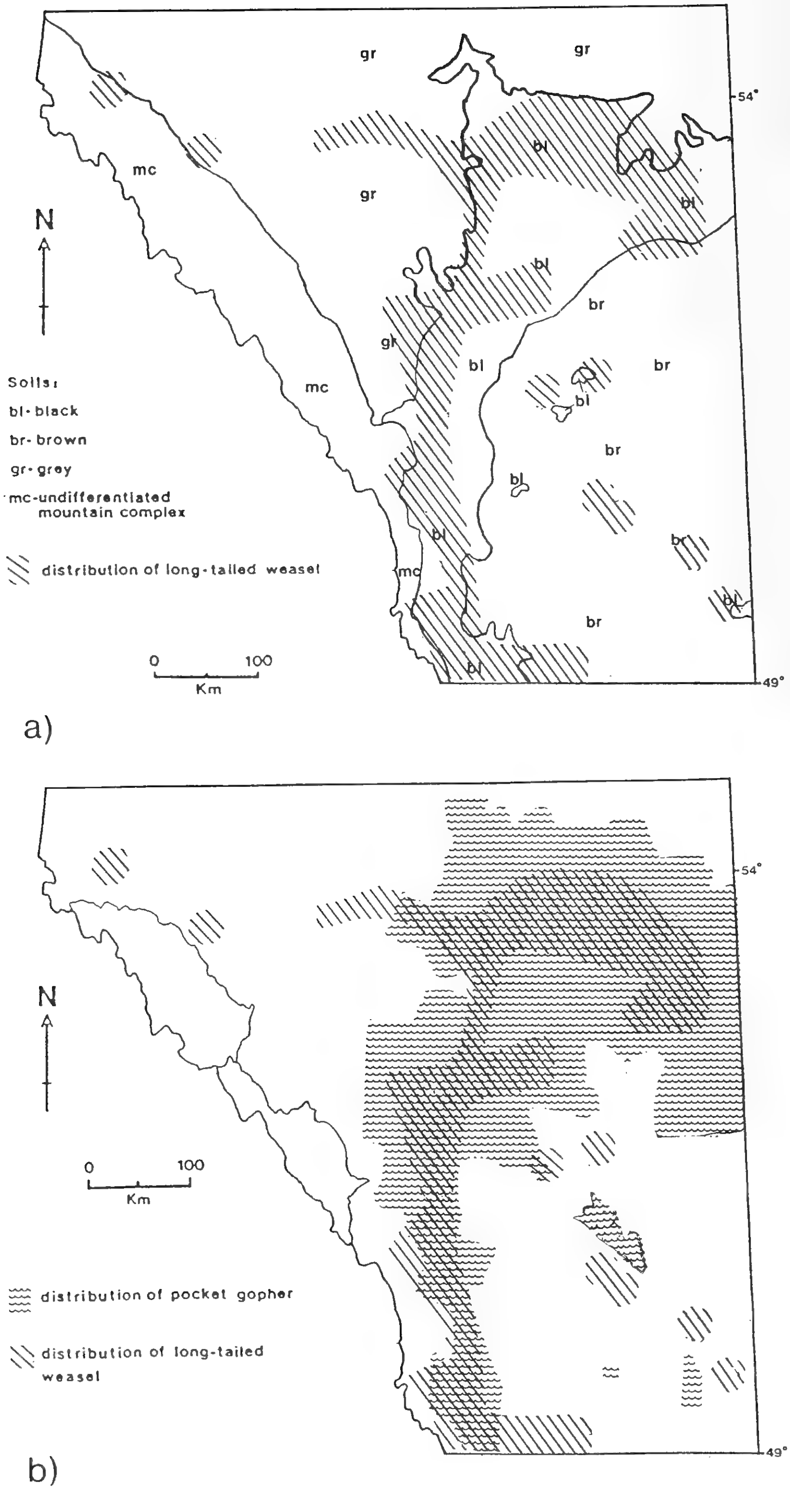

FIGURE 3. Distribution of the Long-tailed Weasel in Alberta in relation to (a) major soil zones and (b) the Northern Pocket Gopher (Nietfeld and Roy 1992).

1941), past food habit studies failed to report pocket gophers as an important prey (see Svendsen 1982). It is possible, however, that Long-tailed Weasels prey on other species that use pocket gopher burrows and mounds. Whittaker et al. (1991) reported a relationship between Meadow Vole (*Microtus pennsylvanicus*) distribution patterns and the location of Plains Pocket Gopher mounds and open areas. More studies will be required to explain better the relationship existing between the Long-tailed Weasel, the Northern Pocket Gopher, and other vertebrates inhabiting gopher burrows.

Results of this survey indicate that Long-tailed Weasel populations are present in the central and southern regions of Alberta. Ecological studies of the Long-tailed Weasel are now needed to determine its seasonal requirements, establish its relationships with other mammals, assess the impacts of agriculture on its populations, and better explain the limits of its distribution.

Acknowledgments

This work was supported by the Alberta Fish and Wildlife Division. We thank all the government employees, trappers and landowners who participated in this study. We are grateful to B. McFetridge, P. Cole and A. Kolenosky for their advice, and P. S. Grey for typing the manuscript.

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Received 1 April 1992
Accepted 2 December 1993

Observations on the Life History and Distribution of the Showy Pond Snail, *Bulimnea megasoma* (Say) (Gastropoda: Pulmonata) in Southeastern Manitoba

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McKillop, W. B., W. M. McKillop, and A. C. Conroy. 1993. Observations on the life history and distribution of the Showy Pond Snail, *Bulimnea megasoma* (Say) (Gastropoda: Pulmonata) in southeastern Manitoba. Canadian Field-Naturalist 107(2): 192–195.

This study examines the growth rate of the Showy Pond Snail *Bulimnea megasoma* (Say). The results indicate that this large gastropod is long lived with a four to five year life span. Egg laying begins in the second summer. Although in Manitoba the species is increasingly difficult to find, specimens can still be observed in the undisturbed relatively soft waters of larger streams and rivers along the western edge of the Canadian Shield.

Cette étude examine le taux de croissance de l'escargot bulimnée géant, *Bulimnea megasoma* (Say). Cet escargot a une durée moyenne de vie de quatre à cinq ans et commence à pondre ses oeufs durant l'été de la deuxième année. Bien qu'au Manitoba cette espèce devient de plus en plus difficile à trouver, des spécimens peuvent encore être observés dans les eaux douces et calmes des grands cours d'eau situés à la bordure ouest du bouclier canadien.

Key Words: Showy Pond Snail, *Bulimnea megasoma*, growth curve, distribution, water quality, threatened species, Manitoba.

Previous research on freshwater gastropods in Manitoba by McKillop (1985) and Pip (1978) indicated that little was known about the life history and distribution of the pulmonate snail *Bulimnea megasoma.*

In Manitoba, as in other areas of North America, this species is rare or locally extirpated (Grimm 1975; Pip 1978). In a study in northern Minnesota, Gilbertson et al. (1978) noted that the species was generally found in the prairie-forest ecotone (parkland), whereas in Manitoba both McKillop (1985) and Pip (1986) found the species in the southern fringe of the boreal biome and only infrequently in the parkland ecotone. Clark (1973) noted that Bell in 1881 found the species in central Manitoba, a finding supported by W. B. McKillop in 1992 during a Province-wide survey. Here, the bedrock, soils and waters are similar to that 350 km to the south where the species has been collected more frequently.

Pip (1985, 1986, 1988) studied gastropod and macrophyte diversity and relationships with selected water chemistry parameters. The present study supports Pip's findings and those of McKillop (1985) with regard to water chemistry, and provides additional data specifically for *Bulimnea megasoma.*

Gilbertson et al. (1978) noted that this species had an annual life cycle with individuals living 12 to 14 months, whereas McKillop (1985) suggested it was long-lived, with at least a triennial life history. In that study (McKillop 1985) the number of specimens taken was limited, preventing the construction of size-frequency tables from which adequate life history information could be drawn. Since the size-frequency tables developed in these earlier studies were incomplete, it was hoped that this inconsistency could be addressed. In the present study we have investigated the growth rate of this pulmonate in the laboratory and integrated this information with observations gathered in the field, thereby yielding a more accurate life history growth curve.

Materials and Methods

Ten sites known to contain *Bulimnea megasoma* were selected in southeastern Manitoba (Figure 1). Seven of these sites had been studied previously (McKillop 1985). In May and June of 1988 both water and biological samples were collected from these ten sites.

Water was collected in plastic bottles, kept cool and returned for analysis the same day. Water analyses were made by the Manitoba Technical Services Laboratory using methods outlined in the Analytical Methods Manual (Anonymous. 1980. Analytical Methods Manual. Technical Services Laboratory, Winnipeg, Manitoba. Unpaginated). To ensure accuracy, these data were used only when the charge balance error was less than 5.0%.

Snails were collected by vigorously sweeping a hand net, with mesh openings of 0.2 mm, through the submerged vegetation as described by McKillop and Harrison (1972). Samples were returned to the laboratory in plastic bags where *Bulimnea megasoma* specimens were removed and placed in covered, aerated aquaria. These aquaria were maintained at room temperature (approximately 21°C) on a

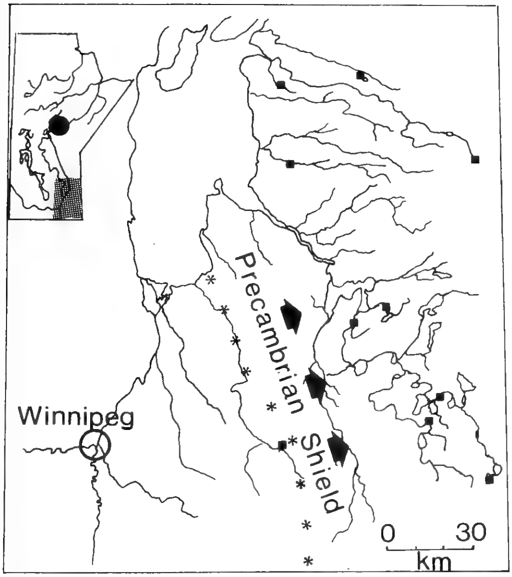

FIGURE 1. The study area, showing the 10 collection sites (●) in relation to the demarcated (*) Canadian Shield — dolomite interface. The north-central area of the Province where the species has been collected is shown on the inset map (●).

window sill subject to north ambient lighting. Because of the proximity to the laboratory, both water and specimens used in the laboratory were taken from Hazel Creek (49° 53'N; 96° 14'W) (site 17 of McKillop 1985). No experiments were undertaken using softer waters. Although considerable effort was made to locate the hatchling and juvenile stages in the field, no individuals smaller than 8 mm were found. Information on these stages was gained by raising young from egg masses derived from mature laboratory specimens. In addition, the simultaneous raising of a variety of larger specimens in the laboratory was necessitated by difficulties experienced with mark and recapture techniques, vandalism of containment cages, the slow growth rate and lack of distinct size classes in the field. Throughout the ice-free season creek water was collected approximately bi-monthly and stored in covered plastic containers. In autumn, larger amounts of water were collected for use throughout the winter.

Weekly, the snails were fed lettuce (*ad libitum*), faecal matter was removed, and fresh aerated creek water added. Complete water changes were made bi-monthly except during winter when more limited water supply allowed less frequent (approximately monthly) changes of water.

The laboratory growth experiments continued over a 24 month period, with the growth of individuals from various size classes being monitored. Measurement of shell height (spire tip to base) for the larger shells was made at approximately monthly intervals using a vernier caliper. The juvenile stages were measured bi-monthly and the hatchlings weekly, using a stereo microscope equipped with an eyepiece micrometer.

The aquaria were monitored daily and when egg masses were noted the adult snails were removed from these aquaria to prevent predation. The egg masses and the eggs therein were measured approximately bi-weekly.

Results

Water samples were taken from all ten sites twice but the charge balance error of 7 analyses exceeded 5.0 % and hence only 13 analyses were included in the statistics for water quality parameters (Table 1). The mean values for the two samples from Hazel Creek are presented as representative of the water used in the aquaria.

The growth curve (Figure 2) was derived from both laboratory raised hatchlings and from larger individuals brought from Hazel Creek and raised in the laboratory. For the smaller specimens it represents the mean size/age (growth rate) of multiple cohorts of hatchlings raised for upwards of a year. For specimens larger than 12 mm the curve was generated by calculating the mean growth rate of specimens brought from the field, categorized into 5 mm size classes and raised in the laboratory for periods of upwards of 18 months.

Specimens exceeding 24 mm and brought from Hazel Creek in spring commenced egg laying within a month of capture with peak egg production occur-

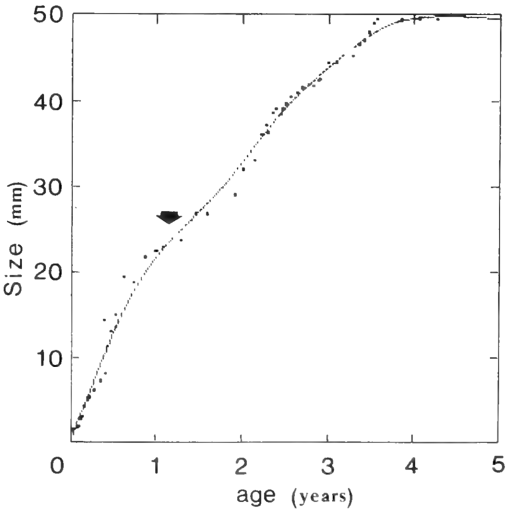

FIGURE 2. *Bulimnea megasoma* growth curve. The size at first egg production is indicated.

Table 1. Water chemistry (N = 13)

	Conductivity (µmho/cm)[a]	pH units	$CaCO_3$ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	SO^{2-} (mg/L)	Residue Filtrate (mg/L)	Cl^- (mg/L)	Na^+ (mg/L)	Fe^{3+} (mg/L)	Mn^{3+} (mg/L)	Colour units	Turbidity (NTU)[b]	F^- (mg/L)	Total N (Kjeldhal) (mg/L)	NH_3^c (mg/L)	$NO_3 + NO_2^d$ (mg/L)	ortho-PO[e] (mg/L)
Minimum	57.8	5.9	10.0	5.0	2.0	4.7	54.0	1.6	1.0	0.05	0.02	15.0	0.79	0.10	0.50	0.01	0.01	0.02
Maximum	347.0	8.7	202.0	56.0	19.2	34.2	290.0	55.0	26.0	6.40	0.29	100.0	8.20	0.19	4.00	0.42	5.90	0.50
Mean	121.2	7.2	50.0	14.5	6.5	11.5	136.4	6.1	7.1	1.00	0.09	45.4	3.13	0.11	1.45	0.05	0.26	0.08
SD	66.7	0.7	44.2	10.5	4.3	6.5	69.4	11.7	5.3	1.51	0.08	18.9	2.26	0.03	0.84	0.08	1.11	0.10
Lab Water Mean	307.5	8.1	187.0	45.0	19.2	9.6	270.0	2.6	8.1	0.29	0.16	37.5	1.95	0.17	1.50	0.03	0.01	0.04

[a] 1 mho = 1 siemens.
[b] Nephelometric turbidity units.
[c] Soluble NH_3 expressed as N
[d] Dissolved NO_3 plus NO_2 expressed as N.
[e] Soluble orthophosphate expressed as P.

TABLE 2. Number of Eggs/Mass (N = 18)

Min = 40
Max = 350
Mean = 116
SD = 78

TABLE 3. "U" Egg Mass Size (N = 18)

	Length (mm)	Width (mm)	Diameter (mm)
Min	14.7	10.9	5.2
Max	32.8	29.7	7.7
Mean	22.3	17.6	6.3
SD	6.4	6.0	0.89

ring during the period May to July. The larger snails generally produced the larger egg masses containing the larger number of eggs (Table 2). Egg masses were U-shaped gelatinous tubes measuring about 22.3 X 17.6 mm with diameters of ca. 6.3 mm (Table 3). The oval eggs were ca. 1.0 X 1.4 mm and the embryos therein ca. 0.2 mm in diameter. The eggs took approximately 21 days to hatch, at which time the hatchlings' shell heights were ca. 1.2 mm.

Discussion

In Manitoba, *Bulimnea megasoma* is found along the western edge of the Canadian Shield. Waters in this area are, for the most part, relatively soft (McKillop 1985) and lie at the lower end of the water chemistry range. Specimens of *B. megasoma* were collected from ten stream and river ("lotic") sites in southeastern portion of the Province. All of these sites showed evidence of ponding with water depths exceeding 1 m locally and very slow flows were the norm. Clarke (1973) noted that Bell in 1881 had collected the species in the Echimamish River, part of the Nelson River system at 54° 20'N; 97° 27'W. Today, much of this area is dry having been impacted by a massive hydro-electric development. In 1992, during a Province-wide study, we collected this species from but one site north of those noted in Figure 1. This "lentic" site, on the Nelson River system at Ponask Lake, 53° 50'N; 96° 31'W, is approximately 80 km southeast of Bell's site. Here, as in the south where the species has been taken more frequently, both bedrock and soils lack the ability to neutralize acids.

In the present study, the results gathered in the field support previous work by Pip (1978, 1985, 1986, 1988) and McKillop (1985). Pip indicated that the species was sensitive to high values of phosphate, pH and total alkalinity, requiring in general low concentrations of inorganics. On the other hand, McKillop's regression predictors for this species showed nitrate and nitrite nitrogen, calcium and colour, as positive correlations. The present study broadened the range for some parameters over the previous studies.

Herein, we report a growth rate lower than that mentioned in the preliminary work by McKillop (1985) and our findings that *Bulimnea megasoma* lives up to four years is in marked contrast with Gilbertson et al. (1978), who suggested an annual life cycle was the norm. Their study indicated that 45 mm was the normal maximum size, although a few reached 50 mm and probably represented slightly longer-lived specimens that had hatched early the previous spring. Although our maximum size measurements are similar, the present study indicates that snails take approximately 3.5 years to reach 45 mm and an additional year to reach 50 mm. McKillop (1985) reported maximum sizes of 40.0 mm, 48.5 mm and 53.4 mm for individuals living in soft, medium and hardwaters respectively (maximum size recorded from Hazel Creek, Manitoba). The water used in the laboratory was at the upper end of this range and has been previously classified as hard (McKillop 1985) since the site is located off the Shield, in the parkland ecotone, west of the Ordovician dolomite-Precambrian granite contact. While our laboratory findings support those of Gilbertson et al. (1978), in that the number of hatchlings peaked in the period May - July, we found that a full year elapses before the 20 mm size is attained. In Minnesota, this size is apparently reached within a couple of months. In the current study, we observed that egg laying did not commence until a shell height of 24 mm is reached, at which time snails were more than one year old. Nevertheless, as outlined above, snails living in softer water had a smaller maximum size and it is probable that these snails may start laying eggs at a somewhat smaller size than those from Hazel Creek. Unfortunately, we did not use softer waters in the current experiment and hence we are unable to determine at what size specimens living in soft water commence egg laying. Hatchlings measured approximately 1.2 mm and grow to less than 12 mm by autumn. As in our study, it is probable that Gilbertson et al. (1978) simply were unable to observe or collect hatchlings in the field as they do not record sizes smaller than 5 mm. Thus, the apparent lack of hatchlings in the field must be an artifact of sampling technique.

It is unfortunate, but *Bulimnea megasoma* is now rarely observed even at sites that harboured large numbers as recently as the mid 1970s. The deterioration of water quality appears to be the obvious factor affecting the species. Hence, in an effort to draw the plight of this animal to the attention of Government authorities, thereby providing some protection to the species, it has been recommended that *B. megasoma* be classified as vulnerable and added to the province's provisional listing of Endangered Plants and Animals.

Acknowledgments

The Manitoba Heritage Federation Inc. and the Manitoba Museum of Man and Nature provided financial support for this research. We thank F. Zawislak for her assistance.

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Received 4 May 1992
Accepted 25 November 1993

Spring Migration Routes of Common Loons, *Gavia immer*, through the Sault Ste. Marie Region of the Great Lakes

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Sanders, Chris J. 1993. Spring migration routes of Common Loons, *Gavia immer*, through the Sault Ste. Marie region of the Great Lakes. Canadian Field-Naturalist 107(2): 196–200.

Spring migration of Common Loons (*Gavia immer*) near Sault Ste. Marie, Ontario, was observed at several locations simultaneously on one day each year from 1985 to 1992. The loons passed on a broad front spanning at least 50 km. The main route was southeast to northwest from the northwest corner of Lake Huron, past the Sault Ste. Marie waterfront and out into Whitefish Bay of Lake Superior past Gros Cap. Observed loons flew in loose associations at heights between 50 and 200 m. Numbers peaked at over 100/h, and the majority passed between 1 and 4 h after dawn. No concentrations of loons were seen on the water in the vicinity of Sault Ste. Marie.

Key Words: Common Loon, *Gavia immer*, Red-throated Loon, *G. stellata*, Pacific Loon, *G. pacifica*, spring migration, migration routes, Sault Ste. Marie, Great Lakes.

For many years birdwatchers have been aware that large numbers of loons pass over Sault Ste. Marie (46°31′N, 84°20′W) each spring. Since 1982, counts of waterfowl and raptors have been made at Whitefish Point on the south shore of Lake Superior (Ewert 1982), and in 1983 the Michigan Audubon Society established the Whitefish Point Bird Observatory to study bird migration at the Point. As many as 5000 Common Loons (*Gavia immer*), 50 Red-throated Loons (*G. stellata*) and a few Pacific Loons (*G. pacifica*) have been counted passing Whitefish Point each year (Annual Reports, Whitefish Point Bird Observatory, Paradise, Michigan, 49768).

Ewert (1982) speculated that, because loons were approaching Whitefish Point from the southeast, the St. Mary's River was a likely corridor for loons migrating from Lake Huron. However, no observations have previously been reported on the spring migration of loons along the St. Mary's River, although many residents of Sault Ste. Marie have been aware of large numbers of loons flying over the city in the spring.

In 1985 a group of volunteers in the twin cities of Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan, carried out synchronised observations at a number of key points between Lakes Huron and Superior in an attempt to determine loon migration routes through the area. This report summarises the observations for 1985 through 1992.

Methods

A day for the observations was selected each year in early May, which is the peak period for loon migration in this region (Ewert 1982; Annual Reports, Whitefish Point Bird Observatory). The observation sites are shown in Figure 1, although not all sites were used each year. A distinction was made between the St. Mary's River corridor, which includes the sites between St. Joseph Island to the east and Gros Cap and Point Iroquois to the west, and the sites along the east shore of Lake Superior. At Whitefish Point, observations were made daily through spring each year. Although they do not form part of this report, they are referred to where relevant.

The volunteers counted the loons passing from dawn until at least 12:00 noon [all times are in Eastern Standard Time] or until migration was over for the day. In addition to the counts, observers recorded species and plumage where possible, and the direction and height of flight.

Sufficient volunteers were mustered for only one day of counts each spring during peak loon migration. Also it was necessary to select the observation day some time in advance. Consequently conditions were not always ideal, either from the loons' or the observers' points of view. Nevertheless, the counts were carried out regardless of the weather, which has provided data covering a variety of weather conditions.

Results and Discussion

The observation dates, total numbers of loons recorded and the numbers at two key sites, Gros Cap and Whitefish Point, are shown in Table 1. Also included are climatic conditions at 09:00 on the observation days, as recorded in the Monthly Meteorological Summary for Sault Ste. Marie, Ontario, airport (Anonymous 1985 through 1992).

Identification

Most loons were too far away to distinguish their plumage, or even for positive identifications. Those that could be identified were Common Loons in

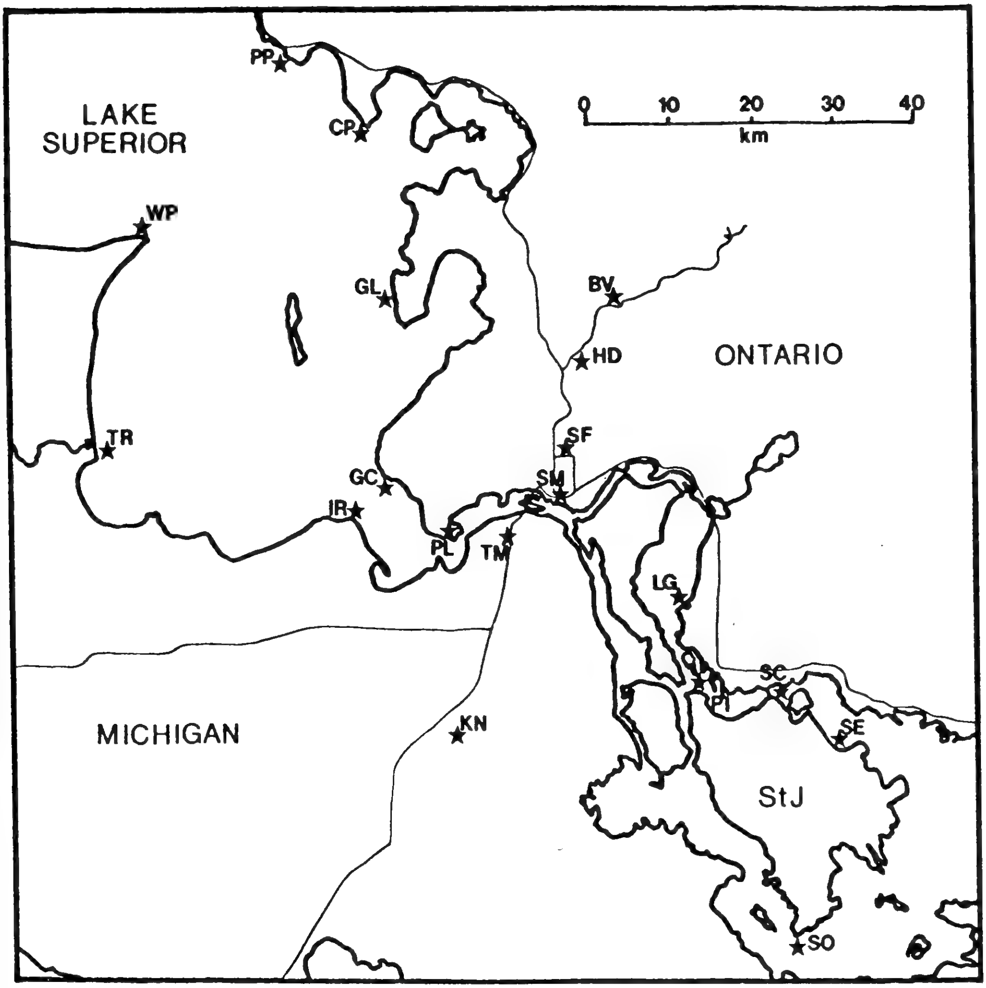

FIGURE 1. Map of the Sault Ste. Marie region of the Great Lakes, showing the location of the observation sites from which loon migration was recorded. See Table 3 for names corresponding to the abbreviations.

breeding plumage, with the exception of four loons passing Gros Cap in 1990 and three flying up the St. Mary's River past Sault Ste. Marie in 1992, which were identified as Red-throated Loons. Of 4838 loons recorded by Ewert (1982) passing Whitefish Point in 1982, only 18 were Red-throated Loons, and of 1150 Common Loons, for which plumage characteristics could be seen, all but 29 were in breeding plumage.

Times of flight

Sunrise at Sault Ste. Marie on 5 May is about 05:20, on 10 May, 05:15. Given that civil twilight extends daylight for a further 38 minutes at this time of year, there is enough light at 05:00 to see flying loons and in most years the first loons were seen as soon as there was sufficient light to detect them. Numbers peaked during the second hour of daylight, between 06:00 and 07:00 (Table 2), which is about 1 h earlier than at Whitefish Point, 60 km further west (Ewert 1982). On five of the observation-days most of the loons passed between 06:00 and 08:00. On the other three days (1985, 1988 and 1992), some loons passed through well into the afternoon. On these days the distribution was distinctly bimodal, with a first peak between 06:00 and 06:30, and a second between 08:30 and 09:00, which suggests that there were two waves of migrants (Table 2).

During fall migration loons congregate on the waters of both Lakes Huron and Michigan in sizable flocks or "rafts" (McIntyre 1988), but there are no

TABLE 1. Dates of loon migration observations with weather data from Sault Ste. Marie airport and a summary of the total numbers of loons recorded, and the numbers at two vantage points, Gros Cap and Whitefish Point.

Year	Day	Temp °C at 09:00	Wind direction (km/hr) at 09:00	Number of sites	Number of loons		
					Total	Gros Cap	Whitefish
1985	May 11	17.0	ESE 17	7	1208	332	473
1986	May 10	13.3	E 11	11	266	34	97
1987	May 9	19.0	WSW 24	6	232	13	24
1988	May 7	12.7	ESE 22	7	1638	340	147
1989	May 7	1.2	NW 26	7	446	182	37
1990	May 5	7.1	WNW 22	9	1025	523	132
1991	May 4	2.2	ESE 17	7	1221	364	259
1992	May 10	16.3	ESE 9	9	2573	628	307

records of rafting in the Great Lakes during spring migration. A total of only 14 loons were recorded on the water in the St. Mary's River corridor during the eight observations days and only five on the water off the east shore of Lake Superior, although a party of about 20 were recorded off Pancake Point on 11 May, 1983 (A. G. Gordon, personal communication). Similarly, there is no information on where the loons terminate their migration for the day. Although most of the migrating loons pass Sault Ste. Marie before noon, only 20 were seen to interrupt their steady flight to the northwest, 16 circled one or more times and flew on, four landed. Where the loons spend the rest of the day and the following night is therefore not known.

Behaviour

At all locations, the loons flew singly or in "loose associations" as described by Ewert (1982). Their estimated heights were between 50 and 200 m. When flying into a strong headwind they tended to fly lower than they did on calmer days or on days with a following wind. When out over the waters of Lake Superior, they again flew lower, as recorded by Ewert (1982). This contrasts with the report by Kerlinger (1982) who tracked loons with radar over Albany, New York at heights between 1500 and 2700 m above sea level (where many were invisible to the naked eye). Possibly they flew this high to cross the Catskills or Adirondacks which rise over 1500 m. It is unlikely that any loons pass through the Sault Ste. Marie region at this height (Lake Superior is only 200 m above sea level); none were seen at intermediate heights and with constant use of binoculars to spot both loons and, on other occasions, raptors, higher-flying loons would be detected sooner or later if they were present.

Most of the loons passing through the St. Mary's River corridor were travelling northwest. Out of 6566 loons for which directions were recorded, 89.3% were going northwest, 4.2% west and 3.7% north. In 1989, 29% of the total 446 seen were flying south. This was the coldest of all the observation days. There was a frost the previous night, and the temperature at the Sault Ste. Marie airport at 09:00 was only 1.2°C, and the high for the day was only 4.0°C, with strong northwest winds and snow showers.

During the eight years 138 loons were recorded from the sites along the east shore of Lake Superior. Of these, 56.5% were headed north, 43.5% northwest. This indicates a tendency for some to swing to a more northerly course once they have passed through the St. Mary's River corridor, possibly fol-

TABLE 2. Numbers of loons passing through the Sault Ste. Marie area recorded each hour, divided into those years when loon migration virtually finished by noon, and those years when it extended well into the afternoon (1985, 1988 and 1992).

	Hour (EST) ending :-								
	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00
1985, 1988, 1992	478	1737	1081	866	605	119	45	66	20
Other years	547	924	524	171	74	26	1	1	0
Totals for all years	1025	2661	1605	1037	679	145	46	67	20
% of Grand total	14.1	36.5	22.0	14.2	9.3	2.0	0.6	0.9	0.3

TABLE 3. The percentages of loons passing each observation site shown in Figure 1, averaged for the numbers of years of observation at the site.

Site	Abbreviation (see Figure 1)	Years of observation	Percent of total count
Lake Superior (south shore)			
Whitefish Point	WP	8	9.9
Tahquamenon River	TR	1	0.5
Lake Superior (east shore)			
Corbeil Point	CP	2	0.8
Goulais shoreline	GL	2	1.0
St. Mary's River (west)			
Gros Cap	GC	8	16.3
Point Iroquois	IR	5	7.1
Point Louise	PL	3	0.9
Sault Ste.Marie			
Waterfront (Ontario)	SM	7	9.9
Strathclair Farm (Ontario)	SF	2	8.0
Heyden (Ontario)	HD	1	0
Bellevue (Ontario)	BV	2	4.3
3-6 Mile Roads (Michigan)	TM	3	2.8
9-15 Mile Roads and Kincheloe (Michigan)	KN	.2	2.0
St. Mary's River (east)			
Lake George	LG	4	9.9
St. Joseph Channel/Pine Island	SC & PI	3	21.3
St. Joseph I. (south)	SO	1	0.3
St. Joseph I. (east)	SE	1	1.5

lowing the shoreline, although many evidently continue in a northwest direction past Whitefish Point.

Migration routes

Summarizing the data to define migration routes of the loons in the St. Mary's River corridor was complicated by the fact that observations were not made from the same locations every year. To allow for this, the total numbers seen at each site were averaged for the number of years that observations were made at the site.

On average the highest numbers were recorded north of St. Joseph Island over the St. Joseph Channel (Table 3). From there the main route was due northwest over the Sault Ste. Marie waterfront and out into Lake Superior past Gros Cap. However, on some days, significant numbers flew overland both south of the river, between Lake Munuscong and Whitefish Bay, and to the north of the river.

In two of the eight years, 1990 and 1992, observations were made along a north/south transect centred on the Sault Ste. Marie waterfront. In 1990, a total of 366 loons was seen along this transect; in 1992, 781. Of the total, 1147, 472 (41%) passed over the Ontario waterfront, 219 (19%) passed to the south (with numbers declining further away from the river, although some were seen as far south as Kincheloe), and 296 (26%) were recorded by observers 3 km north of the river. These latter birds were all flying northwest, which would take them over the Gros Cap batholith and into Goulais Bay. At Heyden, 16 km inland no loons were seen at all, but 9 km further north, from the Bellevue microwave tower which is a vantage point 175 m higher than Lake Superior, 160 loons (14.0% of the total for the two days) were recorded. This suggests that there is a well-established overland route north of the river.

No single location gave a reliable estimate of the total number of loons passing from Lake Huron to Lake Superior. The highest counts were from the St. Joseph Channel, but there is no convenient vantage point there to provide an unobstructed view. Counts were also high at Gros Cap and Whitefish Point, both of which have commanding views. In five of the eight years, counts at Gros Cap were higher than at Whitefish Point (Table 1), but even those were evidently incomplete. By using a channel marker 3 km off Gros Cap as a guide, it was estimated that the maximum range at which migrating loons could be detected, using a x15 telescope, is a little over 3 km (G. Rahn, personal communication). The distance between Gros Cap and Pt. Iroquois is 7 km, and therefore most of the birds recorded simultaneously at Pt. Iroquois and Gros Cap were different birds. In addition, considerable numbers pass overland north of Gros Cap. The data from 1990 and 1992 indicate that this may be half as many again as recorded at Gros Cap. The actual numbers passing through the area may, therefore, be twice the numbers recorded at Gros Cap and 3-4 times the numbers recorded at Whitefish Point.

Acknowlegments

This overview of loon migration in the Sault Ste. Marie area was made possible by the following citizens of Sault Ste. Marie (Michigan and Ontario) who willingly, and cheerfully, braved the elements to record the passage of the loons: Rita Adams, Euan Aitken, Dave Bean, Mark Browning, R. G. Campbell, Ed Czerwinski, Robert and Joy Cohen, Kathie Droy, Ray Gareau, Al Gordon, Harry Graham, Denise Hart, George Harvey, Jim Hunt, Helen Hutchinson, Wendy Lalouette, David Maltby, Tom Marwood, Pat McHattie, Jack Miller, Rhonda Milliken, Howard Nixon, Mike O'Connor, Darcy Ortiz, Rick Orton, S. Pistor, Gary Rahn, John Ralston, Sam Rosa, John Scarratt, Sandra Spiewak, Cynthia Suhay, Noreen Towers, Bill van Atte, Kees van Frankenhuyzen, Tony Walker, Diane Wadden, Karen Whillans, Burt Williams, and Don Wilshire. All of us would like to thank the Directors and staff of the Whitefish Point Bird Observatory for their interest and for making their data on loon migration on our observation days available to us.

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Received 24 August 1992
Accepted 27 October 1993

Multiple Landscape Scales and Winter Distribution of Moose, *Alces alces*, in a Forest Ecotone

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Forbes G. J. and J. B. Theberge. 1993. Multiple landscape scales and winter distribution of Moose, *Alces alces*, in a forest ecotone. Canadian Field-Naturalist 107(2):201–207.

Winter distribution and abundance of Moose (*Alces alces*) was studied in relation to habitat use and habitat disturbance at local and regional landscape scales in Algonquin Provincial Park, central Ontario. Thirteen years of government aerial population survey data (1976-1988) were supplemented with spring pellet surveys of eight habitats to determine differences in forest species composition, winter habitat utilization, and habitat disturbance by Spruce Budworm (*Choristoneura fumiferana*) and non-clearcut logging. At a local scale (< 100 km^2), Moose select closed-canopy habitats in winter. Hemlock (*Tsuga canadensis*) provided important winter habitat for Moose in the Algonquin transition-zone ecotone; Hemlock was disproportionately chosen in both high and low density aerial survey plots, and occurred in greater amounts in high density plots than those in low density plots ($P < 0.05$). At larger, regional scales (> 1000 km^2), Moose are selecting areas of canopy disturbance. Plots impacted by logging by more than 33% of their area supported more Moose than plots with less than one-third of their area logged ($P < 0.05$). Similarily, Spruce Budworm defoliation created more browse and consequently contained more Moose in severely affected areas, but plots in moderately defoliated areas require additional logging activity to produce comparable amounts of browse and Moose use. A methodology of combined pellet survey and aerial survey data appears to identify habitat requirements at different landscape scales.

Key Words: Moose, *Alces alces*, logging, habitat disturbance, Spruce Budworm, *Choristoneura fumiferana*, landscape scale.

Studies of habitat use by Moose (*Alces alces*) related to disturbance have focussed predominantly on the boreal forest ecotype (Hamilton et. al. 1980; Brusnyk and Gilbert 1983; McNicol and Timmerman 1986), and consequently much of the management of Moose habitat relates to boreal ecosystems (Payne et. al. 1988). In central Ontario, Moose live in an ecotone between the southern deciduous and northern boreal forests. The Algonquin region generally represents the southern limit of high Moose numbers in Ontario (Cumming 1972). Tree species associations and logging practices differ considerably from boreal situations, but population densities of Moose are comparable (Bergerud et al. 1983), if not higher, in this transition zone (Brassard et al. 1974). However, only a limited amount of documentation is available on habitat relationships of transition-zone Moose.

The concept of habitat use as a function of landscape scale (Wiens et al. 1986; Holling 1992) should apply well to Moose. Ungulates, such as Moose, are mobile, long-lived animals that can react to changes in their immediate environment and to large-scale habitat changes. The reaction by Moose to short-term events such as a heavy snowfall differs from their reaction to extensive habitat modifications such as burns from fire (Peek et. al. 1976; Cederlund et. al. 1989). If Moose are selecting habitat based upon landscape scale then the methods of interpretation need to vary by similar scales.

This paper documents: (1) the role of forest species composition on Moose abundance and distribution at a local landscape scale using pellet data, and (2) the role of habitat disturbance, mainly logging and Spruce Budworm (*Choristoneura fumiferana*), at a regional landscape scale using aerial survey data.

Study Area

The research was conducted in Algonquin Provincial Park (7571 km^2), located in central Ontario between Georgian Bay and the Ottawa River. Elevation ranges from 180 to 380 m in the eastern half of the Park and up to 580 m on the Algonquin Dome, a raised section of the Precambrian Uplands. Total annual snowfall ranges from 203 to 254 cm with greater amounts in the west (Wilton 1987). Average air temperature is –11.5 °C in January (Brown et. al. 1980). The heavily forested Park exists as a transition zone between the Boreal Forest Region and the Algonquin Highlands portion of the Great Lakes / St. Lawrence Forest Region (Rowe 1972). Two major forest types cover Algonquin; pine/poplar forests in the east and tolerant hardwoods to the west. The tolerant hardwood forest type consists of mainly Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula lutea*), and Eastern Hemlock (*Tsuga canadensis*). The pine/poplar forest growing on the sandy outwash soils of the St. Lawrence Lowlands contain stands of

White Pine (*Pinus strobus*), Red Pine (*P. resinosa*), and Jack Pine (*P. banksiana*) interspersed with Largetooth Aspen (*Populus grandidentata*), and White Birch (*Betula papyrifera*). Poorly drained areas and waterways are typically boreal producing Balsam Fir (*Abies balsamea*) and Black Spruce (*Picea mariana*), with smaller amounts of Eastern White Cedar (*Thuja occidentalis*), Eastern Tamarack (*Larix laricina*), and Speckled Alder (*Alnus rugosa*).

The Moose population during this study ranged from 1455 to 2155 Moose (0.3 moose /km^2) in 1975 to 2278 to 3278 Moose (0.45 Moose /km^2) in 1989 [unpublished aerial survey records, Ontario Ministry of Natural Resources (O.M.N.R.) Huntsville, Ontario].

Methods

Landscape units of local (<100 km^2) and regional (>1000 km^2) scales were chosen to identify habitat use by Moose. The local scale, based on a mean average winter home range of 2 - 5 km^2 (Van Ballenberghe and Peek 1971; Cederlund and Okarma 1988) reflects areas chosen by a Moose within a small (<5 km^2) area. The regional scale identifies areas of the Park where Moose cluster in response to higher quality sites (Peek et. al. 1976). Establishing the limits of a regional scale is difficult because little is known on the extent of clustering in response to quality habitat (Le Resche 1974; Monthey 1984). However, considering the mosaic of habitats in the Park, it is likely that 4000 Moose distributed over the 7000 km^2 park are separating into higher and lower densities.

The distribution and abundance of Moose across Algonquin Park was assessed from a combination of both winter aerial and spring pellet surveys. Though pellet surveys have limited value for density estimates (Fuller 1991), they do provide an indication of winter-long use of a specific habitat (Collins and Urness 1981). A potential bias of pellet surveys occurs in situations when changing snow depths may cause intra-seasonal variation in habitat use. To address this bias we also utilized long-term aerial survey data. Aerial-based data from many years identifies habitats consistently used by Moose on a larger, regional scale and are not as limited by localized, intra-seasonal distribution. Combining each survey type allows a more accurate depiction of winter habitat use than separate aerial or pellet surveys.

To quantify differences in habitat selection over many years, 13 years of aerial survey data were separated into areas of consistently high, medium, or low abundance. Aerial Moose surveys were flown each winter from 1976 to 1988 over 10 km x 2.5 km plots by Ontario Ministry of Natural Resources (O.M.N.R.) biologists. Plots had been selected randomly in 1976 across the entire park. After 1985, surveys alternated between the western and eastern halves of the park. No survey was conducted in 1984. Potential biases in aerial surveys were minimized by the use of standardized O.M.N.R guidelines regarding weather conditions, numbers of observers (two plus navigator), and type of plane (four-person fixed high wing) for each flight (Wilton and Pashuk 1982). Data from surveys not conforming to the specified guidelines were omitted from analysis. The average number of Moose per plot over combined years was used to reduce possible year to year variability in the number of Moose sighted in any particular plot. Similarly, only those plots with a minimum of six out of the possible 13 years were used.

Plot densities were categorized as high (n = 20), medium, or low (n = 13) based upon the total pooled average number of Moose per plot from 1976-1988. The data were then separated to reflect the tolerant hardwood or pine-poplar forest areas. In order to identify major differences in plot characteristics, medium density plots were omitted from analyses. Eight habitats, based upon established winter habitat requirements of Moose (Krefting 1974; Peek et. al. 1976; O.M.N.R. 1984; Thompson and Euler 1984) and identifiable physiognomic classes, were delineated by reclassifying 1977 O.M.N.R. Forest Resource Inventory Maps (F.R.I.) (scale = 1: 15 840). The relative habitat area of the eight habitats in the 33 aerial survey plots, and total and relative area of logging activity were recorded using modified acreage grid overlays (100 dots per inch).

Sixty-seven pellet surveys, each 500 m x 2 m were conducted on eight aerial survey Moose plots. The sample plots selected represent the two forest types, varying Moose density (high/low), as well as a broad geographical distribution to encompass possible climatic differences. The number of transects per plot were stratified to reflect the proportion of each habitat present. Except for alder areas, much of the wetland habitat could not be surveyed because of difficulties associated in counting pellets in standing water. Browse availability was measured by classifying stems into high (>50 stems), medium (25–49) and low (<25) relative categories. Surveys were conducted between the period of snow-melt (April 26) and leaf-out (June 4). It is unlikely that the timing of surveys affected the observability of pellets. A test was made for the number of pellets counted on two typical hardwood and conifer transects. In this test the number of pellets observed in April did not differ significantly from counts conducted at the end of the survey in early June (t-test, $P < 0.05$).

The severity of logging and Spruce Budworm (*Choristoneura fumiferana*) defoliation was compared on high and low aerial survey plots. Data on the extent (% area affected by logging) of logging activity after 1970 were determined from O.M.N.R. and Algonquin Forestry Authority (A.F.A.) maps (1: 60 000). The predominant silviculture methods were uniform shelterwood and selection cutting with clearcutting restricted to less than 100 ha annually (A.F.A. Summary Reports). The percentage of an area logged indicates that one or several of the three logging methods were used in that area and does not represent the total harvestable timber volume. Because logging practices varied between plots, this method provides a standard baseline of the extent of disturbance by logging. For logged areas we chose only those plots where 75% of the logging occurred > 1 year prior to the pellet surveys. Areas cut-over within one year contain tree-top browse and can attract Moose from surrounding areas for short periods (Monthey 1984). Omitting these areas limits a potential bias in Moose numbers at recent cut-overs.

For 8-10 years in the late 1960s and 1970s, Spruce Budworm was a significant source of habitat disturbance and defoliated large portions of Algonquin Park's Balsam Fir and spruce forests (Howse and Harnden 1978). Trees that experience more than 4-5 years of heavy defoliation often die (Howse et. al. 1975). To assess areas of forest die-off from budworm, we mapped areas that were rated as moderate to heavy defoliation for at least five consecutive years (Trieselmann 1970; Howse et. al. 1973; Howse et. al. 1975; Howse and Harnden 1978) and compared them

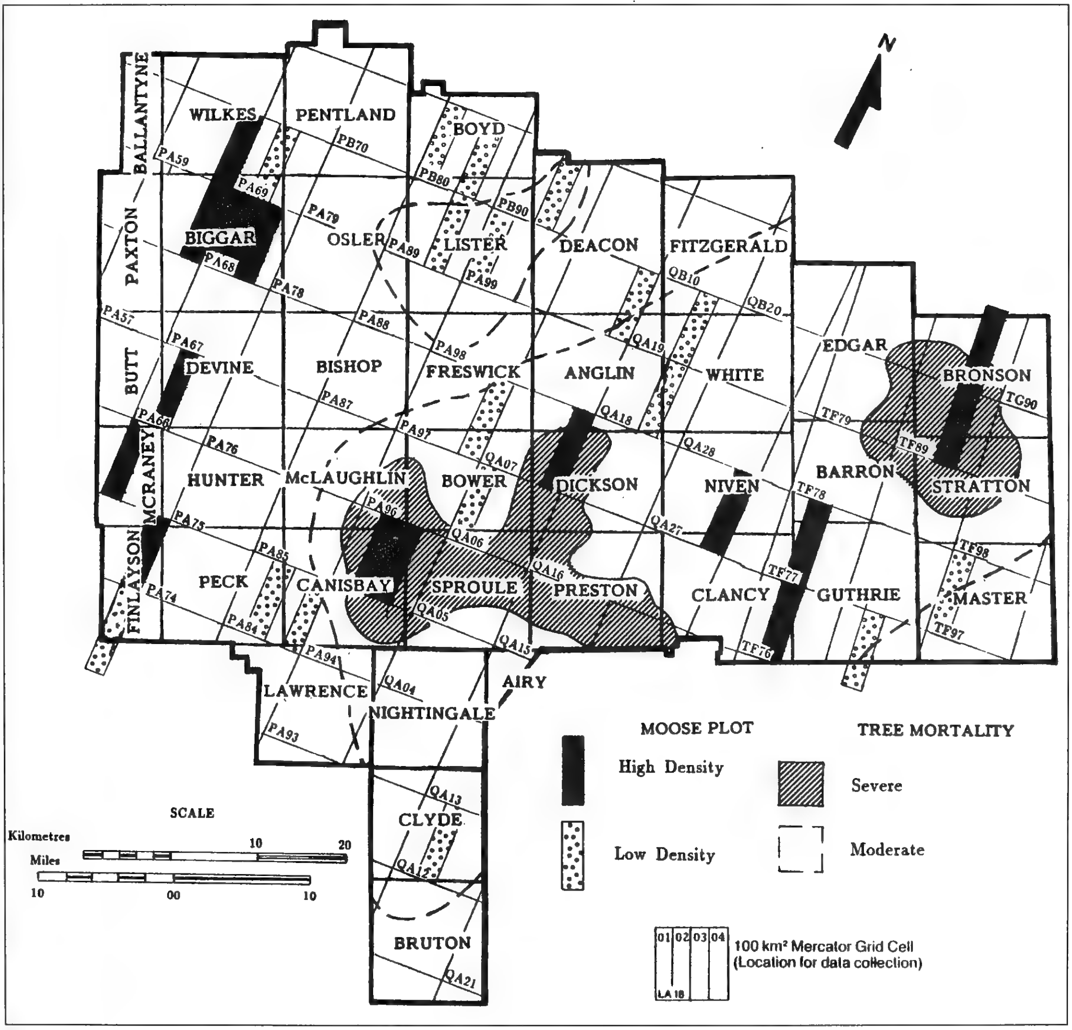

FIGURE 1: Location of aerial Moose survey plots, Moose densities, and areas of severe Spruce Budworm tree mortality, Algonquin Provincial Park.

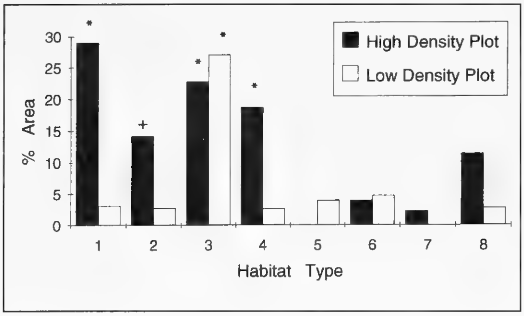

FIGURE 2: Habitat use by Moose in high and low density plots based upon spring pellet surveys. * indicates significant use of Lowland Conifer, Hemlock, and Pine-Poplar habitats compared with other habitat types (t-test, $P<0.05$, $n=67$ surveys). + indicates significant use of Pine habitat (t-test, $P< 0.10$). Habitat Key: 1 - Lowland Conifer; 2 - Pineries; 3 - Hemlock; 4 - Pine-Poplar; 5 - Poplar-Birch; 6 - Tolerant Hardwood; 7 - Wetland; 8 - Mixed Forest.

to the high and low Moose plot densities of this study.

Results

Habitat Use and Availability

At the local scale, Moose preferred coniferous habitats to deciduous habitats.The mean pellet count by habitat for all combined aerial survey plots indicated that Moose utilized Hemlock, Lowland Conifer, Pine-Poplar ($P < 0.05$), and Pine habitats ($P < 0.10$) (Figure 2). Deciduous-dominated habitats generally possessed lower pellet counts throughout all plots; the Poplar-Birch association had on average the fewest pellets. Moose use of the other habitats was not significant. In an analysis of separate high or low density plots, Lowland Conifer, Hemlock and Pine-Poplar were preferred habitats in high density plots. Hemlock was the only habitat of significant preference in low density plots (t-test, $P < 0.05$).

At the regional scale, plots in the tolerant hardwood part of the park that were high in Moose density contained more Hemlock habitat than low density plots (t-test, $P < 0.05$, $n = 20$). The Poplar-Birch habitat occured in greater abundance in low density plots. In the pine-poplar forest part of the park, Hemlock habitat and Mixed Forest habitat were more abundant in areas of high Moose density, while Tolerant Hardwood habitat was greater in low density plots (t-test, $P < 0.05$, $n = 13$). Other habitats were not significantly related to high or low density plots (Figure 3).

Aerial survey plots that were consistently high in Moose density over 13 years also contained significantly more pellets ($\overline{X} = 16.1$, s.d = 3.7) in the one-year pellet survey than plots that were consistently low in Moose density ($\overline{X} = 5.7$, s.d. = 1.9) (t-test; $P < 0.05$, $n = 67$).

Moose Abundance Related to Habitat Disturbance

At the regional landscape scale, Moose responded to disturbed habitats. High density aerial survey plots were more heavily logged than low density Moose plots (t-test, $P < 0.05$, $n = 33$) (Table 1). Aerial survey plots with more than 50% logged contained more Moose than areas with less than 50% logged (phi coefficient = + 0.72, $P < 0.05$). Further analysis showed that cutting as little as one-third (33%) of the plot was also related to higher Moose density (phi coefficient = + 0.63, $P < 0.05$). Non-logged plots or partially cut plots (0-33%) possessed lower Moose densities.

Plots that were logged >33% possessed more available browse than non-logged plots and plots logged <33% (t-test, $P < 0.05$). Moose plots logged by > 33% averaged higher in available browse ($\overline{X} = 2.2$, s.d.= 0.9, n=34) than did plots that were not logged or logged at < 33% ($\overline{X} = 1.7$, s.d.= 0.4, n=33).

Plots impacted by moderate to severe budworm damage supported more Moose than areas with low amounts of budworm damage (Table 1). Four aerial Moose survey plots were located in areas of extreme Spruce Budworm defoliation (Figure 1), two of which (Plots # PA9502, PA9503) had received no logging in the past 30 years. All of these plots ranked high in Moose density. By contrast, no low density plots were found in severe budworm areas. Overall, plots with moderate tree mortality and logging were higher in Moose. Budworm defoliation did occur sporadically in the western townships but had far less impact in this tolerant hardwood forest type where half (50%, n = 16) of the high density moose plots had low budworm damage.

Discussion

Animal distribution in a landscape is often the product of the scale of interpretation. At small landscape scales, species will be perceived to require one environment that may differ from environments selected or perceived at larger scales (Wiens et. al. 1986; Wiens 1989). Without this multi-scale interpretation of habitat use, it is possible to derive conflicting conclusions on habitat selection. In this study, Moose are selecting closed canopy habitats at one scale but canopy disturbed habitats at another scale.

In Algonquin, pellet data showed, that in winter, Moose preferred the sheltered, coniferous habitats of Hemlock, Lowland Conifer and Pine-Poplar rather than the more prevalent deciduous-dominated habitats. Hemlock emerged as a significant winter habitat even though it exists as less than 10% of the total forest cover. Hemlock is heavily used by Moose and also exists in significantly greater amounts as a habitat type in high density plots of both the tolerant hardwood and pine-poplar forest

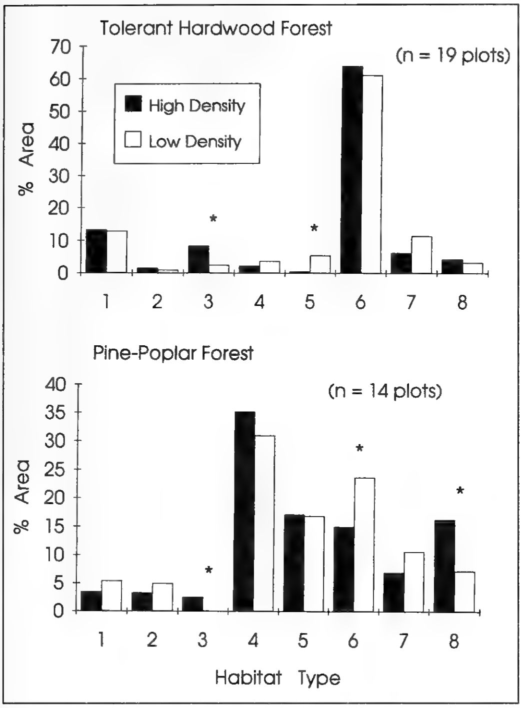

FIGURE 3: Differences in habitat type (% area) between combined high and low density Moose plots for the Tolerant Hardwood and Pine-Poplar Forests. A * indicates a significant difference in habitat quantity between high and low density plots (t-test, $P < 0.05$). Habitat Key: 1 - Lowland Conifer; 2 - Pineries; 3 - Hemlock; 4 - Pine-Poplar; 5 - Poplar-Birch; 6 - Tolerant Hardwood; 7 - Wetland; 8 - Mixed Forest.

types. Conversely, areas low in Hemlock and areas high in non-coniferous habitat also were low in Moose numbers.

Hemlock has already been identified as important habitat for White-tailed Deer (*Odocoileus virginianus*) (Anderson and Loucks 1979; Euler and Thurston 1980). Hemlock has not been previously documented as a significant habitat for wintering Moose. In Algonquin, Hemlock occurs as clustered stands and as Hemlock ridges across the tolerant hardwood hills. During the pellet surveys, these Hemlock ridges were found to be heavily used by Moose and may have acted as important travel corridors between areas of high available browse. Often, Hemlock is the only substantial coniferous species present on the hardwood hills. In the pine-poplar forest section of Algonquin, Hemlock is relatively uncommon, often associated with other conifers and hardwood stands.

At the local scale, the degree of winter protection offered by conifer species (Hemlock, Black Spruce, Balsam Fir, and White Cedar) may be critical in the transition forest zone like Algonquin where non-conifer species occur in greater amounts than in the Boreal Forest zone. This situation differs from typical boreal forest environments that generally contain larger, more extensive tracts of shelter species, where habitat limiting factors are often the result of food availability rather than shelter (Pastor et. al. 1988; Peek et. al. 1976).

Areas of conifer often lack adequate food supplies and, at the regional scale, Moose were found in areas of canopy disturbance, not canopy shelter. In Algonquin Park, with fire controlled, logging is the main, continuous source of older-age class tree removal and canopy change. Typically, areas with at least a minimum level (one-third) of logged area contained more Moose. The amount of browse created by logging can be long lasting and extensive; a 5 to 7-year-old clearcut in New Brunswick provided browse at the rate of 32 Moose days per hectare (Telfer 1970). The amount of browse produced by the uniform shelterwood and selection silviculture that dominates Algonquin forestry is not known but the relationship between logged areas, available browse, and Moose numbers strongly suggest Moose numbers would be lower without even this level of canopy thinning.

Spruce Budworm developed from small pockets near Ottawa in 1967-1968 to an area covering three-quarters of Algonquin Park at its peak in 1978, but then declined to numerous, small pockets by 1983-1984 (Kondo and Taylor 1985). Severe outbreaks of insect defoliants can open the forest canopy in a manner similar to logging activity; stands of Balsam Fir and Black Spruce that had died from extended budworm defoliation often regenerated as areas high in the amount of Moose browse. Areas marked as severe in Figure 1 experienced high and continuous budworm-caused tree mortality. The effect of budworm on moose abundance was greater in the Pine-Poplar forest than the Tolerant Hardwood forest. This may be a result of budworm creating more browse in a conifer region where shelter predominates. We found that all areas that had not been disturbed by logging or extensive fires since the 1940s still supported large numbers of Moose on the browse regenerating under budworm-killed conifers. However, budworm appears to compensate for logging activity only when the tree mortality is very severe. For example, several areas of the park (Lister, Deacon, Freswick and Osler townships) consistently produced lower moose numbers (Figure 1). All of these areas were only moderately damaged by Budworm and were not logged, or were logged over less than one-third of their area.

Considering the similarities in selective logging and severe budworm defoliation on forest habitat, more research on the compensatory or additive

TABLE 1. Comparison of the amount of logging activity and Spruce Budworm damage on high and low density Moose plots.

	Mean Area Cut/Plot (acres)	% Plots With Budworm Defoilation (+)		
		Low	Moderate	Severe
Tolerant Hardwood Forest				
High Density Plots (n = 10)	1987*	80	0	20
Low Density Plots (n = 9)	1380	44	56	0
Pine-Poplar Forest				
High Density Plots (n = 6)	3742*	0	50	50
Low Density Plots (n = 8)	592	25	75	0
Combined Forest Types				
High Density Plots (n = 16)	2535*	50	19	31
Low Density Plots (n = 17)	1009	35	65	0

* = significant difference between densities (t-test, $P < 0.05$, $n = 33$)
(+) = budworm damage based on number of consecutive years of severe defoliation

effects of combined logging and insect defoliation on ungulate habitat would be of value to wildlife and forest managers. This would be particularly valuable in non-boreal areas where shelter may be in relatively limited quantity at both local and regional scales.

Acknowledgments

We appreciate the use of aerial Moose census data collected by M. Wilton, G. Oram, N. Quinn, and staff of the Ontario Ministry of Natural Resources. They, and Dan Strickland helped logistically with our study. C. Callaghan and H. Vogel assisted in the field work. This study was funded in part by World Wildlife Fund (Canada), Ontario Renewable Resource Grant, Natural Science and Engineering Research Council, and the Friends of Algonquin Park.

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Received 10 March 1992
Accepted 29 October 1993

Relative Abundance and Habitat Use by Tree Bats, *Lasiurus* spp., in Southcentral Pennsylvania

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Hart, James A., Gordon L. Kirkland, Jr., and Scott C. Grossman. 1993. Relative abundance and habitat use by tree bats, *Lasiurus* spp., in southcentral Pennsylvania. Canadian Field-Naturalist 107(2): 208–212.

We monitored bats with ultrasonic detectors at 39 localities representing nine habitat types in five southcentral Pennsylvania counties (Adams, Cumberland, Franklin, Fulton and York) from 17 May to 13 September 1989 and 14 May to 6 September 1990. The principal objective was to assess the statuses of two species of solitary tree bats, the Red Bat (*Lasiurus borealis*) and Hoary Bat (*Lasiurus cinereus*), in southcentral Pennsylvania by determining the relative abundance and ecological distribution of these species in this region. On 77 nights we deployed weather-proof remote monitoring units, each containing a frequency-tunable ultrasonic detector, a voice-activated microcassette tape recorder, and a "talking" clock. We also sampled bats with mist nets on 33 nights. Red Bats were detected at 24 localities (60.0%) and Hoary Bats at 19 localities (47.5%). By comparison mouse-eared bats (*Myotis* spp). were recorded at 32 (80.0%) of the sites surveyed. Red Bats were detected on 42 detector survey nights (53.8%) and were netted on 16 nights (48.5%) in all nine habitats sampled. Hoary Bats were detected on 30 detector survey nights (38.5%) in eight of nine habitats but were netted only twice (6.1%), presumably because they foraged above the height sampled by the mist nets. Observed in all nine habitats, *Myotis* spp. were detected on 58 of 78 detector survey nights (74.4%), more often then either *Lasiurus* species but were netted on only 11 nights (33.3%). Both *Lasiurus* species appear to be relatively abundant and ecologically widespread in southcentral Pennsylvania.

Key Words: Red Bat, *Lasiurus borealis*, Hoary Bat, *Lasiurus cinereus*, habitat use, relative abundance, echolocation, bat detectors, remote monitoring, Pennsylvania.

Relatively little is known about the biology of solitary, tree-dwelling bats of the genus *Lasiurus* in Pennsylvania, particularly in comparison to social bats such as members of the genus *Myotis*, which hibernate throughout much of the state (Merritt 1987; Dunn and Hall 1989). Bats of the genus *Lasiurus* generally are present in Pennsylvania only from early May to late September or early October at which time they migrate southward to overwinter (Barbour and Davis 1969). Much of the information concerning foraging behavior (Kunz 1973; Barclay 1984, 1985; Furlonger et al. 1986; Hickey and Fenton 1990), prey selection (Barclay 1984, 1985) and habitat use (Thomas 1988; Hickey and Fenton 1990) by lasiurine bats has been obtained elsewhere in their distribution. The objective of this study was to assess the status of the Red Bat (*Lasiurus borealis*) and Hoary Bat (*L. cinereus*) in Southcentral Pennsylvania by determining their relative abundances and habitat use in this region. To achieve this we monitored these two bat species at 39 localities representing nine habitats in five southcentral Pennsylvania counties (Adams, Cumberland, Franklin, Fulton, and York) from 17 May to 13 September 1989 and 14 May to 6 September 1990.

The ability of researchers to monitor the ultrasonic frequencies at which bats echolocate has enabled them to determine the habitats used by individual species of bats and to compare the relative abundance and activity patterns of different bat species (Fenton 1970; Fenton et al. 1983; Thomas and West 1984; Geggie and Fenton 1985; Thomas et al. 1987; Thomas 1988). In this project we used ultrasonic bat detectors to answer three questions regarding the statuses of Red and Hoary bats in southcentral Pennsylvania: (1) What are the relative abundances of these two species in this region?; (2) What habitats are exploited by these two species?; and (3) What is the intensity of use of individual habitats by these two species?

Methods and Materials

The nocturnal activity of insectivorous bats poses problems when long-term monitoring requires the investigator to be physically present throughout the night. To solve this problem we designed a remote monitoring unit which contained a frequency-tunable bat detector (Skye model 1220), a voice-activated microcassette tape recorder (Realistic Micro-18) and a "talking" clock (SEIKO model QEK 101S). The tape recorder was activated by the bat detector's audible output, which was produced whenever bat echolocation pulses were detected. In order to provide real-time cues for the recorded output of the bat detectors, the talking clock was programmed to announce the time every half hour. This equipment was housed in a weatherproof box. Sounds produced by bats were received through an acoustic window in the top of the box. At each study site, a pair of monitoring units was set out prior to sunset and retrieved shortly after sunrise the following day. The detector in one unit was tuned to a frequency of 20 kHz to detect the Hoary Bat, while the other unit was set at 40 Khz to detect Red Bats (Fenton et al. 1983).

Bats can be identified on the basis of the tonal qualities of their echolocation pulses. *Lasiurus cinereus* emits a discernible tonal chirp at 20–25 kHz because of the constant frequency (CF) componant of its echolocating pulse in that frequency range (Fenton et al. 1983; Thomas and West 1984). *Lasiurus borealis* emits a similar tonal chirp but at 40kHz rather than at 20–25 kHz. When detected at a frequency of 40 kHz the echolocating calls of mouse-eared bats (*Myotis* spp.) resemble sharp ticks, which distinguish their calls from those of *L. borealis*. Because of the lack of sophistication of the detectors used in this study, it was impossible to identify *Myotis* bats to species, so these bats were identified only to genus. Two other species of bats, the Big Brown Bat (*Eptesicus fuscus*) and the Eastern Pipistrelle Bat (*Pipistrellus subflavus*) were also present at many of the localities surveyed. The Big Brown Bat emits an echolocation pulse within the same range as *L. cinereus* but the audible output is heard as a "put" rather then the tonal "chirp" of the Hoary Bat (Fenton et al. 1983). Fenton and Bell (1981) listed *Pipistrellus hesperus* echolocation frequencies as between 53–91 kHz with the most energy emitted around 62 kHz. Since *Pipistrellus subflavus* is comparable in size, its echolocation pulses would most likely occur above 50 kHz and would not be recorded by the monitoring units.

Thirty-nine localities representing nine habitat types were sampled in five southcentral Pennsylvania counties (Adams, Cumberland, Franklin, Fulton, and York) during the periods 17 May to 13 September 1989 and 14 May to 6 September 1990. Seventy-seven nights of detector monitoring at the 39 localities were supplemented with mist-netting on 33 nights at 17 localities. The habitat types, number of times sampled, and brief descriptions of the habitats are as follows: open streams (n = 3; streams bordered on both banks by non-forested habitats), forested streams (n = 10; streams bordered on both banks by forested habitats), mixed streams (n = 13; streams bordered by a mixture of forested and open habitats), agricultural land (n = 7; cropland or pasture with no adjacent bodies of water), forest clearcuts (n = 10; logged areas surrounded by forested land), lakes (n = 9; large bodies of water surrounded by timberland), forests (n = 7; mature or successional forests, not adjacent to water), old fields (n = 7; fallow agricultural fields, not adjacent to bodies of water), and ponds (n = 11; small bodies of water surrounded by cropland, pasture or old field habitat).

Results

The frequency of occurrence and intensity of habitat use (mean number of calls) by the three bat species in the nine habitats sampled as revealed by monitoring with detector units are summarized in Table 1. The Hoary Bat had its highest frequencies of occurrence and mean numbers of calls in lake and mixed stream habitats. The Red Bat was detected most frequently in open stream, wooded stream, clearcut, and lake habitats. Intensity of habitat use by Red Bats was greatest in open stream, wooded stream, lake, and pond habitats (Table 1). Although Red Bats were frequently detected on forest clearcuts (70%), their intensity of use of this habitat was low (Table 1). *Myotis* species were detected most often in wooded stream, open stream and pond habitats. Intensity of habitat use by *Myotis* was high in all habitats associated with water and in agricultural land (Table 1).

We used Spearman rank correlation analysis to determine how similar habitat use was in the three bats in terms of frequencies of occurrence and intensity of habitat use (mean number of calls). There was

TABLE 1. Habitat use by the Hoary Bat (*Lasiurus cinereus*), the Red Bat (*L. borealis*), and *Myotis* spp., as measured by frequency of detection and mean number of calls recorded in each of nine habitats sampled. N refers to the number of times a habitat was monitored for bats.

Habitat Type		Hoary Bat		Red Bat		*Myotis* spp.	
		Freq. Detect.	Mean # Calls	Freq. Detect.	Mean # Calls	Freq. Detect.	Mean # Calls
Open Stream	N = 3	0%	0.0	100%	50.7	100%	64.3
Wooded Stream	N = 10	50%	3.8	80%	52.4	100%	116.4
Mixed Stream	N = 13	69%	15.5	69%	20.1	62%	49.1
Agricultural Land	N = 7	0%	0.0	14%	1.0	57%	38.8
Forest Clearcut	N = 10	50%	9.4	70%	4.4	90%	4.0
Lake	N = 9	56%	18.4	67%	44.3	67%	47.3
Forest	N = 7	29%	2.0	29%	19.5	43%	6.3
Old Field	N = 7	14%	2.0	14%	2.0	57%	9.5
Pond	N = 11	18%	11.0	46%	35.2	91%	60.5

no relationship between the frequencies of occurrence of Red and Hoary bats in the nine habitats (r_s = +0.308), but the correlation between the frequencies of occurrence of the Red Bat and *Myotis* spp. was significant (r_s = +0.829). Likewise, there was no correlation between intensity of habitat use in Red and Hoary bats (r_s = +0.308), but there was a significant positive correlation between the intensity of habitat use in the Red Bat and *Myotis* spp. in the nine habitats (r_s = +0.800). Similar comparisons between the Hoary Bat and *Myotis* spp. revealed no relationship for either frequency of occurrence (r_s = +0.138) and mean number of calls (r_s = +0.100). These results indicate that Hoary Bats differed from both Red Bats and *Myotis* spp. in their pattern of habitat use, while the patterns were similar in Red and *Myotis* bats.

We grouped the nine habitats sampled into four habitat classes based on the presence or absence of trees (forested or non-forested habitats) and water (aquatic or non-aquatic) and then compared the frequency of occurrence and intensity of habitat use in the two pairs of habitat types by the three bat species (Table 2). The Hoary Bat was the only species that exhibited a significant difference in occurrence between habitats, occurring less frequently than expected in non-forested habitats (x^2 = 6.32, $P <$ 0.025). Intensity of habitat use as measured by mean number of calls per visit did not differ between forested and non-forested habitats for any of the bats (Table 2). Intensity of habitat use did not differ between aquatic and non-aquatic habitats for the Hoary Bat but did differ in the Red Bat (Mann-Whitney U = 293.5, $P <$ 0.001) and *Myotis* spp. (Mann-Whitney U = 694.5, $P <$ 0.001). Both exhibited substantially greater intensity of habitat use in aquatic habitats (Table 2).

Bats were captured in mist nets on 22 nights (66.7%). Eighty-nine individuals were mist-netted as follows: 2 Hoary Bats (1♂, 1♀), 42 Red Bats (12♂♂, 20♀♀, 10 sex unknown), 34 Little Brown Myotis (*Myotis lucifugus*) (10♂♂, 22♀♀, 2 sex unknown), 3 Northern Long-eared Myotis (*Myotis septentrionalis*) (1♂, 1♀, 1 sex unknown), 2 Eastern Pipistrelles (*Pipistrellus subflavus*) (1♂, 1♀), and 6 Big Brown Bats (*Eptesicus fuscus*) (5♀♀, 1 sex unknown). Whereas Hoary Bats were detected on 30 nights (38.5%) at 19 sites (47.5%), they were netted on only 2 nights (6.1%) at two sites (11.7%). Red Bats were detected on 42 nights (53.8%) at 24 sites (60.0%) and netted on 16 nights (48.5%) at 6 sites (35.3%). *Myotis* species were detected on 58 nights (74.4%) at 32 sites (80.0%) but were netted on 11 nights (33.3%) at eight sites (64.7%).

Discussion

Both Hoary and Red bats ≤ are solitary species that roost primarily in trees (Shump and Shump

TABLE 2. Comparison of activity in three species of bats (*Lasiurus cinereus*, *L. borealis*, and *Myotis* spp.) in forested and non-forested, and aquatic and non-aquatic habitats in south-central Pennsylvania.

	Lasiurus cinereus		*Lasiurus borealis*		*Myotis* spp.	
	Forested (n = 49)	Non-forested (n = 29)	Forested (n = 49)	Non-forested (n = 29)	Forested (n = 49)	Non-forested (n = 29)
No. times detected	26	4*	32	10	36	22
Percent of samples with detections	53.1	13.8	65.3	34.5	73.5	75.8
Mean no. calls when detected	11.6	14.8	29.3	33.1	52.7	45.6
	Aquatic (n = 46)	Non-aquatic (n = 32)	Aquatic (n = 46)	Non-aquatic (n = 32)	Aquatic (n = 46)	Non-aquatic (n = 32)
No. times detected	21	9	31	11	37	21
Percent of samples with detections	45.7	28.1	67.4	34.4	80.4	65.6
Mean no. calls when detected	13.0	9.8	38.5	6.6**	71.3	12.4**

*$P <$ 0.025; **$P <$ 0.001

1982a; 1982b). In this study the roosting habitat of the Hoary Bat carried over to its foraging habitat. *L. cinereus* was detected significantly more frequently in forested than in non-forested habitats (Table 2); however, when present, its intensity of habitat use (mean number of calls/visit) did not differ between forested and non-forested habitats (Table 2). Although Red Bats in this study tended to be detected more frequently in forested habitats, the deviation from the expected was not significant (Table 2). Intensity of habitat use (mean number of calls/visit) by Red Bats was similar in forested and non-forested habitats (Table 2). In *Myotis* spp. frequency of occurrence and intensity of habitat use were almost identical in forested and non-forested habitats (Table 2).

None of the species analyzed in this study exhibited a preference for aquatic habitats based on frequency of occurrence in habitats associated with water (Table 2); however, in *L. borealis* the deviation towards being detected more frequently in aquatic habitats approached statistical significance ($P < 0.10$). This contrasts with the observations of Furlonger et al. (1987), who found Red Bats more often in terrestrial habitats than in habitats associated with water. The edge type nature of many of the habitats sampled in this study may be the key to the pattern that we observed. Kunz (1973) found that Red Bats preferred edge type habitats to dense, mature deciduous woodland for roosting. Wooded and mixed streams, the edges of lakes, and recent forest clearcuts would provide this type of habitat for Red Bats. In the present study Red Bats were frequently detected in these habitats, particularly in comparison to non-edge habitats such as old fields and agricultural land (Table 1). Edge type habitats found adjacent to many of the lakes, streams and other wetlands in central Pennsylvania should provide abundant roosting and foraging sites for Red Bats.

Although not detected significantly more frequently in aquatic habitats, both *Lasiurus borealis* and *Myotis* spp. exhibited more intense utilization of aquatic habitats compared to non-aquatic habitats (Table 2). Foraging in *Myotis* spp. is closely associated with aquatic habitats (Furlonger et al. 1987). This is particularly true for the Little Brown Myotis, which is the most common species of *Myotis* in Pennsylvania (Merritt 1987) and undoubtedly comprised the vast majority of the bats identified as *Myotis* spp. in this study. The high-intensity use of habitats associated with water by Red Bats in this study may reflect a tendency to forage more intensively in habitats associated with high concentrations of flying insects.

A high aspect ratio and high wing loading in *L. cinereus* (Farney and Fleharty 1969) dictate that this species should be a fast, straight flier. Its preference for foraging above the canopy of trees (LaVal et al. 1977) may reflect its inability to maneuver effectively in the more cluttered environment below the canopy level. Despite being detected on 38.5% of the detector survey nights at nearly half the localities, only two Hoary Bats were captured on only 6.1% of the mist-netting nights and at 11.7% of the sites netted. The low number of Hoary Bats captured in this study may be explained by the fact that this species typically forages at heights above the level of the mist nets used in this study, the tops of which were always less than 3 m high.

Two species of bats, the Eastern Pipistrelle and Big Brown Bat, were captured during mist-netting but were not included in our analysis of the results of the detector monitoring. This was because the monitoring units we used were not set to detect the echolocating pulses of these two species. The principal echolocating frequencies of the Big Brown Bat are in the range of 30–35 kHz (Thomas and West 1984), which falls between the two frequencies monitored in this study. Members of the genus *Pipistrellus* tend to employ frequencies above 60 kHz (Fenton and Bell 1981), which are considerably higher than could be detected by our units.

Our results revealed no correlation between either the frequency of occurrence or intensity of habitat use by Red and Hoary bats in nine habitats. Both of these species feed heavily on moths and beetles (van Zyll de Jong 1985). Since these two *Lasiurus* species may compete for food, they may reduce the intensity of such competition by foraging differentially within the available spectrum of habitats. Whereas there was no relationship between either the frequency or intensity of habitat use between *Myotis* spp. and *L. cinereus*, there were significant positive correlations between the frequency and intensity of habitat use by *Myotis* spp. and *L. borealis*. This indicates a high degree of foraging habitat overlap between these species. Because these bats differ substantially in size and wing morphology (Farney and Fleharty 1969), they might be expected to exploit substantially different portions of the food resource spectrum. Analysis of stomach contents suggests this is the case. Although both *L. borealis* and *Myotis lucifugus* feed primarily on Lepidoptera, the moths eaten by Little Brown Bats are mostly small forms compared to those eaten by Red Bats (Whitaker 1972).

The principle objective of this study was to assess the status of Red and Hoary bats in southcentral Pennsylvania. The results of this study suggest that both species of *Lasiurus* are common in southcentral Pennsylvania and should be considered secure in this region. In this study, *L. borealis* was the most frequently captured species and was second in terms of frequency of detections. Although detected less often then either the Red Bat or *Myotis* spp., the Hoary Bat appears to be fairly common in southcentral Pennsylvania, where there is abundant habitat for both roosting and foraging.

Acknowledgments

This research was funded by grants from the Pennsylvania Wild Resource Conservation Fund in 1989 and 1990. We thank J. S. Findley and two anonymous reviewers for their useful comments on earlier versions of this manuscript. This publication represents Contribution Number 6 of the Pennsylvania Biological Survey.

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Received 6 October 1992
Accepted 9 September 1993

Survival and Nest Success of Sympatric Female Mallards, *Anas platyrhynchos*, and American Black Ducks, *A. rubripes*, Breeding in a Forested Environment

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Dwyer, Chris P., and Guy A. Baldassarre. 1993. Survival and nest success of sympatric female Mallards, *Anas platyrhynchos*, and American Black Ducks, *A. rubripes*, breeding in a forested environment. Canadian Field-Naturalist 107(2): 213–216.

Inverse population trends of Mallards (*Anas platyrhynchos*) and American Black Ducks (*A. rubripes*) in eastern Canada and northeastern United States have led many to speculate whether differential productivity and survival exist between these closely related forms. Monitoring of radio-marked female Mallards and Black Ducks breeding sympatrically in the western Adirondack region of northern New York in 1990-1991 showed that nest success rates of Mallards ($\hat{S} = 0.51$) and Black Ducks ($\hat{S} = 0.61$) were similar ($P > 0.10$), as was the survival rates of females during the 107-day breeding period (5 April - 20 July; Mallard $\hat{S} = 0.88$, Black Duck $\hat{S} = 0.77$). Despite these similarities, a higher proportion of Mallards successfully hatched a clutch than did Black Ducks (67% vs. 44%). Thus, Mallards may be more productive than Black Ducks, contributing to their increasing numbers throughout Black Duck breeding range.

Key Words: Mallard, *Anas platyrhynchos*, Black Duck, *Anas rubripes*, breeding, nest success, survival, sympatric, New York.

In eastern North America, the American Black Duck (*Anas rubripes*) population has declined over the past 30-40 years (Rusch et al. 1989), whereas the closely related Mallard (*Anas platyrhynchos*) has increased (Heusmann 1991). Factors suggested as causing the decline include over-harvest, pollution, habitat loss or degradation, and introgressive hybridization (Rusch et al. 1989). Ankney et al. (1987) recently argued that introgressive hybridization was a major factor causing the decline in Black Duck numbers, but they also speculated that Mallards might have a higher reproductive rate through larger clutch sizes, and/or more persistence in renesting. Similarly, Nichols et al. (1987), after finding no difference in annual survival rates of sympatric populations suggested that differences in reproductive rates or immigration were responsible for the increase in Mallards. Although Nichols et al. (1987) were unable to detect a difference in survival, their data were based on pre-season (July - September) banded ducks. Both species typically depart their breeding areas in July - August and congregate at staging areas (Bellrose 1980), where pre-season banding efforts are concentrated. Thus, Nichols et al. (1987) may have sampled a population that was not entirely sympatric during the breeding period.

It is evident that basic information on these parameters is scarce relative to interactions between Mallards and Black Ducks, particularly where the two species have become sympatric (Kirby 1988; Rusch et al. 1989). As Mallards continue to expand into traditional Black Duck breeding range, there is debate over what, if any, management efforts would increase survival and reproduction of Black Ducks independently of Mallards (Ankney et al. 1987; Conroy et al. 1989). The objectives of our study were to test the hypotheses that nest success and survival rates did not differ between female Mallards and Black Ducks breeding sympatrically in relatively undisturbed forested habitat of northern New York.

Study Area and Methods

Our 189-km^2 study area was located in the western Adirondack Mountains of New York (74°53'W, 44°8'N). Habitat composition within the study area was 71% deciduous forest, 24% wetland, and 5% residential, industrial, and surfaced-road areas. The majority of the forest is currently in mid-successional stages, and land use is in the form of recreation and the harvest of forest products. During the breeding period, Mallards and Black Ducks occur in the western Adirondacks in an approximate pair ratio of 1.2:1.0, and an estimated pair density of 0.7 Mallards/km^2 and 0.6 Black Ducks/km^2 (U.S. Fish and Wildlife Service, Office of Migratory Bird Management, unpublished 1991 survey).

Pre-nesting females were captured from 22 March to 20 April 1990, and 26 March to 16 April 1991, using modified decoy traps (Sharp and Lokemoen 1987). Each female was fitted with a transmitter

(19g) using the Dwyer harness (Dwyer 1972). Daily monitoring of radio-marked females was initiated by 20 April of both years, and continued through 20 July, or until a particular female departed the study area. Telemetry locations were obtained on foot by homing and general triangulation (Mech 1983; White and Garrott 1990) with a 4-element Yagi antenna and scanning receiver. We assumed that marked females were representative of the local population, and that any effects of the transmitter acted similarly on both Mallards and Black Ducks.

Daily survival of nests and females was determined through telemetry observations, as nest attentiveness and female survival could be evaluated through location changes or signal fluctuations. We defined the exposure period as the total number of days a nest or female was observed, and a successful nest was defined as having at least one hatched egg (Klett et al. 1986). Female breeding success was defined as a female that successfully hatched a nest in one or more attempts (Cowardin et al. 1985). We used the Mayfield method (Mayfield 1961, 1975; Johnson 1979) to estimate survival rates of nests and females, and used a Z-test to test for differences ($P = 0.10$) between Mallards and Black Ducks. Variances on survival estimates were calculated following Hensler (1985).

Nest Success

We suspected that nesting activity had been initiated when telemetry information indicated a sudden lack of daily movement, an upland location, or the failure of normal signal fluctuations during night-time checks. We approached approximately six days later to validate nesting. This delay served to reduce the observer-caused abandonment of early age nests, however, we included this interval in the number of exposure-days. Accordingly, the total number of exposure-days was not biased by decisions of when to visit the nest. Rather, if the exposure period was initiated on the day of first visit, the estimate could be biased upward because of fewer exposure-days (Klett and Johnson 1982). Although nest losses may occur during this delay period, we believed that the bias associated with failing to document an unsuccessful nest was compensated for in our overall estimate of female breeding success and survival which perhaps may have been biased had nest-abandonment occurred. The exposure period of nests were terminated on the day of brood exodus, or the lack of nest attentiveness by the female after dusk.

Female Survival

The exposure period used to calculate female survival was initiated five days after capture to allow for adjustment to the radio package. Daily monitoring of females throughout the breeding period provided an indication of any sudden activity change that could indicate mortality. Females not suspected of nesting were approached within two days to determine their status. When we found a female dead, we back-dated to the day in which the event most likely occurred and used this as the termination date. We assumed that a sudden loss of transmitter signal indicated a departure from the study area, since transmitters were detectable from higher elevations and no premature transmitter failures were known to occur. However, a potential bias in survival may have resulted by our failing to detect any predation event that resulted in a destroyed transmitter.

Results

Nest Success

We combined data between years because annual sample sizes were too small for meaningful comparison. This was expected, given the low densities of these ducks breeding on our study area, and resulted in a sample of 18 Mallards and 9 Black Ducks that provided 19 and 6 nests, respectively. Nests that were destroyed during egg-laying may have gone undetected because of our inability to detect them. More important in our determination of overall female breeding success, however, is that we are certain no successful nest went undetected.

Both Mallards and Black Ducks exhibited peak nest initiation dates of 24 April (range 7 April - 12 May). Clutch sizes were similar ($P \geq 0.10$) for both Mallards ($\bar{x} = 9.3$, ± 1.3 SD) and Black Ducks ($\bar{x} = 9.7$, ± 1.1 SD), and required an average incubation period of 28 days. Therefore, nest success calculations were based on a 37-day survival period (9 egg-days + 28 incubation-days). The nest success estimates of Mallards ($\hat{S} = 0.51$, CI 0.31 - 0.85) and Black Ducks ($\hat{S} = 0.61$, CI 0.30 - 1.00) were similar ($P \geq 0.10$), with relatively few Mallards (n = 3) and Black Ducks (n = 1) renesting after the loss of a documented nest. The proportion of marked females successful at hatching a clutch was 0.67 for Mallards (n = 18) and 0.44 for Black Ducks (n = 9).

Female Survival

We again combined data for both years because sample sizes were small. This resulted in 22 Mallards and 11 Black Ducks for the comparison of survival during the pre-nesting (5 April - 23 April), nesting (24 April - 30 May), and post-nesting (31 May - 20 July) periods (Table 1).

All marked birds survived the pre-nesting period; however, the number of exposure-days for each individual varied according to date of capture. During the nesting period, the survival rate of Mallards ($\hat{S} = 1.00$) and Black Ducks ($\hat{S} = 0.90$, CI 0.74 - 1.00) were similar ($P > 0.10$). The highest mortality occurred during the post-nesting period which included both brood-rearing and post-breeding females, although survival also was similar between Mallards ($\hat{S} = 0.86$, CI 0.70 - 1.00) and Black Ducks ($\hat{S} = 0.86$, CI 0.64 - 1.00).

TABLE 1. Mayfield (1961, 1975) survival estimates of radio-marked female Mallards and Black Ducks during the pre-nesting (5 April - 23 April), nesting (24 April - 30 May), and post-nesting periods (31 May - 20 July) in the western Adirondack Mountains, New York 1990-1991.

Period (days)	Number observed	Exposure days	Females killed	Survival estimate	95% CI
Pre-nesting (19)					
Mallard	22	258	0	1.00	
Black Duck	11	87	0	1.00	
Nesting (37)					
Mallard	22	674	0	1.00	
Black Duck	11	365	1	0.90	0.74-1.00
Post-nesting (51)					
Mallard	17	683	2	0.86	0.70-1.00
Black Duck	8	339	1	0.86	0.64-1.00
Total Season (107)					
Mallard	22	1615	2	0.88	0.73-1.00
Black Duck	11	791	2	0.77	0.52-1.00

Overall survival during the 107-day breeding period was similar ($P \geq 0.10$) between Mallards ($\hat{S} = 0.88$, CI 0.73 - 1.00) and Black Ducks ($\hat{S} = 0.77$, CI 0.52 - 1.00). Of four radio-marked females killed during the study, one, a Black Duck, was recovered at a Red Fox (*Vulpes vulpes*) den during the nesting period. The remaining females (two Mallards, one Black Duck) were engaged in brood rearing at the time of death and two were suspected of being killed by River Otters (*Lutra canadensis*) and one by a Great Horned Owl (*Bubo virginianus*).

Discussion

Our results suggested that nest success and female survival rates of sympatric Mallards and Black Ducks were similar on the breeding grounds. The relationship in breeding period survival on our study area agreed with the findings of Nichols et al. (1987) for annual survival rates, and may be similar to survival rates for allopatric breeding populations as well. For example, Kirby and Cowardin (1986) reported a survival estimate of 0.72 for forest-breeding Mallards in Minnesota (calculated from data presented), and Ringelman and Longcore (1983) indicated a survival rate of 0.74 for Black Ducks breeding in Maine. Although it is not likely that mortality factors influencing these survival rates can be directly compared, we see no reason to believe that a population of predators would discriminate between sympatric female Mallards and Black Ducks, unless some as-yet-unknown behavioral difference exists between these two forms that would increase their vulnerability to predation.

The similarities in our nest success figures between Mallards and Black Ducks also agree with those found for other sympatric populations. Laperle (1974) found no differences in apparent nest success rates between island-nesting Mallards and Black Ducks in Quebec. In Chesapeake Bay, Krementz et al. (1992) demonstrated that nest success rates of island nesting Mallards and Black Ducks were similar in the absence of human disturbance. Although these studies indicated relatively little differences in island populations, very little information exists relative to forested areas that comprise a greater proportion of the Black Duck breeding range (Bellrose 1980). More evident, however, is the lack of information pertaining to overall breeding success of Mallards and Black Ducks, which can effectively be determined by following marked individuals through the breeding period (Cowardin et al. 1985). Our results suggested that the probability of successfully hatching a clutch is similar for that portion of the Mallard and Black Duck population which nest, yet overall production by Mallards may be higher through their nesting effort. This is supported by Coulter and Miller (1968) who demonstrated that Mallards nesting on islands in Lake Champlain were more persistent renesters than Black Ducks.

Although our sample sizes may have prevented us from being more conclusive, our data support the suggestions of Ankney et al. (1987) and Nichols et al. (1987) that increased reproductive success of Mallards is potentially contributing to their population increase throughout Black Duck breeding areas. In areas where Mallards and Black Ducks are found breeding in sympatry, it may not be possible to increase the production and survival of female Black Ducks without providing similar benefits to Mallards. Nonetheless, it is imperative that we gain a better understanding of the ecological relationships between these closely related species where they are found breeding in forested habitats.

Acknowledgments

We thank D. C. Allen, R. E. Chambers, M. P. Losito, J. D. Nichols, W. F. Porter, B. L. Swift, and two anonymous reviewers for providing comments on earlier drafts of the manuscript. Radio-transmitters were provided by B. L. Swift, and the New York State Department of Environmental Conservation. Funding for this project was provided through the USDA-CSRS McIntire-Stennis Program and the Adirondack Wildlife Program at the State of New York, College of Environmental Science and Forestry.

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Received 12 October 1992
Accepted 30 July 1993

A Range Extension for the Amphipod *Crangonyx richmondensis laurentianus* in Northwestern Ontario

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Lindeman, Dorothy H., Robert W. Lindeman, and Miranda Lindeman. 1993. A range extension for the amphipod *Crangonyx richmondensis laurentianus* in northwestern Ontario. Canadian Field-Naturalist 107(2): 217–221.

The freshwater amphipod crustacean *Crangonyx richmondensis laurentianus* Bousfield has been found to be very common throughout northwestern Ontario south of 50° N, and has been collected in the shallow littoral of large and small lakes, ponds and streams. The pH of these bodies of water ranges from quite acidic to relatively basic. The wide variety of habitats indicate that this subspecies is far more tolerant of diverse conditions than was previously thought. The known range is extended from Sault Ste. Marie westward to the Manitoba border.

Key Words: Amphipods, *Crangonyx richmondensis laurentianus,* northwestern Ontario, range extension.

The northwesternmost location at which *Crangonyx richmondensis laurentianus* Bousfield, has previously been recorded is Pointe aux Pins (46°29′ N) near Sault Ste. Marie (Bousfield 1958). Previous published reports established its presence in Washtenaw County, southern Michigan, south central Ontario and western Quebec (Bousfield 1958; Holsinger 1972, 1977). *Crangonyx laurentianus* (Bousfield) [sic] was reported from Lake 470 in the Experimental Lakes Area of northwestern Ontario (Servos and Muir 1989).

In 1980, specimens of *Crangonyx richmondensis laurentianus* were captured in a senescent marl pond, Dock Lake (48° 28′ N, 89° 28′ W), near the city of Thunder Bay by D. H. Lindeman. Identification was confirmed by E. L. Bousfield, then at the National Museum of Natural Sciences (now the Canadian Museum of Nature). Several specimens were subsequently taken from the stomach of a walleye (*Stizostedion vitreum vitreum* Mitchill) captured in Henderson Lake (48° 48′ N 90° 17′ W), just east of Upsala, by Chris Nunan (D. H. Lindeman, unpublished data).

Our extensive collecting across northwestern Ontario since 1980 has revealed that *Crangonyx richmondensis laurentianus* is very common throughout the District of Thunder Bay, and in the Arctic watershed regions of the Kenora and Rainy River districts and these results are reported here.

Materials and Methods

Amphipods have been collected in northwestern Ontario annually since 1980, with extensive seasonal series and individual samples from road-accessible water bodies. Amphipods were collected with several types of modified fine mesh dipnets, based on a typical D-net, created by R. Lindeman. Photographs of the sampling gear used are available in the field catalogues deposited with the amphipod specimens at the Canadian Museum of Nature. Sampling was usually carried out in the shallow littoral zone, from the water's edge to a depth of several feet, usually in vegetation (although rocky shores can be sampled with a heavy-duty wire-mesh dipnet). Occasional sampling was performed with a modified bottom dredge towed from a motorboat. This dredge was a steel box measuring 330 mm by 343 mm, and was 140 mm high. The front end was open, while the top side was fitted with a double steel mesh screen. The inner screen layer had 2.5 mm mesh, and the outer had 8 mm mesh. Four 380 mm chains were attached to the four front corners of the box and fitted to the tow line.

Whenever possible, temperature and pH data were recorded at the sample site, using a swimming pool pH meter[1] and/or pH paper. The normal sampling season is from ice-out in spring to ice-in in late fall, although some samples were taken by smashing ice and dipping through the hole. Most stations were sampled several times, in seasonal series. An exception is the 200 series C.S. samples, intended as casual samples only.

Results

Table 1 shows confirmed collection sites for *Crangonyx richmondensis laurentianus* in northwestern Ontario Small, boggy ponds are common habitats, but it is also found in larger lakes and rivers.

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[1]upgraded as of August 1993 to a Fisher Scientific model 13-300-68 electronic pH tester

TABLE 1. Confirmed collection sites for *Crangonyx richmondensis laurentianus* in northwestern Ontario. Station numbers refer to the Lindeman Collection station lists. Watershed codes are from the Watershed Divisions for Ontario map, compiled by the Sports Fisheries Branch, Ontario Ministry of Natural Resources, Watershed Division, 1974. The first number in the code indicates the primary watershed: 2 is the Lake Superior drainage system, 4 the James Bay system, and 5 the Lake Winnipeg system. Key: [a] - ovigerous females in sample; [b] -females with young in pouches in samples; [ab] - some females with young, others with eggs; [c] - newly hatched young

station	collection site	specimens	watershed	latitude	longitude	date
	Dock Lake	2♀[a], 1♂	2AB-08	48° 28′	89° 28′	1980 05 13
	Henderson Lake	2♀	5PB-24	48° 48′	90° 17′	1980 07 06
11A	Big Pearl Lake	2♀	2AC-07	48° 41′	88° 39′	1982 10 23
19	duck pond, Dorion cutoff at Hickey Lake road	1♀, 1♂	2AC-19	48° 56′	88° 51′	1984 05 06
20	unnamed pond on Anders Lake road	11♀[a], 22♂	2AC-19	48° 55′	88° 51′	1984 05 06
29	Raymore Lake	4♀, 7♂	2AC-09	48° 52′	88° 33′	1982 10 28
30	McKirdy Lake	1♀, 3♂, 10 juv.[c]	2AD-01	49° 16′	88° 08′	1983 07 24
39	Burrows River	4♀	4JD-03	49° 53′	86° 44′	1980 09 14
40	small unnamed lake on Hwy 614	1♀, 1♂	2BB-02	49° 06′	85° 49′	1981 09 05
45	Lake Lenore	15♀, 15♂	2AA-04	48° 03′	89° 36′	1983 09 11
46	Mathe Lake	22♀[b], 6♂, 173 juv.[c]	2AB-04	48° 39′	90° 14′	1982 06 12
48	East Divide Lake	16♀[b], 6♂, 50 juv.[c]	2AB-04	48° 40′	90° 19′	1982 06 05
49	Huronian Lake	14♀, 23 juv.	2AB-12	48° 43′	90° 44′	1982 10 15
50	Aramis Lake	8♀, 10♂	5PA-03	48° 44′	91° 22′	1983 10 15
51	Niobe Lake	17♀, 9♂	5PA-03	48° 43′	91° 20′	1983 10 15
52	Nym Lake	37♀, 6♂	5PA-03	48° 42′	91° 24′	1983 10 15
53	small unnamed lake near Marmion Lake generating station	14♀, 6♂	5PB-18	48° 50′	91° 30′	1983 10 15
56	Lang Lake	6♀, 20♂	5PB-05	49° 04′	90° 25′	1983 10 09
57	Brightsand River	27♀, 18♂, 1 juv.	4GB-05	49° 29′	90° 24′	1983 10 09
58	Pakashkan Lake	21♀, 38♂	4GB-05	49° 29′	90° 18′	1983 10 09
63	Prelate Lake	18♀[a], 7♂	5PA-08	48° 12′	90° 22′	1984 05 19
64	small unnamed lake on Hwy 588	12♀[a], 26♂	5PA-08	48° 13′	90° 28′	1984 05 19
67	Moonshine Lake	5♀[a]	2AC-19	48° 53′	88° 40′	1981 05 24
69	Limestone Lake	4♀, 2♂, 3 juv.	2AE-02	49° 07′	88° 09′	1984 07 02
71	Laurenson Lake	3♀[b], 27 juv.[c]	5PD-11	49° 45′	94° 28′	1987 05 26
73	Wabigoon River	14♀, 3♂	5QD-01	49° 44′	92° 50′	1987 10 06
74	Wabigoon Lake	1♂	5QD-01	49° 44′	92° 44′	1988 10 02
75	Milanese's Pond, Dryden	7♀[ab], 3♂	5QD-01	49° 44′	92° 48′	1987 05 20
91	inlet to Paul Lake	3♀, 2♂	2AB-06	48° 43′	89° 24′	1987 03 04
92	Two Island Lake	9♀[b], 4♂, 43 juv.[c]	2AB-06	48° 42′	89° 20′	1987 06 17
100	Pikie Lake	4♀, 6♂	2AB-04	48° 38′	90° 30′	1988 10 22
118	pond no. 3, Hoodoo Creek road, Armstrong	5♀, 1♂, 3 juv.	2AD-09	50° 14′	88° 55′	1988 07 02
120	Shafton Lake	7♀, 3♂	2AB-05	48° 40′	90° 14′	1988 10 22
123	pond south of Pashkokogan Lake	3♀, 5♂	4GA-16	50° 57′	90° 26′	1988 10 01
128	Olli Lake	6♀, 8♂, 20 juv.	5QD-01	49° 37′	92° 29′	1988 10 02
129	Minnowan Lake	6♀	5QA-08	49° 10′	90° 50′	1988 10 03
130	Hilly Lake	7 juv.	5PE-04	49° 45′	94° 22′	1988 08 05
131	Emerson Lake	3 juv.	5PD-08	49° 46′	94° 11′	1988 08 05

TABLE 1. *Concluded.*

143	North Current River	3♀, 4♂	2AB-10	48° 33′	89° 09′	1989 08 21
152	Pinafore Lake	3♀, 10♂, 14 juv.	5QD-01	49° 29′	91° 57′	1989 10 08
153	Lodge Lake	11♀, 3♂	5QA-08	49° 15′	91° 07′	1989 10 08
154	Hoard Lake	3♀, 4♂	5PB-07	48° 45′	92° 46′	1989 10 06
157	Kawawia Creek	13♀, 15♂	5PB-08	49° 12′	92° 51′	1989 10 07
159	Eagle River	6♀, 4♂	5QD-01	49° 47′	93° 08′	1989 10 08
212cs	small unnamed lake on Hwy 527 at mile post 73	2♀[b], 2♂, 10 juv.	2AD-05	49° 22′	89° 23′	1986 06 30
219cs	Fairloch Lake	51 juv.	2AD-22	49° 30′	88° 00′	1986 08 31
220cs	Lake Kabamichigama	1♀, 1♂	2AE-05	49° 13′	87° 41′	1984 11 11
221cs	Gravel Lake no. 3	19♀, 16♂	2AA-03	48° 14′	90° 00′	1984 10 28
222cs	McKecknie Lake	1♀, 6♂	2AA-04	48° 07′	90° 17′	1984 10 06
224cs	Sunbow Lake	3♀, 2♂	5PA-07	48° 13′	90° 31′	1984 10 28
230cs	Davy Lake	18♀[b], 81 juv.	5QA-05	49° 23′	91° 38′	1986 06 25
234cs	Allely Lake	22 juv.	4GB-04	49° 37′	90° 21′	1984 08 11
235cs	Jason Lake	15♀[b], 3♂, 152 juv.[c]	2BA-03	48° 50′	87° 21′	1985 06 22
236cs	Hornblende Lake	13♀[b], 1♂, 120 juv.[c]	2BA-03	48° 55′	87° 22′	1985 06 21
239cs	Mirror Lake	24♀[ab], 16♂	2AC-01	48° 37′	88° 45′	1986 05 18
245cs	small unnamed pond pas Kakabeka, Hwy 11-17	7♀[b], 4♂	2AB-01	48° 27′	89° 37′	1986 05 31
323	Wangoon Lake	19♀[b], 356 juv.[c]	4LE-01	47° 50′	83° 34′	1990 06 16
347	Sharp Creek	1♀	2AB-07	49° 11′	90° 08′	1990 10 28
348	Gilmor Lake	2♀, 6♂	2AB-07	49° 08′	90° 09′	1990 10 28

It has been found in conditions of high as well as low pH. It is often collected with *Gammarus lacustris*, and almost invariably with *Hyalella azteca*. These data constitute a subsample of the Lindeman collection. Identification of all specimens listed in this paper to subspecies was by D.H. Lindeman, using keys in Bousfield (1958) and Holsinger (1972). Several hundred more lots in the Canadian Museum of Nature await curation and confirmation of field identifications. Queries to the Royal Ontario Museum, the Freshwater Institute, and J. R. Holsinger have not brought to light any other specimens from the study region or points west.

Discussion

Specimens of *Crangonyx richmondensis laurentianus* were collected from the Manitoba border to near the previous range record at Sault Ste. Marie. The western boundary of the range has yet to be delineated. The fact that this species is so widespread throughout the Great Lakes, James Bay and Lake Winnipeg watersheds indicates that its presence is not the result of an introduction.

Reasons why this species may have been overlooked in the past include: lack of sampling effort; relatively low population densities as would be expected for a carnivore; the annual life cycle, which eliminates adults from those habitats where most collections are performed during high summer; and also that the adults tend to congregate in deeper water than *Gammarus* or *Hyalella*. For example, in Raymore Lake, a dipnet sample yielded 2 *Crangonyx*, 36 *Gammarus* and large numbers of *Hyalella*. Twenty-three days later, a shallow-water bottom trawl caught 11 *Crangonyx* and 28 *Gammarus*. It often requires a great deal of work to collect any significant number of *Crangonyx* specimens (R. Lindeman, personal observations), except in early spring, when the females are releasing their broods in shallow nursery areas. Another feature of our sampling is the extensive series of late fall samples, in which *Crangonyx* are easily identified, despite not being in breeding condition. High summer sampling (late June through August) will take only very small specimens which can easily be confused with *Hyalella*.

Crangonyx richmondensis laurentianus was previously thought to inhabit only small acidic lakes and bogs (Bousfield 1958; Judd 1963; Sprules 1967). Our data indicate that it is not restricted to acidic conditions or to bog ponds. Specimens have been taken by us in large and small lakes, ponds, springs and slow-moving rivers. It appears to be tolerant of a relatively wide range of pH, from very acidic to rela-

TABLE 2. Some study lakes for which pH data are available. Data taken by R. W. Lindeman at sample sites are compared with data from the Ontario Ministry of Natural Resources database, provided by T. Marshall, with access permission from R. Ryder. Disagreements between Lindeman and O.M.N.R. data may be due to seasonal changes in water chemistry.

Station	Lindeman pH	date	M.N.R. pH	date
Allely Lake	6.8	84 08 11	7.5	76 07 08
Aramis Lake	7.2	83 10 15	7.5	77 07 02
Big Pearl Lake	7.6	84 07 22	7.2	68 06 13
Davy Lake	6.8	86 06 25	7.0	78 07 25
Gravel Lake #3	7.4	84 10 28	8.0	69 08 01
Huronian Lake	7.2	84 09 17	8.0	71 08 19
Lake Lenore	7.2	85 05 12	8.1	73 06 04
Lang Lake	7.2	85 05 19	7.0	73 07 05
Minnowan Lake	6.8	88 10 03	6.8	68 06 03
Mirror Lake	8.4	86 05 18	8.5	74 05 29
Niobe Lake	6.8	83 10 15	7.0	80 05 16
Nym Lake	6.8	83 10 15	6.7	69 06 22
Pakashkan Lake	7.2	83 10 09	7.5	74 08 14
Prelate Lake	7.4	84 05 19	7.5	71 06 21
Shafton Lake	7.6	88 07 30	7.5	75 05 28
Sunbow Lake	6.8	84 10 28	7.0	71 07 10

tively basic. Table 2 lists some lakes for which the pH data are available. In Dock Lake, for example, which supports a thriving population (D.H. Lindeman, unpublished data) the pH ranges from 7.5 to 9.0, due to heavy marl deposits (Momot 1978).

Ovigerous females (carrying eggs) are captured from shortly after ice-out until the broods are released in mid-summer, generally from May to June. The exact timing of mating and egg formation, and the length of time to brood the eggs, seem to vary with the temperature regime of the specific habitat. Reproduction may be controlled by a combination of photoperiod and temperature thresholds, as it is in *Hyalella azteca* (de March 1977). For example, at station 92 (48° 42° N) on 17 June 1986, females were already releasing young, while at station 212cs (49° 25° N) on 30 June, females were carrying unhatched eggs.

Females tend to disappear from upper littoral zone samples toward the end of June. Males are usually not captured in shallow waters after about mid-June. Males are not sexually mature in the fall, and lack the secondary sex characters of calceoli on the antennae and a hooked outer ramus on uropod 2. A very early sample taken under the ice on 4 March, 1987 at station 91 yielded females and males that were still not sexually mature. The onset of sexual maturity may be almost synchronous with ice-out. It is possible that as soon as the ice cover has disappeared, there is an initial molt in which overwintering individuals acquire the morphological secondary sex characteristics.

In many of the lakes sampled, *Crangonyx* was not normally captured in the upper littoral zone until two to three weeks after ice-out, although specimens were often found during late fall, winter, and very early spring in stream mouths and spring areas where there is a constant flow of water (R. Lindeman field observations). The assumption that males die very shortly after mating, and that adult females die after their brood has left the pouch, should be tested by deeper water sampling in summer. It is conceivable that in lakes with very cold temperature regimes, some adults retreat to deeper areas rather than dying off.

The extensive western range of *C. r. laurentianus* strongly suggests that the western (Mississippi) refugium proposed by Smith (1977) for this subspecies during the last glacial advance is correct. Lake Agassiz apparently overflowed through several channels into Lake Superior following the Marquette readvance, and may have brought *Crangonyx* with it. Evidence linking an overflow of Lake Agassiz with the distribution of several fish species in northwestern Ontario has been presented by Hartviksen and Momot (1987). It is possible that separation of the eastern and western populations at that time resulted in the present small morphological differences between the two subspecies *C. r. laurentianus* and *C. r. richmondensis*. If the range of *C. r. laurentianus* was originally much further west and south than it is at present, it could also provide a link between the two eastern subspecies and *Crangonyx richmonden-*

sis occidentalis, presently restricted to a relatively small range in British Columbia and Washington State (Bousfield 1958).

Acknowledgments

Watershed maps, lake surveys and geological data for much of the sample region were provided by a great many helpful individuals at the Ontario ministries of Natural Resources, the Environment, and Northern Development and Mines, including R. A. Ryder, Bob Hamilton, Rob Steedman, Tom Mosindy and Bev Ritchie of the O.M.N.R., who were particularly generous with their time and information. The pH data from the O.M.N.R. database were very kindly provided by Terry Marshal, at the Fisheries Research Section, Ontario Ministry of Natural Resources, Thunder Bay. We would like to thank the Biology Department of Lakehead University for their continuing assistance in providing ethanol and microscope access to R. Lindeman. Diana Laubitz, then Curator of Crustacea, generously provided D.H. Lindeman with a microscope, work space, and access to facilities at the Canadian Museum of Nature, and reviewed the manuscript.

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Received 30 October 1992
Accepted 13 September 1993

Notes

First Occurrence and Breeding of Sprague's Pipit, *Anthus spragueii*, for British Columbia

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McConnell, Stephen D., Ruth van den Driessche, Tracey D. Hooper, G. L. Roberts, and Anna Roberts. 1993. First occurrence and breeding of Sprague's Pipit, *Anthus spragueii,* for British Columbia. Canadian Field Naturalist 107(2): 222–223.

The first occurrence and breeding record of Sprague's Pipit, *Anthus spragueii,* in British Columbia was obtained in summer 1991. The bird nested near Riske Creek, in the Cariboo region, approximately 500 km west of its known breeding range in Alberta.

Key Words: Sprague's Pipit, *Anthus spragueii*, breeding, Riske Creek, British Columbia.

On 17 May 1991, we heard a Sprague's Pipit, *Anthus spragueii,* singing, during a survey of grassland birds in the Riske Creek area (51°52′N, 122°21′W). On 7 June, a pipit was again seen and heard singing high over an open grassland area, 1.5-2 km from the site where first observed. We assumed this was the same bird heard on 17 May as the grassland was continuous between the two sites and the bird was not heard again at the previous site.

On 14 June, the bird was seen and heard singing again in the second location, suggesting a territory had been established. Photographs of the bird were taken on 15 June (*see* front cover).

On 25 June, the site, below where the pipit was displaying, was systematically searched for a nest. The area was swept using a 50 m nylon chain kept taut enough to just make contact with the ground. A bird flushed from a nest when the chain was approximately 2 m away from the nest. The bird flew very low to the ground for about 7 m, then rose 2–3 m above the grass and flew in an undulating flight for about 100 m before suddenly dropping back into the grass.

The nest was a small depression lined with coarse and fine grasses woven into a cup. Almost three-quarters of the nest was covered with a domed roof, formed from long grass adjacent to the nest with additional loose grass interwoven. The nest was 13 cm in diameter and 7 cm deep. The vegetation surrounding the nest was mainly spreading Needle Grass *Stipa richardsonii*. Photographs of the nest, with six eggs, although not of publishable quality, confirmed that the nest belonged to a Sprague's Pipit (R. W. Campbell, personal communication). The eggs were greyish-white with abundant reddish-brown speckling.

On 3 July, the nest's roof had been removed and the nest was empty. Sprague's Pipit chicks typically remain in the nest for 10–11 days (Bent 1950). Because only eight days had passed since the previous observation and no chicks were found near the nest, it is likely that the nest was predated. A second breeding attempt may have been made, as the male was singing and displaying over the site until 21 July.

On 5 July, detailed observations of the male's flight display were made. The display lasted 7–20 min with the bird returning to the ground at intervals. The display began high in the air with the bird gaining altitude by making 7–9 series of rapid wingbeats. It then glided, while singing, with its tail feathers spread out. Occasional wingbeats were made, particularly towards the end of the song. The song lasted 2–3 sec and little, if any, altitude was lost during this time. This sequence was repeated numerous times at 50–100 m altitude. When returning to the ground, the bird folded its wings and dropped from the sky. Just before making contact with the ground, it opened its wings and then flew in a short undulating path before alighting in the grass. This action was difficult to observe, however, as the bird normally dived so fast it was lost from sight. This is consistent with other descriptions of its descent (*see* Bent 1950).

When on the ground, the male was observed for several hours as it walked about and fed on insects. A caterpillar was the only identifiable prey captured.

In North America, the Sprague's Pipit breeds from north-central Alberta, central Saskatchewan, and west-central and southern Manitoba, south to Montana, North Dakota, western South Dakota and north-western Minnesota (American Ornithologists' Union 1983). The previous western limit of the known breeding range in Canada occurs in north-western Alberta from Athabasca to the Peace River district (Salt and Salt 1976). In southern Alberta, the distribution continues west to the Yaha Tinda Prairies in the foothills of the Rocky Mountains (Godfrey 1986). Most breeding records in Alberta are in the southern prairies near Calgary (Sadler and Myres 1976).

The Sprague's Pipit was first recorded on the west coast of North America, in California, on 19 October 1974 (McCaskie 1975). Since then, it has been recorded in California almost annually, between October and mid-December (Roberson 1980). There is only a hypothetical record in Oregon at the Hart Mountain National Refuge, on 22 September 1981 (Schmidt 1989). Although previously reported in British Columbia, there are no documented records of Sprague's Pipit in the province (Munro and Cowan 1947; R.W. Campbell, personal communication).

Riske Creek is 45 km south-west of Williams Lake, on the Fraser plateau in southern interior British Columbia. This ranching area forms the northern limit of continuous grasslands in the Interior Douglas-fir and Bunchgrass biogeoclimatic zones. Bird species most characteristic of this high-elevation (970 m) grassland include Northern Harrier, *Circus cyaneus*; American Kestrel, *Falco sparverius*; Sharp-tailed Grouse, *Tympanuchus phasianellus*; Long-billed Curlew, *Numenius americanus*; Horned Lark, *Eremophila alpestris*; Mountain Bluebird, *Sialia currucoides*; Western Meadowlark, *Sturnella neglecta*; Savannah Sparrow, *Passerculus sandwichensis*; and Vesper Sparrow, *Pooecetes gramineus* (Erskine and Stein 1964; Hooper and Savard 1991). A more intensive search for Sprague's Pipits in British Columbia's grasslands is needed to establish this species' status in the province and whether this was an isolated incident.

Acknowledgments

This paper is the result of research on grassland avian diversity funded by the British Columbia Ministry of Forests (Sustainable Environment Fund), the British Columbia Ministry of Environment (Habitat Conservation Fund), and the Canadian Wildlife Service. We thank Neil and Kerry MacDonald for access to their property, and R. Wayne Campbell for help with the literature review and advice on writing the paper.

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Received 3 February 1992
Accepted 31 August 1993

Reactions of Certain Birds to the Covering of Their Eggs

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Höhn, E. O. 1993. Reaction of certain birds to the covering of their eggs. Canadian Field-Naturalist 107(2): 224–225.

Rock Doves and American Robins incubated over completely covered eggs. Grebes of two species flipped leafy twigs over their eggs with their beaks, one partially moved a cardboard. Plovers of several species uncovered sand over their eggs with their beaks and by body movements. Killdeers flipped a stiff cover off the eggs with their beaks, but one bird would not expose sand-covered eggs. Spotted Sandpipers used only body movements to expose eggs.

Key Words: Rock Doves, *Columbia livia*, American Robins, *Turdus migratorius*, Red-necked Grebe, *Podiceps grisegensa*, Horned Grebe, *Podiceps auritus*, Semipalmated Plover, *Charadrius semipalmitus*, Black-bellied Plover, *Pluralis squatarola*, Common Ringed Plover, *Charadrius hiaticula*, Snowy Plover, *Charadrius alexandrinus*, Little Ringed Plover, *Charadrius dibios,* Killdeer, *Charadrius vociferus*, Spotted Sandpiper, *Acitis macularia*, egg-uncovering behaviour, Alberta.

A number of observations have shown that certain ground-nesting birds can locate their nest sites even when the nest and eggs are completely covered. Only one class of clues by which birds find their nest sites; i.e., prominent objects in a bare area such as sand dune habitat were experimented on by Tinbergen (1953) and Laven (1949). This literature suggested experiments on the simpler question of how birds deal with the problem of finding their eggs covered.

Experimental birds were observed through 10X binoculars from a blind, stationary car, or natural cover. My observations on suitably placed nests were made over a number of years as follows: Red-necked Grebe: 14, 17, 30 June, 1 July 1977, Hastings Lake, Alberta; Horned Grebe: 4, 18 June 1977, 16 June 1979, Hastings Lake area; Semipalmated Plover: June 1967 at Chesterfield Inlet, Northwest Territories; Killdeer: 17 June 1977, 10, 11, 15 June 1979; 9, 10 May 1980, all central Alberta; Black-bellied Plover: 19 July 1953, Banks Island: Northwest Territories; Spotted Sandpiper: 23 July 1975, 23 June 1976, Caribou Mountains, Alberta; Rock Dove: 2 December 1975, 4 August 1976; American Robin: 16, 28 May 1976, both species at Edmonton, Alberta.

The results of my observations and those from the literature are presented in Table 1. The term "shuffling" means the movements by which incubating birds settle over their eggs under with feathers surrounding the brood patch or patches errected. An exaggeration of these movements enable Spotted Sandpipers to remove matter like spruce twigs with needles. The nest scrape movements, which some authors mention, are unlikely to be as effective as shuffling as in these the abdominal feathers are sleeked to the body.

Rock Doves, which (unlike any other of the experimental species) lack a brood patch, tend to incubate over covered eggs. A larger number of experiments on doves would be valuable to confirm this. In Robins, stimuli from the upper half of the nest-cup and its rim may satisfy the urge to incubate. Grebes can flip leafy twigs off the nest with the beak but only one individual partly displaced a stiff paper.

Experiments on plovers are more significant than on other birds, since, apart from the Killdeer, they nest on sandy shores where sand may naturally cover the eggs by wind or wave action. Most plovers mainly used their beak to uncover eggs. Killdeer are able to flip stiff paper off the eggs with their beak and will drop it into nearby waters. One Killdeer was unable to remove sand over its eggs. Two Spotted Sandpipers, perhaps because of their fine beaks or some psychic bann, did not use their beaks in this situation, but uncovered eggs only by shuffling even when confronted by material like spruce twigs with needles. They failed to move a stiff paper cover. More experiments on long-billed shore birds would be useful to more fully test these differences.

Subtropical plovers cover their eggs themselves, e.g., in the Egyptian Plover (*Plavialis aegyptius*), to protect them from solar heat. At times they will moisten the sand by water carried in the plumage. Eggs were covered by this plover by using its beak and by "settling down on the nest," (Howell 1979). Kittlitz's Plover (*Charadrius pecuaris*) covers its eggs by feet and by beak and by, making nest scraping movements" (probably actually shuffling) Maclean (1974).

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Received 21 January 1991
Accepted 14 April 1993

TABLE 1. Experiments conducted at nests of certain nesting birds in Alberta and selected examples from the literature. Each sign denotes one experiment (-) failure to uncover the eggs; (+) eggs uncovered. Number of nests experimented with by author are marked [ ].

Rock Doves (*Columba livia*) [3]						
eggs covered by:	small bits of cardboard	cardboard	cast off tail feathers	sand (2 birds)		
eggs exposed:	+	brief incubation	incubation over	incubated over		
by:	shuffling	over covered eggs	covered eggs	covered eggs		
American Robins (*Turdus migratorius*) [2]						
eggs covered by:	2 cm deep layer of dead leaves both birds incubated over covered eggs		deeper layer of dead leaves bird incubated over covered eggs			
Red-necked Grebe (*Podiceps grisegensa*) nests [2]				**Horned Grebe (*Podiceps auritus*) nests [2]**		
eggs covered by:	nest rim plants	poplar twigs	stiff paper	nest rim plants	poplar twigs	cardboard
eggs exposed:	− + − +	− − + + −	− −	+ +	+ + after long delay	− − (−+) after long delay
by:	beak	beak	beak	beak	beak	beak; only partly/covered
Semipalmated Plover (*Charadrius semipalmitus*) [1]						
eggs covered by:	sand	seaweed	grass			
eggs exposed:	+	—	—			
by:	beak + shuffling					
Black-bellied Plover (*Pluialis squatarola*) [1], Common Ringed Plover (*Charadrius hiaticula*) (Laven 1949), and Snowy Plover (*Charadrius alexandrinus*) (Maclean 1974)						
eggs covered by:	sand		sand		sand	
eggs exposed:	+		+		+	
by:	beak		beak		beak	
Little Ringed Plover (*Charadrius dibios*) [1] and Kildeer (*Charadrius vociferus*) [3] (Nickel 1943; MacKean 1974)						
eggs covered by:	sand	snow	sand	small leaves	stiff paper	rain softened paper
eggs exposed:	+	+	+ + + − one bird	+	+++*	incubated over it
by:	beak	beak	shuffling or beak	beak	beak	
*the stiff paper was dropped into nearby waters in all three cases. Yet one bird would not uncover sand-covered eggs.						
Spotted Sandpipers (*Acitis macularia*) [2]						
eggs covered by:	sand	lichen	chips of bark	spruce twigs	stiff paper	
eggs exposed:	+ +	+	+	+	− −	
by:	shuffling	shuffling	shuffling	shuffling		

First Banded Passerine Recovered in the Magdalen Islands: Yellow-rumped Warbler, *Dendroica coronata*

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McNair, Douglas B. 1993. First banded passerine recovered in the Magdalen Islands: Yellow-rumped Warbler, *Dendroica coronata*. Canadian Field-Naturalist 107(2): 226.

A female Yellow-rumped Warbler, *Dendroica coronata,* originally banded as an immature bird at Island Beach State Park, New Jersey on 16 October 1990, was captured and released the following year in the Magdalen Islands, Quebec, on 16 September. This bird is the first banded passerine recovered in the Magdalen Islands.

Key Words: Yellow-rumped Warbler, *Dendroica coronata,* geographic distribution, recovery, Magdalen Islands.

I captured and subsequently released an AHY-F Yellow-rumped ("Myrtle") Warbler (band number: 1840–06868) at 08:45 ADT within spruce-fir forest at my banding station on Marichite Point, Havre-Aubert Island, Magdalen Islands (47°12′N, 61°54′W), Quebec, on 16 September 1991. The bird weighed 12 g (± 0.125 g) and had no visible fat (fat class 0; Foster and Cannell 1990). Its wing length (maximum flattened method) was 72.5 mm; the tarsus length was 18.5 mm. The skull was completely ossified. I detected no plumage or physical abnormalities, nor any ectoparasites on this bird which had a rather extensive body and wing molt.

The weight of the "Myrtle" Warbler, close to the mean weights of AHY-F for fall migrants along the Atlantic coastal states (Prescott 1981), indicated it was not stressed, and the sequence of the pre-basic molt was normal (*see* Hubbard 1980). On this basis, the bird was apparently healthy.

This "Myrtle" Warbler was originally banded the previous year by G. R. Mahler as a HY-U bird at Island Beach State Park, Ocean County New Jersey (39°52′N, 74°05′W) on 16 October 1990, when it weighed 10.6 g (± 0.05 g) and had no visible fat. The banding site is on a barrier island between the Atlantic Ocean and Barnegat Bay, approximately 1300 km from my banding station in the Magdalen Islands.

The "Myrtle" Warbler is a fairly common breeder in the Magdalen Islands, but I did not capture my first "Myrtle" Warbler until a month later, on 2 September. The "Myrtle" Warbler I recovered on 16 September occurred during a wave of passerine migrants. Of 42 "Myrtle" Warblers captured from 2 September to 4 October, the four I caught on 16 September were my third highest daily sample of this species (maximum: 12 on 17 September).

Though not a direct recovery, the "Myrtle" Warbler I captured on 16 September is the first banded passerine recovered in the Magdalen Islands, disregarding an at-sea recovery of a Brown-headed Cowbird (*Molothrus ater)* 32 km west of the Magdalen Islands on 19 March 1961 (Dennis 1983). The record of the "Myrtle" Warbler is also significant in that the bird was an adult, whereas 92% of the Parulinae banded from 3 August to 5 October 1991 were immatures (27 of 28 "Myrtle" Warblers banded were immatures).

Acknowledgments

I thank G. R. Mahler and the Banding Office of the Canadian Wildlife Service for providing me information on the original banding record. I also thank A. J. Erskine, M. Gosselin, P. Laporte, S. Sealy, and an anonymous individual for their critical evaluation of this note.

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Received 6 April 1992
Accepted 20 September 1993

Intraspecific Killing Observed in Tree Swallows, *Tachycineta bicolor*

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Rendell, Wallace B. 1993. Intraspecific killing observed in Tree Swallows, *Tachycineta bicolor.* Canadian Field-Naturalist 107(2): 227–228.

I describe one observed incident of intraspecific killing (by drowning), and two other possible cases of killings, by Tree Swallows, *Tachycineta bicolor*, at a nest-box population in British Columbia. The observations leave no doubt that fights between Tree Swallows may lead to intraspecific killing in this species, and they are discussed in light of the unusually limited availability of nest-sites at my study area in 1991.

Key Words: Tree Swallow, *Tachycineta bicolor*, intraspecific killing, nest-site availability.

Intraspecific fighting in Tree Swallows, *Tachycineta bicolor*, is frequently observed during the breeding season. Fights can lead to serious injury (Robertson et al. 1986), but to the best of my knowledge direct observation of intraspecific killing by a Tree Swallow has not been described previously, although referred to by Robertson et al. (1986). Lombardo (1986a) also provided strong, but circumstantial, evidence for adult intraspecific killing in this species. Here I describe one incident of adult intraspecific killing by a Tree Swallow. In addition, I include two incidents of possible killings similar to that reported by Lombardo (1986a). My observations leave no doubt that fights among Tree Swallows can lead to the death of a combatant.

These observations were made at the Creston Valley Wildlife Management Area (CVWMA), southeastern British Columbia (49°05′N, 116°35′W). Tree Swallows nested in nest-boxes distributed in pairs (two boxes 3 m apart) on dykes and exposed ground in marsh habitat. All pairs of boxes were within 50 m of open water, and they were at least 40 m away from the nearest pair of boxes. Only one of the two boxes of each pair was occupied by Tree Swallows at any time, but each pair defended both adjacent boxes, so I refer to the paired boxes as a territory. In total there were 79 territories, and territory occupancy was 100%.

On 23 April 1991 at 11:30.45, I observed two after-hatch-year (AHY) Tree Swallows tumble into water within 3 m of shore while engaged in a fight. The fight occurred approximately 30 m from myself and the nearest nest-box territory. Both birds continued to engage each other for 30 sec until one bird managed to get on top of the back of the other. The bird on the bottom was partially submerged but continued to struggle until 11:32.20 when it stopped moving. The bird on top had its wings spread out on the water's surface, and it alternated between pecking the victim and bouts of weak wing flaps. These wing flaps may have allowed the bird on top to maintain its balance while holding the other bird down. The bird on top continued this behaviour even after the victim stopped moving. At 11:32.50 the "winner" flew off. The sex of the winner could not be determined. A necropsy showed that the dead bird was a male. I saw no external injuries but for ruffled feathers about the head and nape. Apparently, the bird drowned.

On 13 and 29 June 1991, I recovered an after-second-year female (sex determined by necropsy) and AHY Tree Swallow (sex unknown) that were found freshly dead in nest-boxes N9 and N50, respectively. Nest N9 contained 10-day old nestlings, and those in N50 were 18 days old. Both birds were found lying on their bellies on the nestlings, with head and tail tilted up and wings in, similar to the dead bird in Lombardo (1986a). The feathers on the heads and napes of both birds were pushed forward as if they had been pecked from above, but otherwise there were no external injuries. Neither bird was a resident of the nest-box. Both residents were banded at N50. Only the female was banded at N9, but both male and female residents were observed to feed nestlings at this nest subsequent to the discovery and removal of the dead bird. Their appearances, and the fact that they were non-residents, suggest that the dead birds were victims of fights with residents. Other species of secondary cavity-nesting birds that could have been responsible for killing a Tree Swallow, such as House Sparrows, *Passer domesticus*, or European Starlings, *Sturnus vulgaris*, were never seen at nest-boxes in the marsh. These are relatively unexpected cases of mortality because Tree Swallows with young typically become less territorial, and less aggressive toward conspecifics, as the nesting cycle proceeds. Late in the nestling stage, both adult and juvenile "attendants" frequently enter nests of other pairs, even when the residents are present, without encountering aggressive defense (Lombardo 1986b, 1987). Lombardo (1985) showed that Tree Swallows do not attack intruding non-residents at nest-sites during the nestling stage until after an apparent act of aggression by a non-resident (e.g., killing young). It seems likely, therefore, that the dead birds recovered from boxes N9 and N50 acted aggressively toward the nestlings, or parents, and that the parents retaliated.

Intraspecific killing in Tree Swallows apparently occurs infrequently, but the likelihood of deaths may vary among populations depending on the availability of essential resources (*see* Enquist and Leimar 1990). For example, limited nest-site availability has selected, at least in part, for territoriality and aggressive behaviour toward conspecifics in Tree Swallows (Kuerzi 1941; Harris 1979; Leffelaar and Robertson 1985; Lombardo 1985). If nest-sites are extremely limited, the number, duration and intensity of aggressive encounters may be expected to rise dramatically.

Consistent with this hypothesis, during behavioural watches of pairs with nestlings I frequently observed intense fights between residents and intruders inside nest-boxes such as I had not witnessed before while conducting research at a Tree Swallow population in southern Ontario. The distribution and availability of nest-boxes at my study site probably contributed to an increase in aggressive behaviour locally. Prior to the 1991 breeding season, approximately 160 nest-boxes had been available to Tree Swallows at CVWMA over a five-year period. These boxes were distributed singly, 20 m apart, and occupancy was approximately 80% (D. Wiggins, personal communication). I redistributed all of these boxes into pairs. As residents could now defend two potential nest-sites, this reduced nest-site availability by half. Assuming that the size of the local Tree Swallow population was similar to previous years, nest-site availability was extremely limited. Similar to these conditions, Belles-Isles and Picman (1987) described possible intraspecific killings committed by House Wrens, *Troglodytes aedon*, at a nest-box population where some boxes had been removed from the study area. They also suggested that limited nest-site availability may have led to these deaths. Unfortunately, a comparison of intruder rates and fight intensities between resident and non-resident Tree Swallows at my study site in 1991 with those from years prior to 1991 is not possible.

Acknowledgments

R. Cohen, P. Hurd, N. Verbeek and an anonymous reviewer commented on earlier drafts of the text. Logistic support was provided by CVWMA. My research was supported by an operating grant and a scholarship from NSERC of Canada to N. Verbeek and myself, respectively, and by a Simon Fraser University Special Graduate Entrance Scholarship, two SFU Graduate Research Fellowships, a SFU Special Graduate Research Fellowship, and a John K. Cooper Award.

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Received 14 April 1992
Accepted 22 December 1993

Partial Albinism in Two Related Beavers, *Castor canadensis*, in Central Wisconsin

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Lovallo, M. J., and M. Suzuki. 1993. Partial albinism in two related Beavers, *Castor canadensis*, in central Wisconsin. Canadian Field-Naturalist 107(2): 229.

We report the collection of two related Beaver (*Castor canadensis*), in central Wisconsin, which display similar patterns of apparent partial albinism.

Key Words: Beaver, *Castor canadensis*, albinism, Wisconsin.

Albinism in the Beaver (*Castor canadensis*) is rarely observed (Novak 1987). We report two Beavers, one male and one female, from Wisconsin with similar patterns of partial albinism. Both specimens were collected in the first week of March, 1992, from a small pond in central Wisconsin (Sec 21, T25N, R8E, Portage Co., Wisconsin). The lodge was determined to be active by the presence of a food cache (Bergerud and Miller 1977) and the pond was completely frozen. No other colonies or bank dens were detected within 1 km of the lodge.

The male (UW-SP Mus. - 7152) weighed 15.5 kg, and the female (UW-SP Mus. - 7153) weighed 7.7 kg. The estimated ages, based on body weights (Fleming 1977), of the male and female were >2.5 years and 0.5-1.5 years, respectively. Both beaver were captured from the same lodge suggesting they were related. The female was probably the yearling offspring of the male.

Both specimens display similar irregular patches of white fur on the venter (approximately 4 cm X 30 cm) and conspicuous white on the skin of both hind feet extending from the toes and adjacent webbing onto the feet (Figure 1). The white was most pronounced on the ventral surface of the webs. The yearling female showed a little white on a front foot that was not observed in the older male. Another yearling female (UW-SP Mus. - 7151), captured from the same lodge as the other specimens, exhibited normal fur coloration and no white markings on the feet. We are unaware of other reports concerning partial albinism or filial inheritance of albinistic traits in Beaver.

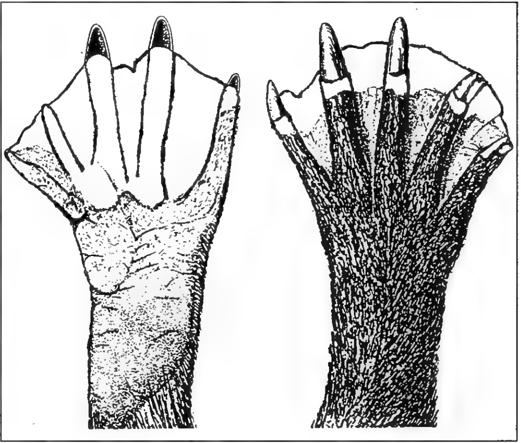

FIGURE 1. Pattern of albinism on hind feet of a Wisconsin beaver (UW-SP Mus. - 7152).

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We thank C. Long, University of Wisconsin Department of Biology, for his assistance.

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Received 6 May 1992
Accepted 25 October 1993

Evidence of Wolves, *Canis lupus*, Burying Dead Wolf Pups

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Boyd, Diane K., Daniel H. Pletscher, and Wayne G. Brewster. 1993. Evidence of Wolves, *Canis lupus*, burying dead Wolf pups. Canadian Field-Naturalist 107(2): 230–231.

We report an observation of a Wolf or Wolves, (*Canis lupus*) probably burying at least two dead Wolf pups in Glacier National Park, Montana. No previous literature reports have been found of a Wolf caching or burying a dead Wolf.

Key Words: Wolf, *Canis lupus*, burying, pups, Glacier National Park, Montana.

Although caching (i.e., food hoarding) behavior has been often reported in Wolves, *Canis lupus*, and other canids (Murie 1940, 1944; Mech 1970, 1988) we have not found any references to a Wolf burying another Wolf. Here we report evidence for a female having buried dead pups.

During a study of Wolves (*see* Ream et al. 1991), alpha female W8653 was located at her den in Glacier National Park, Montana, during 14 of 14 radio-locations from 21 April - 17 May 1989. She was located 6 km southeast of the den on 18 May, 18 km north on 19 May, and 50 km north of her den on 23 May. She did not return to the den until approximately 30 May. W8653 and the other pack members moved throughout their territory for the remainder of the summer, apparently abandoning the den about 18 May.

We examined the den and surrounding area on 13 June. The den was a hollow log, 0.9 m tall and 0.5 m wide on the outside. The inside average cavity height was 0.5 m and inside width was 0.4 m. The excavated den extended 5.5 m back from the entrance. The den was undisturbed, and new vegetation was growing in the entrance, indicating absence of persistent use for several weeks. The decomposed remains of one Wolf pup were found 40 m northeast of the den. The following day a tracking dog found the remains of a second pup 64 m northwest of the den. The remains of both consisted of mostly intact skeletons and associated skin and hair, suggesting the carcasses decomposed almost completely without disturbance. It appeared that the pups had been buried in dry, woody duff several weeks earlier, and were more recently exhumed by a scavenger, because we found excavations approximately 15 cm x 30 cm x 10 cm next to the remains of each pup. Four similar excavations without Wolf pup remains were found within an 80 m radius of the den. The dog behaved similarly at all six excavated sites, sniffing intently and lingering at the sites. An additional pup may have been buried, exhumed, and later consumed by a scavenger at each of the four sites without pup remains. The excavations appeared to be of fairly recent origin compared to the date of den abandonment.

The pups were estimated to be two weeks old at the time of their death; the length of the mandible from the articular process to the mandibular symphysis was 55 mm, and the premolars were erupted to approximately the gumline. This indicated that these two pups died in early May. The mother abandoned the den one to two weeks later, suggesting that some pups may have been alive after these two pups died. Remains of the pups were too decomposed to determine the cause of death.

Blood samples collected from pack members later the same summer had extremely high canine parvovirus (CPV) and canine distemper (CD) titers, compared to low titers of pack members in previous years (Johnson, Boyd, and Pletscher, *in press*); this suggests that CPV or CD may have caused these mortalities.

The mother Wolf (W8653) had successfully raised two previous litters, so inexperience was an unlikely cause of the pup mortalities. Whatever the cause of death, the pups appear to have been buried near the den about the time of their death. At a later date, a scavenger (most likely a Coyote, *Canis latrans*, or Wolf, based on the appearance of the diggings) exhumed the carcasses, an event which brought our attention to this occurrence.

Acknowledgments

Funding was provided by the U.S. Fish and Wildlife Service, National Park Service, and Forest Service through a Cooperative Agreement with the University of Montana, Missoula, Montana. We thank R. Chundawat, R. Ream, and M. Fairchild for their help. L. D. Mech estimated the age of the pups. S. Fritts and D. Holt made helpful comments on the manuscript.

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Received 13 July 1992
Accepted 15 September 1993

Feeding Behaviour of a Burrowing Owl, *Athene cunicularia*, in Ontario

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John, Roy D., and Jack Romanow. 1993. Feeding behaviour of a Burrowing Owl, *Athene cunicularia*, in Ontario. Canadian Field-Naturalist 107(2): 231–232.

An extralimital occurrence of a Burrowing Owl presented an opportunity to examine prey species in relation to those encountered in the bird's typical range. The owl ate mainly Carabid beetles and earthworms, showing the ease with which the bird adapted to using locally available prey.

Key Words: Burrowing Owl, *Athene cunicularia*, pellet analysis, prey species, Ontario.

Burrowing Owls normally breed in Manitoba, Saskatchewan, and Alberta (Godfrey 1986) and the western United States (Scott 1983). Therefore the sighting of one of this species at Arnprior, just northwest of Ottawa, Ontario, between 19 to 24 April 1991 represents an unusual extralimital occurrence. There have been only five other sightings in Ontario (Godfrey 1986).

The bird chose an open field area, similar in appearance to the short-grass, treeless terrain it typically inhabits in the western Canadian prairie. This undulating field had a number of small knolls, several Woodchuck, *Marmota monax,* holes and was covered with short, coarse grass. The bird used the knolls as observation points and retired into the Woodchuck holes at night and during bad weather.

The bird was observed feeding on several occasions. Generally, it appeared to pick up food items from the ground. It did this by running, chicken-like, across the ground and snatching at the prey with its beak. Often, the prey was identified at the time of observation as an earthworm, but many times the victim was not observed well enough to establish its identity.

After the bird's disappearance three pellets were collected from close to a Woodchuck hole that it had used frequently during its stay. These were somewhat distorted by rain, but each was about 0.7 by 4.0 cm. All contained a quantity of grey fur and a large proportion of granular soil material. Additionally, there were a number of beetle parts and one group of bones from a single mammal.

The mammal parts were identified as Meadow Vole, *Microtus pennsylvanicus*. This is a common rodent in this area and is the dominant species found in owl pellets (D. A. Smith, personal communication 1991). The other remains were from six ground beetles (head, pronotum, portions of legs, antennae and elytra), later identified as *Carabus nemoralis*. This introduced European species is widely found in Canada near human habitation. The soil residue was assumed to be the gut content of earthworms after the organic material had been digested.

These results compare closely with other data obtained in the owl's usual range. For example, Marti (1974) showed that, in one Colorado study, Carabidae were the most numerous prey species. The most frequent mammal prey was another microtine rodent, the Prairie Vole, *M. ochrogaster*. Glover (1953) and Hamilton (1941) also gave carabids and *Microtus* spp. as the major dietary items in studies in Arizona and Colorado respectively. These two studies each examined a large number of pellets. Glover studied 405 pellets and Hamilton reported data from 190 pellets.

Longhurst (1942), however, found these two genera were only minor dietary items. That study, conducted in Colorado, was restricted to the summer and, not surprisingly, Locustidae were the dominant food items. This suggests that the Burrowing Owl is an opportunistic feeder. Somewhat more direct evidence come from a California study by Neff (1941) who found owls living near a marsh. These birds fed mainly on Black Terns, *Chlidonias niger,* and Tricoloured Blackbirds, *Agelaius tricolor,* until after the nesting season was over, when they reverted to an insect diet. A study in Nevada by Bond (1942) found a large proportion of the Burrowing Owl's diet consisted of locally abundant amphibians.

Thomsen (1971) gave pellet data from an Oakland Airport, California, site that appeared to be similar in size and conditions to the Arnprior locality. *Microtus* (in this case *M. californicus*) was the dominant mammal eaten, the remains of which constituted 14.9 to 37.9% of the pellet volume. Unfortunately, she only identifies the dominant volume of insects in the pellet as Coleoptera, but Carabidae was the most common family encountered. Interestingly, she gave "sand and dirt" as a major component of the pellets (0.02 to 12.0%, with the highest levels in winter when earthworms are more likely in the diet), but does not comment on their origin as earthworms are not mentioned in the paper.

The prey species reported by other authors (summarised by Fox et al. 1989) show that the Burrowing Owl takes advantage of the most abundant prey in the area and reflects the opportunistic nature of this bird.

The Arnprior owl was able to live, without apparent distress, for at least six days on beetles, earthworms and the occasional vole — a diet that is similar to what it would find in its usual range.

Acknowledgments

We thank Libby Fox for help in having the insect parts identified, and to Marvin Silver for useful comments on the manuscript.

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Received 20 August 1992
Accepted 25 August 1993

Nursing by a Yearling Moose, *Alces alces gigas,* in Alaska

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Molvar, Erik M. 1993. Nursing by a yearling Moose, *Alces alces gigas*, in Alaska. Canadian Field-Naturalist 107(2): 233–235.

Suckling of a yearling moose was observed on two occasions in Denali National Park, Alaska. Although other cervids may occasionally suckle their yearling offspring, this event has never before been recorded for Moose. The prolonging of lactation in Moose may result in increased calf survivorship through greater protection of the offspring from predators.

Key Words: Moose, *Alces alces gigas*, lactation, parturition, life history strategies, Alaska.

The cow-calf bond is crucial to offspring survival in Moose (Sigman 1977) and hence to the fitness of the mother. This bond is maintained through lactation and other social behaviors such as grooming (Fraser 1968; Lent 1974). Through this bond, the mother increases the ability of her offspring to survive, both through providing a food source for the developing calf and by offering some degree of protection from predators (Conley 1956; Geist 1963; Mech 1966, 1970). There is, however, a cost to the mother associated with the maintenance of this bond. Indeed, the metabolic cost of lactation can exceed the costs incurred during pregnancy for many species of ungulates (Blaxter 1964; Pond 1977).

In Alaskan Moose (*Alces alces gigas*), calves are born around the first week in June, and are usually weaned by the onset of rut. Stringham (1974) reported that lactation bouts averaged 6.6 min. in length for neonates, and showed an exponential decrease in duration until weaning. Although Hosley (1949) believed that Moose calves were not weaned until the birth of the next neonate, numerous cases demonstrate that weaning normally occurs between mid-September and early December throughout the circumboreal range of Moose (Dodds 1955; Denniston 1956; Altmann 1958; Knorre 1961), and may occur even earlier in the southern parts of the range (Geist 1971). The latest recorded dates of weaning in Moose were for January (Stringham 1974; Knorre 1961). Furthermore, female Moose generally drive off their yearling offspring prior to giving birth (Peterson 1955), and although the yearling may remain in the general vicinity of its mother, it is rarely allowed to remain in close proximity (Altmann 1958). There are reports of yearling nursing in other ungulates (*see* Lent 1974 for review); herein I present what is to my knowledge the first documented case of yearling nursing in Moose.

Methods

Observations of nursing took place during the course of a larger study on Moose behavior conducted in Denali National Park, Alaska (63°45′N, 150°W), during spring and summer 1991. This summer was preceded by a winter of high snowfall, and thick snow cover resulted in the deaths of several animals due to malnutrition (J. Burch, personal communication), and may have contributed to a low rate of successful parturition observed during the following spring (V. van Ballenberghe, unpublished data). Natural predators in the Park include Grizzly Bears (*Ursus arctos horribilis*) and Grey Wolves (*Canis lupus*) and similar predator-rich ecosystems in Alaska have shown a sustained rate of Moose calf predation of up to 70% (Gasaway et al. 1992). The study area is characterized by patches of White Spruce (*Picea glauca*) with a willow (*Salix* spp.) understory interspersed with brushy tundra dominated by low-growing Dwarf Birch (*Betula glandulosa*).

A radio-collared female, hereafter referred to as cow #49, was of medium age and appeared to be in good condition at the time of the study. She showed no evidence of calving during the 1991 season. She was first located on 10 May, in the company of a calf of the previous year, almost certainly her own. This pair was subsequently located five times during the next three months, and was last located on 13 July 1991.

Results

I observed two bouts of nursing on different dates, and each bout showed similar characteristics. The first bout, on 10 May, lasted for 36 seconds, and the second bout, on 16 May, lasted for 60 seconds. These bouts were initiated when cow #49 assumed a head up, ears forward posture characteristic of a solicitation of nursing (Stringham 1974). In neither case was the cow disturbed immediately prior to the nursing bout. In both cases, the yearling bunted its snout vigorously against the udder of the dam, a behavior that stimulates milk release (Fraser 1968), for the duration of the nursing bout. Both bouts were terminated when cow #49 issued a "protest moan" vocalization and stepped forward half a step. This cow-yearling pair was seen in close proximity to each other (5-15 m) each time cow #49 was located, and were never seen in groups with other Moose.

Discussion

This observation of yearling nursing in Moose suggests that cow Moose may be capable of sustaining lactation well beyond the usual weaning date. Lengths of the nursing bouts that I observed are consistent with the average duration for nursing bouts (42.6 seconds) reported by Stringham (1974) for calves three weeks post-partum, suggesting that these bouts represented the transfer of some substance from dam to offspring, rather than the brief (< 5 seconds) "false nursing" reported for post-weaning calves by Sigman (1977). However, Hutchins (1984) reported that yearling Mountain Goats (*Oreamnos americanus*) commonly engage in dry nursing, which may be a behavior used to maintain the mother-yearling bond. Because cow #49 was not immobilized and examined for the condition of her udders, it cannot be determined with any certainty whether or not any milk actually passed from the cow to her yearling during the nursing bouts which were observed.

It is unlikely that prolonged lactation would provide a mechanism for the alternate-year breeding strategy employed by some species when in poor condition (Clutton-Brock et al. 1982); indeed, studies of lactation in Bighorn Sheep (*Ovis canadensis*; Berger 1979), Muskoxen (*Ovibos moschatus*; Jingfors 1980), and Mule Deer (*Odocoileus hemonious*; Bowyer 1991) link poor physical condition with early weaning. Furthermore, there is strong evidence that prolonged lactation itself hormonally interferes with conception (Loudon and Kay 1984; Howie and McNeilly 1982). Therefore, it is unlikely that an animal can opt to terminate a pregnancy in progress and continue to nurse the young of a previous year if it finds itself in poor physical shape.

In areas where calf survival is high, mothers that do not prolong lactation should leave more offspring over the long term. However, where predation significantly reduces calf recruitment, as it does in my study area, prolonging the cow-calf bond into the second year should improve the chances of survival to reproductive age for an individual calf, through extending the period of maternal protection. If lactation is actually occurring during this time, the yearling would derive the additional benefit of an increase in nutritional intake. Such a life history strategy would increase inclusive fitness of non-parturient mothers, as suggested by Hutchins (1984), and thus be selectively advantageous in ecosystems where calf mortality is high.

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Received 6 August 1992
Accepted 8 October 1993

Polar Bears, *Ursus maritimus*, Feeding on Beluga Whales, *Delphinapterus leucas*

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Two sightings of Polar Bears (*Ursus maritimus*) with dead Beluga Whales (*Delphinapterus leucas*) on ice were made by aerial teams looking for Bowhead Whales (*Balaena mysticetus*) during their spring migration near Point Barrow, Alaska, from 1985 to 1992. Along with other sightings of Belugas being killed and eaten by Polar Bears reported in the literature, these records suggest that Belugas may make an important contribution to the diet of Polar Bears in some areas.

Key Words: Polar Bear, *Ursus maritimus*, Beluga Whale, *Delphinapterus leucas*, Bowhead Whale, *Balaena mysticetus*, predation, Barrow, Alaska.

Since 1985, the National Marine Mammal Laboratory (NMML) has conducted aerial photogrammetric surveys each year (except 1988) from mid-April to early June near Point Barrow, Alaska. The objective of these studies has been to photograph Bowhead Whales (*Balaena mysticetus*) during their spring migration from the Bering Sea to the Beaufort Sea. The surveys involved some systematic transects to study the offshore distribution of whales, but most of the effort has been non-systematic searches in areas where Bowhead Whales are most likely to be found (Rugh 1990; Withrow and Angliss 1992). Typically, this area has been north of shorefast ice, east of Point Barrow (to avoid active whaling camps to the west), and within a 100 km radius of Point Barrow (roughly 71°N to 72°N and 153°W to 156°W).

Incidental to the search for Bowhead Whales, Polar Bears (*Ursus maritimus*) have been observed: during a total of 596 hours flown in 1985–1992 (excluding 1988), there have been 136 Polar Bear sightings (Table 1). There were 30 recorded kill sites, 17 with bears present at the time of the sighting. Based on the apparent size of the kill sites and what could be seen of the carcasses, most of the remains were probably from either Ringed Seals (*Phoca hispida*) or Bearded Seals (*Erignathus barbatus*), the only pinnipeds commonly found in this area during the spring. However, two of the kills were Beluga Whales (*Delphinapterus leucas*). These are detailed below.

On 12 May 1989, two Polar Bears were seen north of Point Barrow (71° 31.0'N, 156° 29.2'W) at the site of a Beluga carcass. Another Polar Bear was seen 0.4 km to the east. Little remained of the carcass except the characteristic contour and flukes. The sea ice was very dense in the general area, with only a few small fractures in the vicinity of the dead Beluga. One narrow fracture ended 7 m from the carcass, but because it was refrozen, it was not evident that this was where the Beluga had been hauled up through the ice.

On 9 May 1992, an adult Polar Bear was seen feeding on the remains of a Beluga on the sea ice north of Point Barrow (71° 25.3'N, 156° 33.8'W). Two other Polar Bears were seen within 1 km, but no interaction between the bears was observed. No opening in the sea ice was apparent, perhaps because floes were compressing in the area covering up holes. Ice could be seen riding up over the floe with the carcass, gradually covering the blood marks. This was a season of unusually dense sea ice in the area, a function of atypically persistent west winds through much of late April and May (John Craighead George, Department of Wildlife Management, North Slope Borough, Box 69, Barrow, Alaska 99723, personal communication). The high rate of Polar Bear and kill sightings in 1992 (Table 1) was probably related to this dense ice, although the bear concentration could also have been caused by a Bowhead Whale stranding in Elson Lagoon 20 km northeast of Barrow in the fall of 1991 (Department of Wildlife Management, North Slope Borough, Box 69, Barrow, Alaska 99723, unpublished data). A team doing an ice-based census of Bowhead Whales near Point Barrow saw as many or more Polar Bears in 1992 as in any other year since 1975 (J. C. George, personal communication).

In addition to the preceding sightings, seven or eight Polar Bears were seen near an unidentified carcass 37 km northeast of Point Barrow (71° 31.9'N, 155° 31.4'W) on 2 June 1989. Since the survey aircraft was running low on fuel, the team was unable to circle back to identify the remains. The high concentration of bears and size of the carcass indicate they were attracted to a dead whale, most likely a Beluga or Bowhead, the only whales commonly found near Barrow during this season.

Because our search image during aerial surveys for Bowheads is for dark whales in dark water, our records probably under represent the number of Polar Bears in the area. For the same reason, blood on ice from seal kills might be under represented. However, because Beluga kills result in far more blood than seal kills, and seeing a dead Beluga is more novel than seeing a dead seal, we may assume that Beluga kill sites were always reported. The ratio of Beluga kills to total kill sites in our records (2:30, or 7%) is biased upward, but it does provide a rough indication of the relative frequency of Polar Bear predation on Belugas in the Barrow area during the whales' spring migration.

The high density of Belugas migrating in the spring along restricted openings in sea ice provides opportunities for predation by Polar Bears. Although there are not many documented sightings of Polar Bear predation on Belugas from Alaskan coastal areas (seven were reported by Lowry et al. (1987) since 1967, four of which occurred in April 1984 during a period of dense ice cover), the rate is high considering the low likelihood that anyone would come across a bear kill on the sea ice and report such a sighting to a scientist. Furthermore, moving ice and snow accumulation tend to cover evidence of kills.

There have been several reports of Polar Bears eating Belugas in the Canadian High Arctic, including Freeman (1973), Heyland and Hay (1976), Mitchell and Reeves (1981), and Smith (1985), but the only documented observations of Polar Bears killing Belugas were made by Degerbol and Freuchen (1935), Kleinenberg et al. (1964), and Smith and Sjare (1990), along with an observation made by Harry Brower Sr.[1], a principal whaler in Barrow. However, the sighting reported by Lowry et al. (1987) and the original sightings of dead Belugas reported here included blood tracks on the ice, indicating relatively fresh kills. Because of their negative buoyancy, Belugas tend to sink when killed (Kemper 1980; Finley et al. 1982; Lowry 1985). This reduces opportunities to scavenge a dead Beluga until internal gasses expand, the carcass floats to the surface, and it becomes available for scavenging by Polar Bears. Since most sightings of dead Belugas on ice occur when sea ice is dense and whales are forced to use small openings in the ice, it

TABLE 1. Polar Bear sightings made by aerial teams near Barrow, Alaska, during the spring. Kill sites were evidenced by blood on the sea ice.

Survey dates	Flight hours	Bear sightings*	Kill sites*
20 April - 7 June 1985	138	15	2
2 May - 1 June 1986	93	10	2
21 April - 5 June 1987	50	6	1
15 April - 2 June 1989	73	26	6
19 April - 3 June 1990	86	10	3
18 April - 3 June 1991	69	12	1
20 April - 5 June 1992	87	57	15
Total	596	136	30

*Aerial teams may have under-counted the number of bears and kill sites in the area because the focus of the effort was for Bowhead Whales in open water.

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[1] A Polar Bear was seen grabbing a Beluga, diving underwater for several minutes, and surfacing with a dead whale. (personal communication, John Craighead George)

appears that the whales are being killed by the bears and not scavenged after having succumbed due to other causes. Entrapped whales are probably vulnerable to predation, but pulling a whale onto the ice is an impressive feat because a Beluga may weigh five times as much as a Polar Bear (Freeman 1973).

Based on stable-carbon isotope ratios in tissues (Ramsay and Hobson 1991), Polar Bears make little use of terrestrial food webs even though they may spend a third or more of the year on land, emphasizing the importance of what they can hunt or scavenge while on ice. Though Bowhead Whales killed by Eskimos might attract Polar Bears, the whale carcasses would not fully provide for the bears' nutritional needs because whalers usually remove all of the blubber and muscle. Blubber is apparently the preferred part of seals consumed by Polar Bears (Stirling and McEwan 1975), and when Lowry et al. (1987) examined a Beluga carcass, they found that the bear(s) had only consumed blubber and muscle, leaving viscera intact. Whereas a 28 kg Ringed Seal could supply a 230 kg Polar Bear with six days of nourishment (Best 1977), a 600 kg Beluga could provide nourishment for 140 days (Lowry et al. 1987). Clearly, when Belugas instead of seals can be taken opportunistically, the bears receive a greater nutritional benefit.

Acknowledgments

Our observations were made during photographic surveys for Bowhead Whales supported by NMML. These surveys were conducted by the Arctic Ecosystem Program under the leadership of Mary Nerini (1985–1987) and David Withrow (1988–1992). We are grateful to the field teams for their contributions through all of these years. Editorial comments were provided by Robyn Angliss, Merrill Gosho, Sally Mizroch, David Withrow, and Allen Wolman of NMML, Gary Duker and James Lee of the Alaska Fisheries Science Center Publications Unit, and two anonymous reviewers.

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Received 15 September 1992
Accepting 4 October 1993

Foraging Flights of Pacific, *Gavia pacifica*, and Red-throated, *G. stellata*, Loons on Alaska's Coastal Plain

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Andres, Brad A. 1993. Foraging flights of Pacific, *Gavia pacifica*, and Red-throated, *G. stellata*, loons on Alaska's Coastal Plain. Canadian Field-Naturalist 107(2): 238–240.

Breeding Red-throated Loons, *Gavia stellata*, are generally thought to make foraging flights to nearshore marine sites whereas breeding Pacific Loons, *G. pacifica*, are thought to feed near their nest sites. Observed marine foraging flights were essentially equivalent between Red-throated Loons (51%) and Pacific Loons (49%) on the Colville River Delta, Alaska. Equal nesting populations of the two loon species indicated that use of nearshore marine feeding flights was indeed equivalent for both species. This provides further evidence that the marine/freshwater dichotomy between Red-throated Loons and Pacific Loons varies with locality and local foraging behavior of Pacific Loons will need to be determined if the Pacific Loon is to be an effective indicator of environmental change.

Key Words: Red-throated Loon, *Gavia stellata*, Pacific Loon, *Gavia pacifica*, foraging, feeding, breeding, Arctic, Alaska.

Bergman and Derksen (1977) proposed the Red-throated Loon (*Gavia stellata*) as an indicator of nearshore marine habitat change and the Pacific Loon (*G. pacifica*) as a barometer of freshwater habitat change. They based these recommendations on nest site observations of adult loons feeding young. On the Coastal Plain of Alaska, Red-throated Loons nested on small ponds and flew several kilometers to the ocean to secure fish to feed their young. Pacific Loons foraged for invertebrates in ponds or lakes adjacent to their nest sites. Although distant marine-foraging flights by Red-throated Loons have been routinely reported by others (e.g., Reimchen and Douglas 1984), distant foraging flights by Pacific Loons depend on the location of the nest site and the proximate food supply (Davis 1972). Palmer (1962) described the foraging behavior of Pacific Loons as going "as far as necessary to fish"; the periodic absence of territorial male Pacific Loons during brood-rearing in western Alaska (Petersen 1989) might be attributed to remote feeding forays. Male Arctic Loons (*G. arctica*, a sibling species of *G. pacifica*) brought fish to chicks and mates from remote sources (Palmer 1962). Bergman and Derksen (1977) also noted seaward flights of Pacific Loons. This paper presents further quantitative evidence that Pacific Loons regularly engage in flights to nearshore marine waters.

Study Area and Methods

While surveying coastal areas of the Colville River delta for shorebirds, I had the opportunity to document the feeding flights of Pacific and Red-throated loons. The Colville River Delta lies 70 km west of Prudhoe Bay (70°30'N, 150°35'W) at the mouth of the largest river on the North Slope of Alaska. Saltmarshes, vegetated with *Carex*, *Dupontia* and *Puccinellia* spp., and dotted with brackish ponds, lie immediately inland from expansive silt barrens at the shore of Harrison Bay. The extent of nearshore environment varies (1–15 km) with the movement of the pack ice and is influenced by the freshwater discharge of the river. The study period extended from 1 July to 31 August in 1987 and 1988. All surveys were conducted between 0800 hrs and 1800 hrs. Observations of inflight loons were made in coastal habitats to ensure that birds were going to or returning from the nearshore waters of Harrison Bay. On these flights, loons tended to follow the river channels, usually in a north-south direction except in the extreme eastern delta where orientation was northeast-southwest. When a flying loon was detected (either visually or aurally), I recorded the date, time, weather conditions, species, and heading. Experience gained in 1986 was used to identify loon species by bill shape, plummage pattern, inflight posture and voice. This combination of features, coupled with favorable environmental conditions, occasionally allowed for identification of individuals at relatively long distances (≤1 km). A loon was considered engaged in a seaward (or returning) foraging flight if its heading was ± 45° of either side of the direction of the ocean-flowing channel closest to where it was observed. This procedure excluded east-west flying migrants. The proportion of all oceanward and returning loon flights represented by each species was averaged across years.

I used nest information from the U.S. Fish and Wildlife Service's North Slope Bird Habitat Study (J. R. Nickles, R. Field, J. Parker, R. Lipkin and J.

Bart, Bird-habitat associations on the North Slope, Alaska – progress report 1986, Unpublished report, U.S. Fish and Wildlife Service, Anchorage, Alaska, 1987; R. Field, F. Gerhardt, J. Tande, G. Balogh, R. McAvinchey, J. Bart, Bird-habitat associations on the North Slope, Alaska – progress report 1987, Unpublished report, U.S. Fish and Wildlife Service, Anchorage, Alaska, 1988) and from my own observations (1987, 1988) to determine the proportion of the total nesting loon population that was represented by each species in the delta. Although I lacked complete delta coverage for the 1988 breeding season, information was available for coastal sites. The proportion of nesting Pacific Loons found in the coastal zone was relatively constant from 1987 (2 of 5) to 1988 (3 of 9). Therefore, I felt that delta-wide data from 1986 and 1987 were representative of the proportional populations of Red-throated Loons and Pacific Loons nesting in the delta. Additionally, Bergman and Derksen (1977) reported that Coastal Plain nesting densities of Red-throated and Pacific loons were relatively stable over their five-year study period, as did Dickson (1992) for Red-throated Loons on Canada's arctic coast.

To control for differences in the numbers of individuals of each species in the breeding population, I used *t*-tests to compare the average proportion of nesting loons to the average proportion of oceanward flying loons for the two species. Degrees of freedom for *t*-tests were calculated with Satterthwaite's approximation (Snedecor and Cochran 1980) and were based on the average number of flights (or nests) in a given year. Using the yearly average to compute degrees of freedom reduces the falsely inflated power that results from treating the combined years' flights (or nests) as the independent sampling unit. Yearly flight sample sizes were well below my estimate of the delta's loon populations, and, therefore, seemed realistic. Following Bergman and Derksen (1977), I expected to find a greater proportion of Red-throated Loons making nearshore marine flights than was represented by the proportion of nesting birds.

Results

A yearly average of 119 oceanward loon flights was recorded during 1987-1988. Few birds were engaged in east-west flights (Pacific – 9%; Red-throated – 11%). Individuals were occasionally (Pacific – 8%, Red-throated – 18%, $n = 69$) observed returning with fish in their bills. All observed fish were at least as long as the loon's bill. Transport of smaller items and long detection distances make this a conservative estimate of prey delivery rate. Significantly more flights ($t \geq 3.8$, df = 57, $P \leq 0.001$) were made during the brood-rearing period in August by Pacific Loons (72%) and Red-throated Loons (73%) than during the incubation period of July (28%, 27%). Nesting chronology on the Colville River delta was essentially the same for both species (F. Gerhardt, R. Field, J. Parker, Bird and habitat associations on the North Slope, Alaska – chronological species summaries, Unpublished report, U.S. Fish and Wildlife Service, Anchorage, Alaska, 1988). Increased flights in August circumstantially indicated that nearshore marine foraging flights were to secure and deliver prey items to young. A difference in survey effort ($\Sigma = 39$ hrs) between July (45%) and August (55%) did not account for the greater number of foraging flights in August for either species ($\chi^2 = 16.0$ for Red-throated, $\chi^2 = 14.3$ for Pacific, df = 1, $P < 0.005$). Daily timing of surveys during the two periods was also similar.

On average, 31 nests of Red-throated and Pacific Loons were located in each year on the 104 km^2 study area of the delta (Nickles et al. 1987; Field et al. 1988). Contrary to my expectation, no difference between the proportion of nests and the proportion of marine flights was detected for either loon species (Table 1). Because delta breeding populations of Red-throated and Pacific loons were equivalent, differences in the proportion of each species undertaking marine foraging flights could be directly compared. From this analysis, no difference in the number of foraging flights made by loons was detected (t-test [one sample] = 0.228, df = 118, $p > 0.40$). Small intraspecific differences between nesting and foraging flight proportions, small interspecific difference in foraging flight proportions and adequate sample sizes indicated that Red-throated Loons and Pacific Loons did not differ in their nearshore marine foraging flight behavior on the Colville River Delta.

Discussion

My results imply that on the Colville River Delta, both the Red-throated and Pacific Loon for-

TABLE 1. Numbers and proportions of nearshore flights and nests of Pacific and Red-throated loons on the Colville River Delta, Alaska.

Species	Average no. of flights	Proportion of flights	Average no. of nests	Proportion of nests	*t*	*P*
Pacific Loon	58.5	0.49	15.5	0.50	-0.104	>>0.3
Red-throated Loon	61.0	0.51	15.5	0.50	0.104	>>0.3

age in marine waters with equal intensity. With equivalent nesting populations of both species, the number of foraging trips taken from inland nest sites to Harrison Bay did not differ between the two species. Pairs nesting near Hudson Bay used nearshore marine resources to provision themselves and their hatchlings (Davis 1972) and pairs nesting on lakes in Alaska used nearby rivers for foraging (Sjölander 1978). Whether feeding themselves or their young, Pacific Loons are relying on food resources of the nearshore waters of Harrison Bay to the same degree as are Red-throated Loons.

If Red-throated Loons and Pacific Loons are to be used dichotomously in assessing habitat impacts, the local foraging behavior of Pacific Loons must be determined. Although the uncontentious nearshore foraging behavior of the Red-throated Loon makes it a valuable indicator, the Pacific Loon might be replaced by a less variant model. Alternatively, intraspecific variation in foraging behavior of Pacific Loons could be used to monitor differences between populations that forage at inland sites and those that forage at nearshore sites. If local populations of Pacific Loons were found to make nearshore foraging flights, monitoring these individuals along with Red-throated Loons could greatly increase local sample sizes for relatively little additional cost. Because coastal oil development pressures continue in arctic Alaska and Canada (Dickson 1992), consideration of the overlap of nearshore foraging strategies in coastal breeding Pacific and Red-throated Loons is important if these species are to be effective environmental indicators.

Acknowledgments

I express gratitude to A. Creighton for assistance in the fieldwork for this project. This paper has benefitted from the comments of S. E. Andres, C. I. Bocetti, T. A. Bookhout, W. R. Haag, J. M. Dettmers and R. P. Dettmers, and two anonymous reviewers.

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Received 12 October 1992
Accepted 14 September 1993

Minimum Breeding Age of Dall Sheep, *Ovis dalli dalli,* Ewes

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On 21 June 1992 two 13-month-old female Dall Sheep gave birth to single lambs in a 40-acre enclosure at the Yukon Game Farm near Whitehorse. This is the first time that successful breeding has been documented for Dall lambs. This early sexual maturity can be attributed to supplementary feed provided to these sheep, which is also reflected in larger body sizes, improved horn growth and higher productivity.

Key Words: Dall Sheep, *Ovis dalli dalli*, early sexual maturity, minimum breeding age.

Most studies of North American wild sheep (*Ovis dalli* and *Ovis canadensis*) report that sexual maturity of ewes is reached on the average at about 2½ years of age and the first lamb is delivered at about 3 years (Buechner 1960; Cowan and Geist 1971; Geist 1971; Hoefs and Cowan 1979). However, exceptions have been observed. Nichols (1978) collected 22 Dall ewes in the Kenai area of Alaska, four of which were yearlings. All the mature ewes were pregnant, and so were three of the yearlings. Simmons et al. (1984) collected 101 Dall ewes in the MacKenzie Mountains of the Northwest Territories. These included seven long-yearling females (21 months) of which three were pregnant. A number of investigations documented breeding of Bighorn ewes at an age of 18 months (Berger 1982; Festa-Bianchet 1988; Jorgenson and Wishart 1984; Woodgerd 1964).

On the other hand, delayed puberty has been reported by Bunnell and Olsen (1981). They marked 63 Dall Sheep ewes with individually recognizable collars in the Kluane area of Yukon and documented their lambing success for two seasons. Their sample included 12 three-year-old ewes, none of which had a lamb, and four four-year-olds, of which two had a lamb. Only with age five was full reproductive success with 80% or more achieved.

This report documents the successful breeding of two Dall lambs in a 40-acre enclosure at the Yukon Game Farm in Whitehorse. A captive Dall Sheep herd was established here in 1970 and description of the enclosure and the initial use of it by introduced Dall sheep was provided by Hoefs (1974). In its 20+ years of existence, the captive herd, whose size varied between 6 and 15 sheep, has produced 96 lambs. While breeding of yearlings was common, 1992 was the first year when two 13-month-old ewes contributed to the lamb production.

The two lambs (one male and one female) were born on 21 June 1992, which is about five weeks later than the peak of the lambing season in this captive herd. Dall sheep have a gestation period of about 171 days (Nichols 1978) which translates into successful breeding in early January, when these ewes were about 8 months old.

Figure 1 is a photograph of one of these young ewes with her lamb, taken on 15 July 1992 when the lamb was about 24 days old and its mother 14 months. This ewe is exceptionally large for her age, but facial features such as skull width to length ratio, as well as the relationship of ear length to horn length, and the slenderness of the horns reveal her youth to a trained observer.

While breeding of lambs has not been previously documented for Thinhorn Sheep or Bighorns, it has been observed in Desert Sheep and in European Mufflon, though not at as early an age. A Desert Sheep ewe (*O. c. nelsoni*) transplanted from the River Mountains (Mojave Desert), Nevada, to Zion National Park, Utah, attained sexual maturity at about 10½ months (McCuthen 1977). Also, Berger (1982) reports that two Desert Sheep ewes (*O. c. cremnobates*) at the Living Desert Reserve, California, gave birth at about 19 months of age. Breeding by lambs has more frequently been witnessed in the European Mufflon (*Ovis ammon musimon*), one of the smallest wild sheep. In a recent investigation, Briedermann (1992) reported that 9 out of 60 births monitored were by very young ewes, about 13 to 15 months old.

Young ewes, breeding and giving birth for the first time, usually do so at a later date than mature females (Briedermann 1992; Festa-Bianchet 1988). In the latter's study area in Alberta, the mean lambing time for two-year olds (n=14) was 5 June, while that of older ewes (n=80) was 25 May. Delayed lambing, and thus delayed conception of young ewes, could be the result of a lower energy reserve, as documented for other ungulates (Mitchell and Lincoln 1973; Verme 1985). However, since there is no further weight gain in Dall Sheep between the

FIGURE 1. Dall Sheep ewe at 14 months of age with her 24-day old lamb.

regular rutting period in late November/early December and early January, when these ewes were bred, the reason is more likely delayed socially-induced estrus (Festa-Bianchet 1988).

This occurrence of sexual maturity of Dall ewes at an age of only eight months can be explained by the supplementary feed provided. The superior nutrition, as compared to the quality of forage available to free-living Dall sheep, is reflected not only in earlier sexual maturity but also in larger body sizes, improved horn growth, higher reproductive performance and a secondary sex ratio distorted towards females. Numerous investigations have shown that the attainment of puberty in mammals is associated with a minimum body weight rather with a specific chronological age (Asdell 1964; Donovan and van der Werff ten Bosch 1985; Dyrmundsson and Lees 1992; Mitchell and Brown 1974; Widdowson and McCance 1960). This minimum body weight is not known for Dall Sheep. Nichols (1978) observed that the yearling ewes he collected in the Kenai Mountains, which were found to be pregnant, had reached 80 and 92% of the mature weight and shoulder height of ewes in that area. Hudson et al. (1991) reported that Red Deer and Wapiti hinds must achieve 65 to 70% of their mature weight to attain a 50% chance at conception. Doe White-tailed Deer fawns can attain puberty at 6 to 7 months of age, if they weigh approximately 80 lbs [36 kg] (Moen 1973). Mature does weigh around 100 lbs.[45 kg], which means that sexual maturity is reached when attaining about 80% adult weight (Sauer 1984).

While the weight of these two ewes at time of breeding is not known, an estimate is possible. For a number of years, these captive sheep were captured, measured and weighed at regular intervals (Hoefs, unpublished data). Female lambs, shortly after birth, had mean weights of 7.8 lbs (n=6) and they reached 72.0 lbs (n=9) in October. Two exceptional animals attained weights of 86 and 78 lbs by their first winter. Bunnell and Olsen (1976) captured sheep and determined weights in the Kluane population, from which this captive herd originated. For mature ewes, over 6 years of age, they computed a mean weight of 107.4 lbs (n=8). It is therefore not unreasonable to suggest that these two early breeders had attained 70 to 80% of the mature weight of ewes at time of conception, which complements observations for other ungulates.

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Received 14 October 1992
Accepted 7 September 1993

Observations of the Copulatory Behaviour of the Ocean Pout, *Macrozoarces americanus*

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Mercer, Sandra, Grant E. Brown, Susan Clearwater, and Zuxo Yao. 1993. Observations of the copulatory behaviour of the Ocean Pout, *Macrozoarces americanus*. Canadian Field-Naturalist 107(2): 243–244.

The Ocean Pout (*Macrozoarces americanus*) is a common species of eelpout found off the coast of Newfoundland. It has previously been suggested that the Ocean Pout is an internally fertilizing species but no direct observations of this have been reported. What is thought to be the first observation of the copulatory behaviour of mature Ocean Pout in the wild is described here. Similar behaviour was videotaped under laboratory conditions.

Key Words: Ocean Pout, *Macrozoarces americanus*, copulation, Newfoundland.

The Ocean Pout (*Macrozoarces americanus*) is one of 15 known species of eelpout (Zoarcidae) reported to occur in the waters of the Canadian Atlantic (Scott and Scott 1988). The Ocean Pout is a benthic species which typically inhabits the Shelf regions of the North West Atlantic (Anderson 1985). Ocean Pout move inshore during the spring, pair during the summer and spawn in late summer and autumn (Keats et al. 1985; Methven and Brown 1991). This species is thought to be oviparous because its egg mass typically consists of relatively few but large eggs (Anderson 1985). Female Ocean Pout exhibit parental care during the 2.5–3 months incubation period by fanning the egg mass to increase water flow around it and by protecting it from predation (Keats et al. 1985; Methven and Brown 1991). Although nesting and egg guarding has been previously observed in the Ocean Pout, direct field observations on reproduction (particularly copulation) have not been reported.

What we believe to be the first field observation of the copulatory behaviour of mature Ocean Pout was observed at approximately 11:30 a.m., 29 August 1992, while SCUBA diving at St.Phillip's, Newfoundland (47° 35'N, 53° 57'W) at a depth of approximately 12 m. The substrate at this location consists mainly of large boulders and scoured bedrock with extensive sandy patches. The pout were observed on a large (approximately 10 m in diameter) sandy patch, surrounded by large rocks imbedded in the substrate. There was no vegetation in the immediate area and the pout were observed to be at least 10 m from any potential nesting site(s). This fact is interesting in that it has previously been thought that Ocean Pout do not mate outside of the burrow or nest site.

The fish were sexed based on sexually dimorphic characteristics. Size was estimated to be 50 cm (female) and 45 cm (male). The fish were stationary on the substrate in a ventrum to ventrum position. The male was lying on its side, with the dorsal surface at a 45° angle to the substrate. The female was in a superior position (i.e., with its ventral surface at a 45° angle to the substrate). The pectoral fins were crossed at the base (i.e., interlocked) and the tails were coiled together. The male exhibited quick successive lateral movements of the head (quivering) while arching its dorsal surface (forcing the ventral surfaces together). The behaviour was observed for several minutes until the female broke off the coupling.

Mating behaviours were also captured on videotape in a group of broodstock Ocean Pout held at the Ocean Sciences Centre. A group of six Ocean Pout were videotaped in a 1.25 m x 1.25 m tank on 13 to 14 August 1992. The videotapes revealed that male and female Ocean Pout do indeed make ventrum to ventrum contact while mating, and their elongate tails do coil and wrap around each other. The interlocking of pectoral fins while making ventral contact was also seen on the videotapes. These behaviours were observed to occur in artificial crevices (sections of 20 cm pipe) unlike the field observations which took place in an open clearing. However, the relatively high stocking density in the tank may account for the use of the pipes. In the rearing tank, fertilized eggs were recovered, suggesting that species-typical mating behaviour had occurred.

It has been suggested that Ocean Pout are internal fertilizers and require this form of copulatory behaviour to ensure insemination. This speculation is derived from a number of physiological observations and characteristics of the Ocean Pout. Yao and Clearwater (personal observations) have found that there is a dramatic decrease in the motility of the Ocean Pout's sperm when it comes in contact with seawater. In addition, male pout produce very few sperm (relative to other marine fish species) and the tails of the sperm are quite long, suggesting sperm have to travel relatively long distances in order to reach potential eggs for fertilization. Demersal spawning species, unlike Ocean Pout, typically have large numbers of sperm which are characterized by short tails. Since eggs and milt of these species are mixed in the water column, long distance swimming bouts are not required. Therefore, both laboratory and field observations provide evidence supporting internal fertilization as the means of reproduction in the Ocean Pout.

Acknowlegments

The authors thank D. Methven for his suggestions and encouragement, and V. Gotceitas for his comments on earlier versions of this manuscript. This note is Ocean Sciences Centre Contribution number 216.

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Received 26 November 1992
Accepted 8 September 1993

Prey Escaping Wolves, *Canis lupus,* Despite Close Proximity

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We describe attacks by Wolf (*Canis lupus*) packs in Minnesota on a White-tailed Deer (*Odocoileus virginianus*) and a Moose (*Alces alces*) in which Wolves were within contact distance of the prey but in which the prey escaped.

Key Words: Wolf, *Canis lupus*, Moose, *Alces alces*, White-tailed Deer, *Odocoileus virginianus*, predation, predator-prey relations.

Observations of Wolves (*Canis lupus*) hunting White-tailed Deer (*Odocoileus virginianus*) and Moose (*Alces alces*) indicate that > 90% of chases result in the prey escaping predation (Mech 1966; Peterson 1977; Nelson and Mech unpublished). Nevertheless, human intuition suggests that prey that are grabbed or encountered within a Wolf's leaping distance would likely be killed, especially if several Wolves were attacking simultaneously.

Herein, we report two observations of single prey in northeastern Minnesota, 48° N, 92° W, escaping death from predation by several Wolves. Aerial tracking of radio-collared Wolves yielded the observational data (*see* Mech 1979), and Nelson made the observations.

On 7 March 1980, eight members of the Snowbank Lake pack were located just southeast of Clear Lake traveling east, single file, through 43 cm of snow which was a minimal hindrance to both Wolves and White-tailed Deer. Previous aerial observations indicated that there were 11 Wolves in the pack, but the tree canopy and terrain probably obscured the view of the entire pack. One Wolf, located 200 m north of the main group, was also observed moving eastward. The pack next made an abrupt and complete reversal of direction and started running just 1–2 m behind, and to the sides of, a bounding White-tailed Deer in their midst. The deer apparently ran into the Wolves, probably initially chased by other pack members apart from the main group and apparently unaware of the Wolves ahead on the escape route. Within 1–2 seconds the deer had increased its lead to 10–20 m. Within another 200–300 m there was only one Wolf pursuing the deer, and the deer was increasing its lead. After that, the deer stopped and looked back several times before moving on. Apparently the Wolf gave up the chase because the deer stopped moving during several minutes of observation, and the Wolf was not near it. Five minutes later, the pack was bedded down near where the chase observation began.

At 1000 on 22 June 1992, seven members of the Pike Lake pack were seen attacking a cow Moose running in Arrowhead Creek, 1.6 km northwest of Helen L. The creek was approximately 5 m wide and meandered with curves every 30-50 m. Wolves in the water appeared to be swimming. Some Wolves ran along each bank of the creek as the Moose ran and swam down the center. Other Wolves jumped toward the Moose from each bank and grabbed at what they could with their teeth. During at least one moment of the attack, all seven Wolves were hanging on the Moose.

One Wolf held the Moose's nose (Mech 1966, 1970) and was thrown from side to side by the thrashing Moose. Others grabbed the shoulders, flanks, and rump but were shaken off within seconds by the momentum and running motion of the Moose in water. One Wolf was even on top of the Moose during crossing of a deep section of the creek where the Moose appeared almost fully submerged. Once clear of the Moose, individual Wolves swam to the nearest bank, crawled out, shook themselves off, and then ran ahead to the next curve in the creek where they crouched and waited for the advancing Moose.

Once the Moose was opposite their position the Wolves leaped into the air landing with a splash just short of the Moose. At one time during the attack, the Moose momentarily flailed a mostly submerged Wolf with its front legs. After traveling a distance of about 500 m, the Moose abruptly reversed direction, but the Wolves continued the attack as previously described. At 1024 the Moose stopped running and stood in some shallows as the Wolves ceased the attack and rested on one bank. The Moose moved into deeper water but immediately returned to the shallows. The Moose appeared steady and strong with no large wounds or blood visible. The Wolves acted excited, and several rolled in the grass 50 m from the Moose, although it was probably obscured from their view by thick willows (*Salix* sp.). The scene was unchanged when we left at 1042. Four hours later the Moose was gone but the Wolves remained bedded at the attack site. Three days later, the Pike Lake pack was 10 km distant, and there was no evidence of a dead Moose near Arrowhead Creek.

Our Moose observation is consistent with previous reports indicating that fleeing Moose tend to be killed, whereas Moose that stand and defend themselves survive (Mech 1966; Peterson 1977). Few published observations of Wolves killing deer exist (Mech and Frenzel 1971; Mech 1970; Pimlott et al. 1969). The present observation is contrary to those that do exist and to our unpublished data which suggest that Wolves are generally successful when they close to within 1–5 m of a deer they are chasing. Of 60 chases of Deer (including this account) observed between 1967 and 1993, Wolves chased to within 5 m of 16 deer and killed 12 of them. Thus 75% of close encounters but only 20% (12/60) of all chases observed resulted in kills. In 25 (42%) and 19 (32%) chases, Wolves got no closer than 10–50 m and 50–250 m, respectively, of fleeing deer.

In two of the four escapes at < 5 m, aggressive behavior by the deer toward the Wolves aided the deer's escape. In the third chase, speed alone enabled a successful flight. The fourth escape is the Clear Lake account where apparently the element of surprise and maximum speed by the deer when first encountering the Wolves was more than the Wolves could successfully react to and negated any numerical advantage the Wolves had.

These two accounts emphasize how inadequate human intuition and perception can be in understanding the nature of predation. In both attacks, individual prey escaped imminent death from an overwhelming number of Wolves. For deer, at least 25% escape despite close proximity to Wolves which suggests that the deer observation herein is not an extremely rare event. These observations also demonstrate the difficulty Wolves can encounter when attempting to kill swift and large-bodied prey (Nelson and Mech 1985; Mech and Nelson 1990).

Acknowledgments

This investigation was funded by the USDI Fish and Wildlife Service and the USDA North Central Forest Experiment Station. We thank Wayne Erickson, USDA Forest Service, for skillfully piloting the tracking aircraft.

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Received 22 November 1992
Accepted 2 September 1993

News and Comment

The Ottawa Field-Naturalists' Club 1992 Awards

At the Club Soirée on 30 April 1993 a full complement of our awards was presented for 1992 activities and achievements. Frank Pope, President, hosted the evening. The Honorary Membership citation was read by the President, and the awards were presented by members of the Awards Committee.

Members of the Mocoun Field Club set up five interesting exhibits. Pascal Lassier, Aaron Lynch, and Rebecca Danard won prizes for their exhibits. Representatives of the three Macoun groups reported on their activities during the past year.

1992 Honorary Member: George F. Ledingham

There is a rich and special connection between prairie people and the land. This productive and often eloquent relationship has produced remarkable interpreters of western grasslands, be they writers like W. O. Mitchell, painters like William Kurelek, or scientists like George Ledingham.

Dr. Ledingham has enjoyed a long and productive botanical career as a college and university teacher in Saskatchewan, commencing full-time in 1945. That was also the year he joined the fledgling Saskatchewan Natural History Society (SNHS). Although the long academic career from which he recently retired is distinguished by a reputation as an inspirational teacher and patient researcher, he is probably most widely known through his work with the SNHS.

He has been a stalwart of that organization. His contributions to the *Blue Jay,* the superb field naturalists' journal of the Saskatchewan Natural History Society, have been particularly significant. He has contributed numerous articles in addition to serving 17 years (1956-1965; 1966-1972) as editor. His editorship was distinguished by a remarkable balance between valuable and enduring items that are rigorously scientific and others of a general, more popular nature, reporting activities and interests of particular naturalists.

His keen understanding of grassland ecology and his passion for protection of natural prairie encouraged him to take a leading role in the effort to establish a national grasslands reserve in Saskatchewan. The end product of years of lobbying, study, and not a little frustration is Grasslands National Park, a magnificent tract of short-grass prairie south of Swift Current. If Black-footed Ferrets once again hunt prairie-dogs on the open Canadian prairie it will happen here and only because of the effort and dedication of Ledingham and his associates.

George Ledingham's scientific, educational and conservation achievements make him a worthy OFNC Honorary Member. His work and dedication is a source of pride and inspiration to those who share his passion for the land, wherever whey may be. It is also most fitting that the *Blue Jay*'s longest serving editor be acknowledged in 1992, the 50th anniversary of that remarkable publication.

1992 George McGee Service Award: Patricia Narraway

The George McGee Service Award is given annually in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Patricia Narraway has been chosen as the recipient of this year's award because of her consistent and dedicated service to the Ottawa Field-Naturalists' Club since 1967. Indeed, it is difficult to find any aspect of the Club to which she has not contributed.

Since her enrollment in 1967 she has served on the OFNC Council from 1969 to 1975 and again in 1984 and 1985. She set up the membership computer program, ran the program for ten years, and chaired the Membership Committee. She has also made a valuable contribution to the publication of the *Canadian Field-Naturalist.*

It should be remembered that the many hundreds of hours she has spent on these activities just touch upon her total impact on the Club.

In addition to her valuable work on the administrative side of the Club she has given selflessly of her time and knowledge on what many would consider to be the most important aspect of a field naturalist's activities. That is, field work. She has led evening field walks with the Macoun Club and has been involved in a number of private and co-operative bird banding projects. Some of the results from her extensive banding program have been described in *Trail & Landscape* articles.

In other words, she has done it all!

We firmly believe that George McGee would have heartily approved of this year's Service Award selection. After all, it was George who introduced 'Mickey' to our Club in 1967.

1992 Member of the Year Award: Colin Gaskell

This award is given to a member who has contributed the most to the Ottawa Field-Naturalists during the previous year. On rare occasions it is given twice to the same person.

Colin Gaskell has continued his dedicated service to the Club since he last received the award in 1987. As Chairman of the Lectures and Excursions Committee he has given unstintingly of his time and energy to the arrangement of monthly meeting speakers and programmes and to the organization of field trips.

He has acted effectively as a group leader and as an OFNC spokesman at various gatherings. His efficient and gracious hosting of the 1992 Soiree in the unavoidable absence of the Club President is an good example. He has also been an active member of Council since 1990 where his keen insights and wide interests in the varied activities of the Club have been of great value.

In addition to his regular Club activities Colin Gaskell has been very active on the committee organizing the Federation of Ontario Naturalist annual conference being hosted by our Club in June 1993.

It is with great pleasure, once again, to acknowledge Colin's contribution to the Club.

1992 Anne Hanes Natural History Award: Donald Cuddy

Because of his governmental position and activity in conservation matters we tend to over-look the exceptional natural history expertise of Don Cuddy. His investigations in and about eastern Ontario go back to at least the early 1970s and include explorations of the upper Ottawa Valley as well as the areas closer to Ottawa. His field explorations have resulted in important ecological discoveries in almost every significant natural area in eastern Ontario. Some of these would technically qualify as part of his professional activity as an Ontario government ecologist, but only a portion. Don is one of the declining number of natural science specialists who see their profession as a calling, not just a job, and never 'turns off the clock'.

The article Don published in *Trail & Landscape* in 1983 on the Alfred Bog is typical of his unassuming expertise. Most of the data presented in that piece were either initially gathered by Don or were evaluated in the field by him. Similarly, he discovered many unusual and significant floral and faunal features in the Marlborough Forest and the Burntlands, including the huge, unique meadows of rare Dropseed Grass (*Sporobolis heterolepis*) in the latter and is actively involved in studies of the provincially endangered Loggerhead Shrike in eastern Ontario.

Don Cuddy has quietly gone about his business gathering and documenting important – often critical - natural environment data and has demonstrated the vital importance of a sound technical foundation and factual context as the first step in tackling conservation issues. The firmness of these data have provided him, the OFNC and various government agencies with the necessary confidence to undertake needed conservation action.

It is increasingly important that naturalists carefully observe and assess natural environment features and values encountered in the field and document these in a manner that helps to protect dwindling natural systems. Don provides a superb example of this important role for contemporary naturalists.

The applied side of his ecological contributions has been recognized by his receipt of an OFNC Conservation Award; the more academic, investigative side is now honoured by naming Don Cuddy a most worthy recipient of the 1992 Anne Hanes Natural History Award.

1992 OFNC Conservation Award — (MEMBER): Ian Huggett

When development plans in Aylmer were approved which would have gutted the remnant White Pine stand at Blueberry Point in Wychwood, Outaouais resident Ian Huggett decided to change all that. Experienced, perhaps battle-weary conservationists in Ottawa told him to forget it, that he would never stop an approved development in the outaouais because west Quebec people had never shown any interest in conservation issues.

Fortunately, Ian ignored these Ontario sages. He tackled the developers despite threats and at least one physical attack, mobilized the people of Aylmer, antagonized every politician from Gatineau to Pontiac... and saved the pines. They are now an official ecological reserve, as status to be formally installed in the municipal official plan.

Not one to rest on his laurels, Ian formed *Ecowatch* in the Outaouais, a non-governmental citizens' group concerned with protecting ecological values in west Quebec. The group has been a forceful and effective voice for conservation ever since. Huggett now also writes a regular environmental column in an Aylmer newspaper and is a frequent commentator on ecological matters in the regional media.

And the powers-that-be are listening. As a direct result of Ian's inspirational efforts the city of Aylmer is establishing an Environmental Advisory Committee and including considerations for formally protected ecologically sensitive areas in its official plan.

There are still serious conservation problems in the Outaouais. Due to Ian Huggett's influence, though, the growth in public awareness and effective responses has been nothing short of revolutionary.

To Ian Huggett goes the lion's share of credit for this important achievement. He has vividly demonstrated what one person can achieve if motivated and dedicated to a cause. To use that oft abused but here so appropriate adjective, his efforts and achievements have been truly inspirational.

It is with real pride that the 1992 OFNC Conservation Award is offered to environmentalist Ian Huggett.

1992 Conservation Award - (Non-MEMBER): Merle Nicholds and Alan Austin, Kanata Lakes Natural Environment Area (NEA) Committee

The OFNC has long worked for the protection of the highly significant natural landscape of the Carp Hills, particularly the South March Highlands in the Kanata portion of the Hills. One of our biggest stumbling blocks has been the apparent lack of interest from the local community, effectively making the issue a city vs. country issue. A couple of Natural Environment Areas (NEAs) with poor development potential and questionable ecological credentials were designated in the 1980s by the strongly pro-development city administration of the day, but that was that. Some of us, frankly, thought it was all over for this beautiful area as the growth of residential development crept ever closer to the famed Trillium Woods.

That all changed in the winter and spring of 1991 when the Kanata Lakes Community Association became involved. This community was the geographically closest residential area to South March Highlands and could see all too clearly what the loss of this natural complex of upland forest and wetlands would mean. Under the leadership of President Merle Nicholds they formed an NEA Committee to monitor the expansion of the development. Importantly, as opposed to the actions of all previous Kanata interests, they immediately began searching for sound ecological advice and information.

They contacted OFNC people early on in this process and, through careful consideration of subsequent information, adept use of the media and sound, persuasive argument, convinced the city of Kanata and the landowner, Genstar Development Ltd., to jointly fund a natural environment inventory of the entire site and a re-evaluation of the old NEA designations. The result? In concert with a parallel investigation of the rest of the South March Highlands also undertaken due to urgings by Merle Nicholds, the need and rationale for the establishment of a reserve of over 400 hectares to protect the ecologically most significant 400 hectares of the South March Highlands is before Kanata Council.

The NEA Committee, now under the leadership of Alan Austin, was significantly involved in the entire unique study process and, importantly, remains vigilant to ensure that the city follows through on its conservation commitments. Encouraging coverage of the natural environment studies and analysis through the local and national media has been an important incentive for wavering politicians. The NEA Committee continues to focus public attention on the sites and to lobby the Kanata Council and the mayor. The latter, at least, is on-side for she is none other than environmental activist and ex-Kanata Lakes Community Association President Merle Nicholds.

The job's not done yet in the South March Highlands but the process is finally on track. With the diligence of Alan Austin and the NEA Committee and the continued commitment of Mayor Nicholds, the future of the most significant portion of this provincially important natural site appears to be bright.

The Kanata Lakes NEA Committee has earned the thanks and appreciation of the OFNC and we are accordingly delighted to award them our 1992 non-members Conservation Award.

President's Prize: Gillian Marston

The President's Prize was awarded by Frank Pope, in absentia, to Gillian Marston. This was in recognition of outstanding contributions to the O.F.N.C. as Treasurer, as financial organizer of the Fletcher Wildlife Garden, and as a member of the FON Conference Committee. The President expressed appreciation of Gillian's leadership qualities, her competence and enthusiasm.

ENID FRANKTON
Chair, Awards Committee

Editor's Report for Volume 106 (1992)

A total of 96 manuscripts were submitted to *The Canadian Field-Naturalist* in 1992. Publication dates were 106(1) 21 December 1992, 106(2) 5 May 1993; 106(3) 14 June 1993, and 106(4) 31 January 1994. Volume 106 totalled 582 pages, the largest issue (1) was 174 pages. The number of research and observation contributions is summarized in Table 1 by topic, the totals for Book Reviews and New Titles in Table 2, and the distribution of published pages between issues in Table 3.

M.O.M. Printers, Ottawa, set and printed the journal and special thanks are due Emile Holst and Eddie Finnigan and their staff. Review of COSEWIC Status Reports on fish and marine mammals was provided by Bob Campbell and these appeared in 106(1) with financial support for their publication provided by the Department of Fisheries and Oceans. Wanda J. Cook again proof-read the galleys for the volume. Mickey Narraway remained on call for any additional assistance to the Editor. Bill Cody continued as business manager, assisted by Lois Cody. Bill also oversaw the production, and edited, the Index. Harvey Beck, long-time compiler of the volume Index, resigned this task which he carried out so throughly with the completion of Volume 105, and I express not simply my thanks of but that of the Club, its Council and Publications Committee for his years of dedication, and our regret that he has stepped down. *The Canadian Field-Naturalist* has always been fortunate in having exceptionally competent indexers who have provided a much more extensive coverage than most journals publish annually. For volume 106, Leslie Cody undertook the job of indexer and the task was computerized for the first time. Wilson Eedy continued as book review editor (see separate report). George La Roi continued as Coordinator of the Biological Flora of Canada series; no further parts were published during the year. Our associate editors in 1992 were C. D. Bird, R. R. Campbell, B. W. Coad, A. J. Erskine, W. E. Godfrey, D. Laubitz, W. O. Pruitt, Jr., and S. M. Smith. With regret, we accepted the resignation, effective in 1993, of S. M. Smith, long-time associate editor for entomology.

In addition to the associate editors, the following reviewers also evaluated one or more manuscripts submitted during the year: B. Ackerman, Robert Anderson, C. Davison Ankney, George W. Argus, Neil Arnason, Jean-Marie Bergeron, David M. Bird, J. Roger Bider, Bob Betcher, J. Sherman Bleakney, Gary Bortolottil, D. A. Boag, R. Boonstra, Thomas Bosakowski, E. L. Bousfield, Ronald J. Brooks, Daniel F. Brunton, Harold N. Bryant, J. Burns, Paul M. Catling, Lou N. Carbyn, John Chardine, Jacques Cinq-Mars, C. S. Churcher, W. J. Cody, E. J. Crossman, Justin D. Congdon, Peter Ross Croskery, C. Dauphine, Frederick Dean, Dirk V. Derksen, Ken De Smet, D. Lynne Dickson, Erica H. Dunn, Lester

TABLE 1. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 106 (1992) by major field of study.

Subject	Articles	Notes	Total
Mammals	10*	17	27*
Birds	18	9	27
Amphibians and reptiles	3	1	4
Fish	9*	2	11*
Invertebrates	1	2	3
Plants	9	4	13
Other	2	0	2
Totals	52	35	87

*Includes COSEWIC Status Reports for 3 mammals and 5 fish.

TABLE 2. Number of reviews and new titles published in Book Review section of Volume 106 by topic.

	Reviews	New Titles
Zoology	51	92
Botany	14	38
Environment	16	53
Miscellaneous	14	20
Young Naturalists	0	94
Totals	95	297

TABLE 3. Number of pages published in *The Canadian Field-Naturalist* Volume 106 (1992) by section (number of manuscripts in parenthesis).

Issue number:	- 1 -	- 2 -	- 3 -	- 4 -	Total
Articles	125(16)	74(12)	78(14)	84(10)	361(52)
Notes	11 (6)	20 (9)	25(11)	16 (9)	72(35)
News and Comment	16 (6)	9 (4)	2 (3)	16 (8)	43(21)
Book Reviews*	21(24)	24(28)	19(28)	12(15)	76(95)
Index	-- --	-- --	-- --	26 (1)	26 (1)
Advice to contributors	1 (1)	1 (1)	3 (1)	3 (3)	-- --
New address notice	-- --	-- --	1 (1)	1 (1)	-- --
Total pages:	174	128	124	156	582

*Total pages for book review section include both reviews and new titles listings but parenthesis figures include only number of reviews.

E. Eberhardt, Richard Elliot, Craig Ely, David L. Euler, L. Scott Forbes, Pat Foster-Turley, D. E. Gaskin, Anthony J. Gaston, Jon Gerrard, Valerius Geist, Frederick F. Gilbert, J. Ginns, John Gilhen, Henri Goulet, Patrick T. Gregory, Erich Haber, Fred Harrington, Thomas B. Herman, J. Holsinger, C. Stuart Houston, Ross D. James, Robert E. Jenkins, Gordon L. Kirkland, Jr., John L. Koprowski, Richard I. Knight, Lloyd Lowry, Richard A. Malecki, André Martell, Norman Martin, Ross D MacCulloch, C. J. McCoy, Martin K. McNicholl, F. Messier, L. David Mech, Wayne E. Melquist, W. T. Momot, Ralph D. Morris, Joseph S. Nelson, R. W. Nero, David Nettleship, David Nagorsen, Martyn E. Obbard, Richard Pace, James M. Peek, R. H. Peters, Peter Petokas, Eva Pip, Kenneth Pollock, Pal Prestrud, Thomas E. Reimchen, Raleigh J. Robertson, John P. Ryder, Charles Schaadt, W. B. Scott, David Scott, Kevin Seymour, Norman R. Seymour, Robert O. Stephenson, Robert Trost, C. G. van Zyll de Jong, Paul Watts, Wayne F. Weller, D. V. Weseloh, Robert C. Whitmore, R. G. Zweifel.

My thanks are also due President Frank Pope of the Ottawa Field-Naturalists' Club, the Club Council, Chairman Ron Bedford and the Publications Committee of the OFNC for support through the year. The Canadian Museum of Nature contributed support in space and facilities, and at this institution, Claude Renaud provided special assistance with certain french abstracts and Arch Stewart with Library searches and reference verification. Joyce continued to provide encouragement throughout the year.

Frances R. Cook
Editor

Book-review Editor's Annual Report, Volume 106

Every year I am both looking for new reviewers and hoping that experienced reviewers keep contacting me when interesting titles are published or listed as available in our New Titles. There are over 250 active reviewers. Their services are essential for the success of the reviews published in our journal.

We received 80 complimentary books last year. Thirty-six books were requested from publishers or reviewers. Most publishers responded with complimentary copies. Eighty-one books were sent out to reviewers. In the same period 95 reviews were completed and published. These numbers are all slightly lower than previous years. There are always a number of well-meaning reviewers who procrastinate in completing reviews. If this notice reminds you of an abligation, please comply as quickly as possible. Publishers are promised reviews when they provide the books. The number of new titles listed, 297, was down from the normal average, but up from the previous issue.

Reviews published in our journal should be between 1 and 2 pages, double-spaced in length. The opinions expressed in the review are those of the reviewer. Editing is mostly for grammar, style, and length. It is also assumed that those offering to write reviews have the appropriate expertise. The editors do have the final decision as to whether a review is published. Edited versions are provided to the author as galley proofs prior to publication. Review guidelines are available to anyone requesting them. The reviewer gets to keep the complimentary book. Anyone interested should contact the Book-review Editor at the address below, indicating the area that you are interested in reviewing and/or titles from our lists.

Wilson Eedy

R.R. #1, Moffat, Ontario L0P 1J0 Fax: (905) 333-0798

New Journal For Invertebrate Systematics: AMPHIPACIFICA

AMPHIPACIFICA is an international journal of invertebrate systematics, aimed primarily at publication of monographic treatments that are too large or bulky (50–100 printed pages including plates) for acceptance by standard taxonomic journals. Initially, the contents will feature monographic studies on crustaceans of the faunistically rich and geologically ancient North American Pacific coastal marine region. The scope of this new journal extends, geographically to other broadly Pacific regions, and faunistically to other arthropods, mollusks, annelids, to other regional invertebrate taxa, both aquatic and terrestrial, including parasites and to aspects of vertebrate animals that may involve systematics, ecology and behaviour.

The journal will appear quarterly, or approximately so, with a run of 300–400 copies per issue, each of about 200 pages, and a volume (yearly) total of 1000 pages (approximately). The printed page size is 8.5 X 11 inches (22 X 27.5 cm). Paper quality accommodates line cuts and half tones at 400–600 dpi., and a limited number of colour plates at author cost. Manuscripts are to be submitted in "camera-ready" computerized format (IBM- or MAC-compatible diskettes), and also in hard copy, that have previously been refereed (name to be supplied) and text-edited at the author's instigation. Suitability of manuscripts, based on content and adherence to submission regulations, will be decided by the Advisory Board of the Journal.

The cost of printing and mailing of each issue is defrayed by institutional and individual subscriptions to the Journal of $50.00 Canadian Funds ($40.00 US) per annum, and by page charges to the authors of $15.00 per printed page (including plates). Further information may be supplied on request.

Publication. AMPHIPACIFICA is published by Amphipacifica Research Publications, Registrar of Companies for the Province of British Columbia No. 0152988, 1993.

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Registration.

The journal "AMPHIPACIFICA" is registered at the National Library of Canada, Legal Deposit Office, 395 Wellington St., Ottawa, Canada, as ISSN Number 9946895.

Printing.

Island Blue Print Co. Ltd., Victoria, B.C., Canada.

E. L. BOUSFIELD

Is Population Decline in Short-billed Dowitchers, *Limnodromus griseus,* Related to Hydroelectric Projects?

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Maisonneuve, Charles. 1993. Is population decline in Short-billed Dowitchers, *Limnodromus griseus,* related to hydroelectric projects? Canadian Field-Naturalist 107(2): 253–255.

A significant population decline in the Short-billed Dowitcher maybe due to loss of breeding areas due to extensive flooding or drought following hydroelectric project development. There is a pressing need for studies on northern shorebird breeding grounds facing development pressure because of the possible cumulative effect of these projects.

Key Words: Short-billed Dowitcher, *Limnodromus griseus*, habitat loss, reservoirs.

Shorebirds (Charadrii) are particularly exposed to population declines because of their dependence on rapidly disappearing wetlands. On migration and on the southern wintering grounds, high proportions of many populations are concentrated into a few, distantly separated and vulnerable sites (Senner and Howe 1984; Morrison and Myers 1987; Morrison and Ross 1989). This situation led to a strategy for the conservation of staging and wintering sites essential to these shorebird populations (Myers et al. 1987).

Howe et al. (1989) recently underlined significant population declines in the Short-billed Dowitcher (*Limnodromus griseus*), Sanderling (*Calidris alba*) and Whimbrel (*Numenius phaeopus*). The purpose of this paper is to (1) suggest possible causes for the Short-billed Dowitcher population decline, and (2) stimulate studies on northern shorebird breeding grounds.

Although some authors mention that shorebird habitats in coastal staging and wintering areas are threatened by agricultural and pesticide pollution, industrial and port development, and potential oil spills (Morrison 1983; Morrison et al. 1987; Morrison and Ross 1989), there is no evidence yet that habitats used by dowitchers during their migrations or on their wintering grounds have been subjected to major environmental perturbation.

Hydroelectric projects are among the pressures that threaten shorebirds in their North American breeding grounds (Morrison 1984). Hydroelectric reservoirs in northern Finland may have caused population declines in shorebirds nesting in peat-lands (Hildén and Hyytia 1981), and I suggest that they may be the main cause for the decline in Short-billed Dowitchers in North America.

Within their vast breeding range (Québec to British Columbia), Short-billed Dowitchers are restricted to bogs, muskegs, fens or wet meadows (Todd 1963; Erskine 1974; Gill et al. 1981; Godfrey 1986). These low-lying habitats are affected by hydroelectric projects through flooding by reservoirs or through drying out following river diversions. In the period during which dowitchers declined, many major hydroelectric projects were carried out within their breeding range (Table 1). In northern Québec and Labrador, more than 16 300 ha of bogs, fens, and sedge meadows were lost to Phase 1 of the James Bay hydroelectric project (Julien et al. 1985), and about 66 000 ha were lost following the creation of Smallwood Reservoir (Bajzak *in* Goudie and Whitman 1987), these habitats representing about 25% of the total flooded areas. The W. A. C. Bennett Dam on the Peace River in British Columbia caused the dry-out of 50 000 ha of wetlands in the Peace-Athabasca Delta (Groupe de travail national sur les terres humides 1988). A reduction of more than 38% in water surface and disappearance of 36% of the perched basin shorelines occurred in the three years following the closure of the dam (Townsend 1975).

Following major habitat loss due to flooding or drought, waterfowl are displaced and forced to seek other nesting areas (Hansen and McKnight 1964; Foote 1989), and shorebirds presumably behave similarly. Rates of reproduction and survival probably are affected following changes in predation intensity, disease or competition. Some studies have shown that competition is greater in areas of high nesting densities (Vines 1979), and that breeding success is lower when shorebirds nest in habitats of inferior quality (Skeel 1983; Galbraith 1988).

Information on dowitcher densities and overall numbers on their breeding grounds is scant. Erskine (1974) reported one partial territory on a 21 ha study plot in a Saskatchewan muskeg (0.02 pair/ha). McLaren and McLaren (1981) obtained similar den-

TABLE 1. Total and wetland areas flooded by hydroelectric projects[1] undertaken in the general breeding range of the Short-billed Dowitcher, 1970 to 1983.

Project	Total flooded area (ha)	Wetland area (ha)	Period
Churchill Falls, Labrador	284900	66000	1971-1973
Nelson River, Manitoba	33230	n.a.[2]	1970-1977
Churchill River, Manitoba	139340	n.a.	1975-1976
James Bay (Phase 1), Québec	63290	16300	1976-1983

[1]Adapted from Efford (1975), Julien et al. (1985) and Goudie and Whitman (1987).
[2]n.a. = not available

sities in northeastern Manitoba from line transects on 55 sites. At those breeding densities, the bogs, fens and sedge meadows flooded by Phase 1 of the James Bay project and by Smallwood Reservoir, if used by dowitchers, might have supported about 1645 pairs. The major hydroelectric projects in the breeding range of the species, and their subsequent effects on breeding success, may be responsible for a far greater impact on the whole population.

It may be impossible ever to demonstrate a clear direct relationship between recent breeding habitat losses and the decline noted in Short-billed Dowitchers migrating through the eastern United States. The previous comments underline a pressing need for studies on northern shorebird breeding grounds facing development pressure. As noted by Morrison and Myers (1987), better knowledge of the location of the main population centres, habitats, year-to-year variability in densities, breeding success and productivity of shorebird species is needed for the planning of sound conservation and management initiatives.

Furthermore, efforts should be made to evaluate cumulative impacts of northern development projects. Environmental assessment of individual projects may lead to the conclusion of minor and local effects, but the global assessment of several major projects planned within vast breeding ranges for several species could lead to a better understanding of the consequences on whole populations.

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Received 24 June 1992
Accepted 20 September 1993

Book Reviews

Zoology

Antarctic Birds: Ecological and Behavioral Approaches

By D. F Parmelee. 1992. University of Minnesota Press, Minneapolis. xviii + 203 pp., illus. U.S. $39.95.

Although Professor Parmelee has written many scientific papers; this is only his second book. This is a pity. For although he writes as a scientist about serious scientific studies, he uses a style that is very easy to digest. In addition, his chosen subject is, for most of us, remote and exotic. The combination make for an enjoyable book that, while entertaining is also very informative.

This new book leads the reader through the decision to set up a research station in Antarctica, to the selection of the site at Palmer Station, and the work and results of the ensuing years. Parmelee explains the logistics and physical difficulties, not to say the dangers, of working in such a demanding environment and he provides a basic overview of the area's natural history. He gives a brief outline of the scientific techniques used. These are more to set the scene than to assist other researchers. There is also an extremely brief description of the Antarctic life zones.

The main text, fully 70 per cent of the book, is a compilation of the results of the work done by Parmelee and his students. Each of the thirty species listed in the Palmer Station checklist is covered in some detail. Using the banding, satellite and observational data Parmelee gives an outline of seasonal distribution. Where appropriate, he describes what is known of the breeding biology. The depth of this coverage depends in part on the work done and in part on the opportunities offered by the location. Some birds are covered somewhat sparingly, while others are treated in significant detail. One of the more thoroughly covered species is the Southern Giant Petrel. This is the species on which the researchers used satellite tracking devices. The results were quite fascinating and this is clearly a technique with promise. The six individuals fitted with transmitters lived out very different lives, with one wandering over 2000 km in two months.

Palmer's group have also made some interesting discoveries about diet. The Kelp Gull, for example, primarily feeds on one species of limpet (wherever it is not tempted away by garbage dumps) and its range is thus governed by the limpet's range. The dominant food item for South Polar Skuas is fish, whereas Brown Skuas prefer penguins. What really emerges as the most important food source is krill, however. It is either the major direct source of food or is the basis of the food chain for all the important prey species. The effects on Antarctic biology of harvesting large quantities of krill by humans is disturbing to contemplate. This may be Parmelee's greatest contribution to science and the future of this region.

The book is illustrated by the author's photographs, line drawings, and paintings. The quality of the photographs is extremely good, with the really magnificent ones being in colour. The drawings and paintings vary somewhat in quality but all possess a degree of charm.

Dr. Parmelee has been fortunate to spend so much time in this fascinating part of the world. We are fortunate too, in having a scientist who can contribute so much on this remote area and also write and illustrate so well. We can all now enjoy some of what this region has to offer.

Roy John

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Ecology and Conservation of Neotropical Migrant Landbirds

By John M. Hagan III and David W. Johnson. 1992. Smithsonian Institution Press, Washington. xii + 609 pp., illus. Cloth U.S. $48.00, Paper U.S. $17.95.

There is increasing evidence that many neotropical migrant songbirds are declining in numbers since 1970s (e.g., Robbins et al. 1989; Terborgh 1992). Human induced environmental changes (e.g., habitat fragmentation, pesticides, etc.) may be responsible for these declines. This publication, therefore, is a timely contribution on the ecology of neotropical migrant songbirds. It is based on papers presented at a Manomet Bird Observatory symposium held in December 1989 at Woods Hole, Massachusetts.

The purpose of the symposium, and subsequently this monograph, was to identify gaps in our knowledge about neotropical migrant landbirds. The monograph starts with two papers based on plenary addresses, one on the conservation of neotropical migrant landbirds and the other on forest loss in Central America. The former makes a plea to all scientists working on these neotropical migrants to come together so that productive conservation measures can be taken.

The rest of monograph (49 papers) is divided into five parts: trends in populations, the nonbreeding season, hemispheric perspectives, and concluding remarks. Many papers in the trends of population section report significant population declines for some neotropical migrant landbirds that associate with the forest habitat. However, some authors report population increases for forest-dwelling neotropical migrant songbirds (James et al.), or report declines both for neotropical migrants and for short-distance migrants (species that migrate to other parts of North America).

In his introduction to the nonbreeding season section, Greenberg correctly states that basic natural history studies are urgently needed on most of neotropical migrant landbirds. The studies in this section show that these species are diverse in their habitat use during winter. In addition to mature primary forest they also occur in agricultural areas, pastures, and early successional forests. Some studies in the breeding season section show that there is a need to preserve unfragmented forests as they may serve as immigration sources for poorly reproducing populations as far as 200 km away and save them from extinction (Robinson). In this section, like Greenberg, Martin also points out that we lack basic breeding data on most of neotropical migrant landbirds.

In the hemispheric perspectives section, Hunter postulates that neotropical migrants may be more adaptable to habitat change because they encounter and use different habitats when breeding, migrating, or wintering. Reed ranks different species according to their extinction probabilities based on habitat selection, geographic distribution, and local population sizes and reaches a disturbing conclusion that about a quarter of neotropical migrant songbirds are vulnerable to extinction.

There are two concluding chapters. Morton by reviewing different studies concludes that many neotropical migrant songbirds are indeed showing long-term population declines. He also recommends standardizing and improving methods to count birds both during the breeding season and winter. Finally, 12 neotropical ornithologists (Naranjo et al.) make a plea for an increase in cooperation between scientists of both hemispheres. Symposium program and resolutions are presented at the end.

The papers in this monograph are easy to read. This monograph is an excellent contribution on neotropical migrant landbirds and will interest both scientists and wildlife managers. Reading this monograph, however, made me sad. I wondered, if we will ever be able to save these attractive birds?

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Studies of High-latitude Seabirds: 1. Behavioural, Energetic, and Oceanographic Aspects of Seabird Feeding Ecology

Edited By W. A. Montevecchi and A. J. Gaston. 1991. Canadian Wildlife Service, Environment Canada, Ottawa. 56 pp., illus.

Studies of High-latitude Seabirds: 2. Conservation Biology of Thick-billed Murres in the Northwest Atlantic

Edited by A. J. Gaston and R. D. Elliot. 1991. Canadian Wildlife Service, Environment Canada, Ottawa. 63 pp., illus.

Atlas of Pelagic Birds of Western Canada

By K. H. Morgan, K. Vermeer, and R. W. McKelvey. 1991. Canadian Wildlife Service, Environment Canada, Delta, British Columbia. 72 pp., illus.

These are all publications in the Occasional Papers series from the Canadian Wildlife Service. The first two are a compilation of a number of papers presented at a symposium on Population Biology and Conservation of Marine Birds held at Memorial University, Newfoundland in 1989.

The first volume deals mainly with alcids in the northern hemisphere (except for a comparison with penguins). Three of the papers focus on food and one is partially oriented towards feeding. There is an interesting attempt in one paper to relate the carbon

13 to nitrogen-15 ratio in lipid-extracted muscle tissue to the trophic level of food species. Both isotopic separation and accurate measurement are fraught with difficulty and will influence the results. This was not discussed by the authors. Such a discussion would have been meaningful, for while the results show some correlation, the data scatter is also significant. Another paper gives a statistical summary of seabirds off the coast of Newfoundland. I had some difficulty distinguishing between when the authors were meaning true parameters and when they were referring to variables. Also they did not discuss the effect of using fixed observations with a randomly-based statistical technique.

Six of the seven papers in the second volume are devoted to population studies of Thick-billed Murres, including two interesting accounts of the Newfoundland murre hunt. The seventh paper concentrates on Atlantic Puffins and Common Murres. Sadly, the underlying message of the articles is the decline of these birds. This points to the need for a multi-disciplinary evaluation of the status of fish stocks (including capelin and shrimp), fishing activity level, marine chemistry, and seabird and sea mammal survival rates. We would then have a better understanding of what we are doing to the marine environment as a whole, and we could then develop a management strategy that would reverse the damage done to date.

The above criticisms are minor. These papers are an important contribution to the use of database and to seabird science. Any marine ecologist who was not at the symposium should get a copy of these publications. CWS and the editors are to be congratulated on making this material widely available.

The third title, *Atlas of Pelagic Birds of Western Canada,* while still a scientific publication, is likely to be more used by amateur birders. It is a compilation of the observations made by 18 people during 45 voyages. This resulted in over 5000 transects covering some 20 000 km of ocean. The data have been translated into seasonal distribution maps for 22 species and locational map for twelve rare and accidental species.

The maps have one irritating characteristic. The lowest level of abundance, zero observations, is shown as a small solid dot. The next two levels (generally 0.01 to 0.10 and 0.11 to 10.0 birds/km) are designated by open dots. Subsequently higher levels of observation are again shown as even larger solid dots. Thus, for sample, the Tufted Puffin fall map shows around 150 small solid dots that obscure the dozen or so small open dots. The first impression is that these puffins are seen all over the area whereas they really occur in small numbers in restricted localities. The mapmakers should have used a completely different symbol to show absence. Beware too, the scales occasionally vary from map to map, particularly with the abundant species. Also the scale on Figure 8 is inconsistent and probably contains an error.

Despite this source of confusion, this publication is most useful. It will enable both professionals and amateurs to more efficiently plan their time and so produce more meaningful results. This should ultimately lead to even better atlas information in the future.

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Animal Minds

By Donald R. Griffin. 1992. University of Chicago Press, Chicago. x + 310 pp. U.S. $24.95.

Already well known for significant contributions in the study of animal behaviour, Donald Griffin has become, as he is cited on the cover, "the dean of cognitive ethology" for his claims that this study, if it is to be successful, must reach beyond behaviouristic methods to include mental concepts. The present volume, the third and longest by him on this theme, like its predecessors, with which he admits "considerable overlap", contains two components intellectually. The bulk is a broad review of intelligent and complex behaviour in many species, especially birds, dolphins, and primates, under such headings as finding of food, construction of nests and use of tools, neurophysiological correlates of such activities, and social deception and manipulation within the framework elaborated by Richard Dawkins and John Krebs in 1978. The other component, contained in the Preface and the first and last chapters, and largely unconnected to the remainder, is a repetition of his earlier claims plus acknowledgments, but not responses, to critics. Some linkage is attempted in the chapters dealing with concepts (in which "behavioristic inhibitions" are attacked), communication (once again touted, without support, as an area in which "windows" to the mind can be opened), and the use of symbols (which remain undefined: the text deals with the dances of honeybees).

The first component will be useful to readers looking for an overview and prepared to avoid unwarranted conclusions. The second remains basically unconvincing for reasons familiar to those who have followed the field. Understanding of the scientific (e.g., neurophysiological continuity across species), philosophical (e.g., the folly of dualism), and ethical (e.g., animal suffering) issues which Griffin raises nonetheless provides no basis for agreeing with his conclusions. Conviction cannot be based on "a highly suggestive incident' or result when "the data are not sufficient", and the absence of essential definitions and of suggestions for specific programmes of study underscores the emptiness of the enterprise. Additionally, innuendos and distortions mar the presentation: for instance, rather than belittling nonhuman animals, as claimed, science has surely enhanced our appreciation of them. Readers should attend to the wide variety of unanswered scientific and philosophical criticisms which have been justly levelled at the author (and, *per contra* Griffin's remark, this critic, at least, harbours no guilt for this). The natural history of mind has been in crisis at least since the work of David Hume that applies as devastatingly here as it does elsewhere. Current work in neuroscience, behavioural analysis, and artificial intelligence are jointly shedding much light on complex activities. Against this, "cognitive ethology" as presented in this book is not contributing to this advance, and the publisher should have known it.

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BOTANY

Atlas des plantes vasculaires de l'île de Terre-Neuve et des îles de Saint-Pierre-et-Miquelon/ Atlas of the Vascular Plants of the Island of Newfoundland and of the Islands of Saint-Pierre and Miquelon

By Ernest Rouleau and Gisèle Lamoureux. 1992. Fleurbec, 198 Chemin de la Grande-grillade, Saint-Henri-de-Lévis, Québec. G0R 3E0. 777 pp. $125. French and English.

Only the Maritime Provinces have such detailed published maps of their floras. Ernest Rouleau, following in the footsteps of M. L. Fernald and associates, botanized in Newfoundland for many years, sometimes island- and mountain-hopping by helicopter. He originally did the maps, on which this volume is based, in the late 1950s. An original set was deposited in the Agnes Marion Ayre Herbarium, Newfoundland, at a ceremony on 4 August 1960. The other set of original maps is at the Université de Montréal. The maps were based on 12 years of collecting under contract to the Newfoundland government and he included data from specimens deposited in six herbaria in Europe and North America.

The maps and final text were completed by Gisèle Lamoureux and workers with the Fleurbec team. This atlas contains 1197 maps based on the work of Rouleau and Andre Bouchard and his colleagues as well as information from Saint-Pierre-et-Miquelon. The maps in the Ayre Herbarium have been continuously updated and these data are not included in this atlas. Consequently, many species are more widespread than is indicated on the maps. For example, *Apocynum androsaemifolium* is uncommon but more widely distributed, and *Typha latifolia* has now reached the St. John's area. It is a pity that such an attractive and monumental tome is so dated upon publication.

This book is more than an atlas. It has a warmly-written biography of Rouleau, who passed away in January 1991, a complete bibliography of his work, a brief history of botanizing on the island, and a fairly complete bibliography of this. Ernie, as Rouleau was affectionately known by many Newfoundlanders, made an important contribution to our knowledge of the flora of Newfoundland. He arranged that the watercolours and specimens of Mrs. Agnes Marion Ayre, which represented five-sixths of the flora, be used as the foundation of the Ayre Herbarium. This volume is a fitting tribute to a wonderful botanist.

Some comments: This atlas does not represent "the only flora available" for these territories as it was preceded by *Gray's Manual* and Scoggan's *Flora of Canada* and there are several others contributing to our knowledge of the flora. A few of the errors noted: page 46, Robert Bell collected on the southwest, not the southeast, coast of Newfoundland; page 454, *Rhinanthus minor* and *R. borealis* are chemical but not morphological taxa; *Helianthus annus* is not indigenous to Saint-Pierre; a published map of *Solanum dulcamara* and *S. nigrum* was cited in the bibliography but not included on page 442-443, and the map on page 737 shows no records of *Sorbus aucuparia* on the island which is an oversight; and the grass, *Phippsia algida,* which is new to insular Newfoundland, has been uncovered through archival research since the publication of this book (Day 1993. *The Osprey Magazine* 24(1): 59).

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Practical Plants

By Joyce Pope. Facts On File, New York. 62 pp., illus.

Plants of the Tropics

By Susan Reading. Facts On File, New York. 62 pp., illus.

These two children's books are part of a group of four. The other two volumes are *Plant Partnerships* and *Desert Plants*. They have a large format with descriptive sections on each plant or plant group, supported by a number of illustrations per page. For example in *Practical Plants* there is a section on sweeteners which has paragraphs on sugar cane, sugar beet, and maple syrup. These are illustrated with photographs of cane cutting, collecting maple sap, and small, coloured drawings to show beet sugar production and the uses of sugar.

This format is followed throughout. In general terms the *Practical Plants* book covers plants as a source of food, fuel, building material, fabric, and chemicals. The section on fibres is representative of this book. It begins with a history of human use from stems and grasses to woven items, and then looks at the key fibres uses today; flax, cotton, jute, hemp, and China grass. Colour drawings illustrate each of the plants and there are photographs of a cotton field and a flax mill.

The volume on *Plant of the Tropics* explains the various plant communities within a tropical forest, the relationship with animals and people, and the alarming rate of destruction currently under way. For example, there is a section on what happens when a tree falls. In it, the whole concept of recycling nutrients and the beneficial changes that occur to various members of the forest community are explained.

Each book is clearly written with illustrations that are both colourful and supportive of the text. I was impressed with the use of illustrations from around the world. So often authors claim a global basis for their books but show a definite North American or British bias. Scientific terms associated with plants are used often, but they are always explained clearly, and would teach rather than deter a young reader. There are a few other words, such as ophthalmologist, however, that a young person might have trouble with that are left unexplained. Otherwise, the style of both books is straightforward and clear.

Overall these are two excellent books and would provide a young reader with an enjoyable introduction to the plant kingdom. They also provide some sense of the global use and importance of plants, not just in the richer countries, but in places where the relationship between plants and people is more direct. An imaginative teacher can use these books as a resource in more ways than one.

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MISCELLANEOUS

The Modern Beginnings of Subarctic Ornithology: Northern Correspondence with the Smithsonian Institution, 1856-68

Edited and Introduced by Debra Lindsay. 1991. Manitoba Record Society, Winnipeg. xxx + 226 pp., $30.

Fifty letters written by Canadian fur traders, selected from their correspondence with Spencer F. Baird at the Smithsonian Institution in Washington, D.C., form a precious record of early natural history collecting in northwest Canada. The collector-correspondents, all fur traders with the Hudson's Bay Company, are (with the number of their published letters in parentheses): Bernard Rogan Ross at Fort Simpson (14), James Lockhart at Fort Youcon and Resolution (10), Roderick Ross MacFarlane at Fort Anderson (8), Donald Gunn at Red River (8), George Barnston at Michipicoton (4), William MacTavish at Fort Garry (4), Lawrence Clarke at Fort a la Corne (1), Strachan Jones at Fort Rae (1). Ten letters from Robert Kennicott, who had been sent into the north by the Smithsonian to make collections and to encourage the factors to increase their shipments of specimens south, augment the collection.

This book is a spinoff from Debra Lindsay's Ph.D. thesis in history at the University of Manitoba in 1989, "Science in the Sub-Arctic: Traders, Trappers and the Smithsonian Institution, 1859-70." It is especially valuable because Spencer Baird, who received nine thousand specimens from his three most prolific collectors north of sixty degrees latitude, never did get around to writing his promised book on Arctic Fauna.

The first part of Lindsay's introduction places these collectors in their historical context, in a section entitled "Science in Rupert's Land before 1859", followed by six pages of biographical information about the correspondents, with appropriate footnotes and references. One inconsistency is the years of birth and death are given for only some of the fur traders. The letters speak for themselves, but Lindsay has written helpful notes at the beginning of all but twelve of them.

There are a few obvious errors of transcription, evident from those letters of B. R. Ross that I had transcribed independently in the Smithsonian; but Lindsay has given logical corrections for approximately an equal number of words that I had, in retrospect, and equally obviously from the context, transcribed in error. Since this is a selection of the most interesting of the available letters, others including an additional 12 letters from B. R. Ross and 13 from Donald Gunn, have not been included in this book.

Lindsay's lack of ornithological expertise and interest is apparent. The four-page list of bird names unfortunately does not use modern terminology. She omits, without showing this by ellipses, a list of 30 species for which eggs were collected by B. R. Ross – and similarly omits his list of books in his personal library. She does not tell us for example, how the Ross' Goose (for Bernard Rogan Ross) and the *aliciae* race of the Gray-cheeked Thrush (for Kennicott's sister, Alice) came to be named. She fails to mention the significance of the set of two Whooping Crane eggs taken somewhere south of Fort Resolution by James Lockhart in 1864 or that Roderick Ross MacFarlane collected 36 of the 37 sets of Eskimo Curlew eggs ever recorded anywhere. I could find no reference for the paper published in *Edinburgh New Philosophical Journal* by Mr. Andrew Murray of Edinburgh concerning the Natural History of Hudson's Bay, nor for the four papers published by B. R. Ross in *Canadian Naturalist and Geologist* and *Natural History Review*. Evidently she failed to obtain the requisite help from naturalists regarding such matters.

One hopes that more information about Kennicott, who died tragically at age 30 and was a century later the subject of one of the finest biographical sketches of any naturalist ever written [Zochert, *Audubon* 82(2): 37–47, March 1980], will appear in Lindsay's promised second book. Meanwhile, this book is a valuable addition to the history of Canadian ornithology.

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863 University Drive, Saskatoon, Saskatchewan S7N 0J8By Olin Sewall Pettingill. 1992. University of Oklahoma Press, Norman. xiv + 245 pp., illus. U.S. $24.95.

My Way to Ornithology

By Olin Sewall Pettingill. 1992. University of Oklahoma Press, Norman. xiv + 245 pp., illus. U.S. $24.95.

Sewall Pettingill is a renowned ornithologist and bird photographer, well known for his best-selling *Laboratory and Field Manual of Ornithology* and for the first extensive guides to bird finding sites. This book, only the first half of his autobiography, documents his "way to ornithology," covering his childhood and his student days.

I found the book interesting, in part because Sewall, like me, was a doctor's son and an only child, because his father operated a sanatorium for treating tuberculosis, a historical research topic of mine, and because he shared a Churchill collecting trip with Bert Lloyd of Davidson, Saskatchewan.

Sewall provides unusually detailed accounts of his experiences. Quite apart from ornithology, his autobiography is a fine account of childhood in New England, of Bowdoin years of 1926-1930 and graduate studies at the Cornell Laboratory of Ornithology, 1930-1933.

Undergraduate days at University were very different from today – Sewall courted Eleanor Rice for ten years. Eleanor went to Wheaton College in Norton, Massachusetts, while Sewall attended Bowdoin College in Brunswick, Maine. Here he was assigned to interview Professor Alfred O. Gross for the student newspaper *The Orient*. Learning of Sewall's interest in birds, Gross persuaded Sewall to major in biology and enroll in his ornithology class. This led to an unequalled trip to Martha's Vineyard with Gross and Thornton W. Burgess, the storyteller, to see the last three surviving Heath Hen males do their courting dance in vain; the last female had already died. Dr. Gross taught the ornithology course that summer at the University of Michigan Biological Station, and Sewall got to undertake Hermit Thrush research. After his third year at Bowdoin, a return trip to Martha's Vineyard revealed only a single surviving male Heath Hen, but during two weeks on Great Duck Island, ten miles off the coast of Maine, he secured many excellent photographs for later talks and articles.

Sewall next studied the American Woodcock under Dr. Arthur A. Allen at Cornell. The first summer was spent on a collecting trip at Churchill, Manitoba, where George Miksch Sutton found the first-ever nest and eggs of the Harris' Sparrow. On their return to Ithaca, Sewall roomed for two years with Sutton. When he completed his Ph. D. studies, he married Eleanor; their honeymoon was spent studying birds together at Cobb Island, Virginia. While there, a devastating storm wiped out the bird colonies on the island, including all skimmer nests.

Sewall's first teaching positions, one-year stints, were at Bowdoin, assisting Dr. Gross, and at Westbrook Junior College in Portland, Maine. There was an intervening year when only Eleanor had a teaching position. The book ends when he sets out for Northfield, Minnesota, to begin his professional career of teaching ornithology.

Throughout the book he tells of many birding encounters; he describes how he mastered the art of photography in spite of cumbersome equipment and the need to hand-colour each individual slide.

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The Origins of Natural Science in America: The Essays of George Brown Goode

Edited with an introduction by Sally Gregory Kohlstedt. 1991. Smithsonian Institution Press, Washington. xi + 411 pp. U.S. $45.00.

A century ago Goode was a leader in museology and the history of science. In this volume his institution recognizes his contributions through a compilation of five essays, accompanied by a biographical introduction. The first three deal with the beginnings of natural history and of national scientific and educational institutions in the United States. The scope of these essays is impressive: from the earliest accounts, sometimes written as poetry, through what Goode labels the ages of Jefferson, Silliman, and Agassiz, there is the development of the various disciplines and associated expeditions, organizations, and publications. The sometimes rather dry litany of Who Was is leavened by general discussion of issues and evaluation of the importance of individuals. The institutional history ranges from the American Philosophical Society through the collapse of plans for a federal university, the Morrill Act for land-grant colleges, to the elaboration of a panoply of governmental and private agencies (including no less the American Society for Psychical Research). The final two essays overlap on the topic of museums past and future. Both their history, from classical roots through the Renaissance to the nineteenth century, and a philosophy of their social functions, in conjunction with libraries, are given. While the catalog of museums will not interest everyone, the analysis of the roles of government and of private individuals remains germane.

In the intervening hundred years both the history of science and museology have made enormous strides. This is seen, for instance, in the growing number of excellent biographies, the contents of journals devoted to museums, and contemporary museological conferences. Notwithstanding, by its inclusion of key historical documents as appendices, this book will serve as a valuable source for students of the history of natural history. For the general reader, also, there are interesting accounts and viewpoints. We do not need to be a genealogist like Goode to agree that it is "incumbent upon workers in science to keep green the memory of those whose traditions they inherited". In an age of competitiveness, cost-recovery, and the culture of contentment, we do well to "feel that the highest function of science is to minister to the mental and moral welfare of mankind" and to hope "that museums may never cease to increase".

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NEW TITLES

Zoology

†**Aerial radio-tracking of whooping cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981-84.** 1992. By E. Kuyt. Canadian Wildlife Service Occasional Paper No. 74. Environment Canada, Ottawa. 53 pp., illus.

The ancient murrelet: a natural history in the Queen Charlotte Islands. 1992. By Anthony J. Gaston. Academic Press, San Diego. 249 pp., illus. U.S.$34.95.

*__Atlas of breeding birds of the maritime provinces.__ 1992. By Anthony J. Erskine. Nimbus, Halifax (U.S. Distributor Chelsea Green, Post Mills, Vermont). 280 pp., illus. $29.95.

*__Bats.__ 1992. By M. Brock Fenton. Facts on File, New York. 224 pp., illus. U.S.$45; $55 in Canada.

Bird census techniques. 1992. By Colin J. Bibby, Neil D. Burgess, and David A. Hill. Academic Press, San Diego. c272 pp., illus. cU.S.$37.50.

Birds in jeopardy: the imperiled and extinct birds of the United States and Canada, including Hawaii and Puerto Rico. 1992. By Paul R. Ehrlich, David S. Dobkin, and Darryl Wheye. Stanford University Press, Stanford, California. x + 253 pp., illus. Cloth U.S.$45; paper U.S.$17.95.

The birds of Africa, volume iv: broadbills to chats. 1992. Edited by Stuart Keith, Emil K. Urban, and C. Hilary Fry. Academic Press, San Diego. 632 pp., illus. U.S.$185.

Birds of Tikal: an annotated checklist for Tikal National Park and Peten, Guatemala. 1992. By Radell A. Beavers. Texas A & M University Press, College Station. 192 pp., illus. Cloth U.S.$29.50; paper U.S.$12.95.

A chronological taxonomy of *Conus*, 1758 - 1840. 1992. By Alan J. Kohn. Smithsonian Institute Press, Washington. 368 pp., illus. U.S.$45.

The common names of North American butterflies. 1992. Edited by Jacqueline Y. Miller. Smithsonian Institute Press, Washington. 192 pp. U.S.$14.95.

*__Declines in Canadian amphibian populations: designing a national monitoring strategy.__ 1992. Edited by Christine A. Bishop and Karen E. Pettit. Canadian Wildlife Service Occasional Paper No. 76. Environment Canada, Ottawa. 120 pp., illus.

†**The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island.** 1992. Edited by Kees Vermeer, Robert W. Butler, and Ken H. Morgan. Occasional Paper No. 75, Canadian Wildlife Service. Environment Canada, Ottawa. 136 pp., illus.

*__Environmental physiology of the amphibians.__ 1992. Edited by Martin E. Feder and Warren W. Burggren. University of Chicago Press, Chicago. 654 pp., illus. Cloth U.S.$135; paper U.S.$47.50.

*__A field guide to eastern butterflies.__ 1992. By P.A. Opler and V. Malikul. Peterson Field Guide Series. Houghton Mifflin, Boston. xvii + 396 pp., illus. Cloth U.S.$24.95; paper U.S.$16.95.

*__The fishes of Alberta.__ 1992. By Joseph S. Nelson and Martin J. Paetz. University of Alberta Press, Edmonton. xxvi + 437 pp., illus. Cloth $34.95; paper $24.95.

†**Guide to marine mammals of Alaska.** 1992. By Kate Wynne. Alaska Sea Grant, Fairbanks. 75 pp., illus. U.S.$15.

*__Hawaiian insects and their kin.__ 1992. By F.G. Howarth and W.P. Mull. University of Hawaii Press, Honolulu. 160 pp., illus. U.S.$19.95.

Illustrations of the birds of California, Texas, Oregon, British and Russian America. 1992. By John Cassin. Reissue of 1856 edition. 348 pp., illus. + 5 plates. U.S.$29.95; limited edition U.S.$75.

*__Illustrated key to the skulls of genera of North American land mammals.__ 1992. By J. Knox Jones, Jr., and Richard W. Manning. Texas Tech University Press, Lubbock. 75 pp., illus. U.S.$9.95.

In search of arctic birds. 1992. By Richard Vaughan. Academic Press, San Diego. 431 pp. U.S.$39.95.

In search of sparrows. 1992. By J. Denis Summers-Smith. Academic Press, San Diego. 141 pp. U.S.$39.

Insect potpourri: adventures in entomology. 1992. Edited by Jean Adams. Sandhill Crane Press, Gainesville, Florida. xii + 336 pp., illus. U.S.$25.

*__Kingfishers, bee-eaters, and rollers: a handbook.__ 1992. By C. Hilary Fry and Kathie Fry. Princeton University Press, Princeton. xi + 324 pp., illus.

Life histories of North American woodpeckers. 1992. By Arthur Cleveland Bent. Indiana University Press, Bloomington. 270 pp., illus. U.S.$29.95.

*__The migration of knots.__ 1992. Edited by Theunis Piersma and Nick Davidson. Wader Study Group Bulletin 64, Supplement. Joint Nature Conservation Committee, Peterborough, United Kingdom. 209 pp., illus. £15.

New World parrots in crisis: solutions from conservation biology. 1992. Edited by Steven R. Beissiuger and Noel F.R. Snyder. Smithsonian Institute Press, Washington. xv + 277 pp., illus. Cloth U.S.$35; paper U.S.$16.95.

*__Oklahoma bird life.__ 1992. By Frederick M. and A. Marguerite Baumgartner. University of Oklahoma Press, Norman. xxxv + 443 pp., illus. + plates.

*__The ostrich communal nesting system.__ 1992. By Brian C.R. Bertram. Princeton University Press, Princeton. viii + 196 pp., illus. U.S.$35.

The pinyon jay: behavioral ecology of a colonial and co-operative corvid. 1992. By John M. Marzluff and Russell P. Balda. Academic Press, San Diego. 317 pp., illus. U.S.$45.

Primates of the world. 1992. By Rod and Ken Preston-Mafham. Facts on File, New York. 192 pp., illus. U.S.$24.95; $31.95 in Canada.

*__Raptors: birds of prey.__ 1992. By John Hendrickson. Raincoast Books, Vancouver. 85 pp., illus. $24.95.

Botany

*__American wildflower florilegium.__ 1992. By Jean Andrews. University of North Texas Press, Denton. 128 pp., illus. U.S.$50; limited edition U.S.$200.

*__Atlas des plantes vasculaires de l'île de Terre-Neuve et des iles de Saint-Pierre-et-Miquelon/Atlas of the vascular plants of the island of Newfoundland and the islands of Saint-Pierre-et-Miquelon.__ 1992. Par Ernest Rouleau et Gisele Lamoureux. Fleurbec, Saint-Henri-de-Levis, Québec. GOR 3EO. 777 pp., illus., bilingual. $125.

Bamboos. 1992. By Christine Recht and Max Wetterwald. Timber Press, Portland, Oregon. 160 pp., illus. U.S.$32.95.

Calymperaceae. 1992. By William D. Reese; and **Leucophanaceae.** 1992. By Noris Salazar Allen. New York Botanical Garden, Bronx. 1 volume, 120 pp. U.S.$17.50 plus postage.

*__Les Cyperacees de l'est du Canada.__ 1992. Par Bernard Boivin. Provancheria No. 25. Université Laval, Québec. 230 pp., illus. $15.

Desertified grasslands: their biology and management. 1992. Edited by G.P. Chapman. Academic Press, San Diego. 360 pp. U.S.$99.50.

†**Fire and vegetation dynamics: studies from the North American boreal forest.** 1992. By Edward A. Johnson. Cambridge University Press, New York. xiii + 129 pp., illus. U.S.$49.95.

The illustrated encyclopedia of orchids. 1992. Edited by Alec Pridgeon. Timber Press, Portland, Oregon. 304 pp., illus. U.S.$39.95.

Indices to the species of mosses and lichens described by William Mitten. 1992. By Barbara M. Thiers. New York Botanical Garden, Bronx. 128 pp. U.S.$21.35.

*__Plants of northern British Columbia.__ 1992. Edited by Andy Mac Kinnon, Jim Pojar, and Ray Coupe. Lone Pine, Edmonton. 352 pp., illus. $19.95.

Rollinia. 1992. By P.J.M. Maas, et al. New York Botanical Garden, Bronx. 192 pp. U.S.$28.50 plus postage.

Willows: the genus *Salix*. 1992. By Christopher Newsholme. Timber Press, Portland, Oregon. 224 pp., illus. U.S.$34.95.

Environment

*__After the ice age: the return of life to glaciated North America.__ 1991. By E.C. Pielou. University of Chicago Press, Chicago. 366 pp., illus. U.S.$24.95.

The biocycle guide to yard waste composting. 1992. Edited by staff. Biocycle, Emmaus, Pennsylvania. Cloth U.S.$59.95; paper U.S.$49.95 plus U.S.$5 outside U.S.A.

Diversity and the tropical rain forest. 1992. By John Terborgh. Scientific American Library, New York. ix + 242 pp., illus. U.S.$32.95.

Global development and the environment: perspectives on sustainability. 1992. Edited by Joel Darmstadter. Resources for the Future, Washington. xi + 91 pp. U.S.$9.95.

*__Guide to the natural history of the Niagara Peninsula.__ 1991. Edited by J.C. Lewis. J.C. Lewis, St. Catharines, Ontario. x + 447 pp., illus. $125.

*__Messages from earth: nature and human prospect in Alaska.__ 1992. By Robert Weeden. University of Alaska Press, Fairbanks. xiv + 189 pp., illus. U.S.$16.95.

The nature of Borneo. 1992. By Steve Yates. Facts on File, New York. 224 pp., illus. U.S.$45; $55 in Canada.

†**On nature's terms: contemporary voices.** 1992. Edited by Thomas J. Lyon and Peter Stine. Texas A & M University Press, College Station. vi + 212 pp. Cloth U.S.$35; paper U.S.$14.95.

*__The origins of natural science in America.__ 1991. Edited by Sally G. Kohlstedt. Smithsonian Institute Press, Washington. xi + 411 pp. U.S.$45.

Perspectives in environment management. 1992. By Ralf Buckley. Springer-Verlag, New York. 287 pp. U.S.$69.

Preserving Eden: the nature conservancy. 1992. By Noel Grove. Abrams, New York. 176 pp., illus. U.S.$39.95.

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ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 107, Number 3 July-September 1993

The Ottawa Field-Naturalists' Club

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Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: July-September 1993 (June 1994).

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Cover: Two Wolf, *Canis lupus*, pups at aquatic play, Dalhousie Animal Behaviour Field Station, Nova Scotia, June 1991. Photo by Elizabeth M. Coscia. See note on pages 361–362.

The Canadian Field-Naturalist

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Gastropods from Small Northeastern Ontario Lakes: Their Value as Indicators of Acidification

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Bendell, Barry E., and Donald K. McNicol. 1993. Gastropods from small northeastern Ontario lakes: Their value as indicators of acidification. Canadian Field-Naturalist 107(3): 267–272.

Gastropoda were sampled in 15 small lakes covering pH 5.0-7.5 northeast of Sudbury, Ontario. Twelve species were found among nine lakes with pH>6.0. The most widespread was a freshwater limpet, *Ferrissia* sp., which was the only one occurring in those lakes with pH 5.2-6.0. In less intensively sampled lakes in the area, other species were recorded between pH 5.5 and 6.0. In lakes with pH>6.0, there was no evidence of a relationship between the total number of gastropods, dominated by *Helisoma anceps* and *Physella gyrina*, and pH, alkalinity, or calcium ion concentration. However, the $\log_e$ total number of gastropods was significantly correlated with total phosphorous concentrations ($r=0.72$, $n=9$, $p<0.05$). Above minimum pH thresholds, gastropod densities in small oligotrophic lakes appear to be limited by food resources, and not by calcium concentrations or alkalinity.

Key Words: Gastropoda, lakes, northern Ontario, indicator, acidity, calcium, phosphorous.

Gastropoda are among the most acid-sensitive groups of freshwater organisms (Eilers et al. 1984). In an extensive survey of Norwegian lakes, Økland (1983) found that gastropods were absent from that country's acidified lakes. Many studies have related gastropod abundance or species richness to calcium ion concentrations or alkalinity, in Canada (McKillop and Harrison 1972; McKillop 1985) and elsewhere (Boycott 1936; Macan 1950; Aho 1966, 1978; Williams 1970; Dussart 1976). Because the acidification process involves a loss of alkalinity prior to a pH decline (Henriksen 1982), it might be expected that the disappearance of gastropods would be a reliable early warning indicator of acidification (Raddum and Fjellheim 1984; Mills and Schindler 1986). However, some studies have suggested that gastropods are more likely to be affected by differences in food resources than by calcium ion concentrations or alkalinity (Reavell 1980; Dillon and Benfield 1982).

In previous studies (Bendell and McNicol 1987; McNicol and Wayland 1992), we sampled the invertebrate communities of many small oligotrophic lakes as part of a project investigating the effects of acidic precipitation on waterfowl and their foods. That sampling did not accurately reflect the species distribution and composition of the gastropod community. As gastropods are a potentially important source of calcium for breeding waterfowl, we undertook a small but intensive sampling program to better document their distributions and relative abundances in headwater lakes. We also assessed their value as an indicator of the acidification of small calcium-poor lakes, typical of those used by breeding waterfowl in northern Ontario.

Methods

Invertebrates were sampled in small lakes in an area 40 to 70 km northeast of Sudbury, Ontario (see Table 1). The area is described in detail by McNicol et al. (1987). Lakes in the area occur over a wide range of pH, and include those acidified by sulphur dioxide deposition from the sulphide ore smelting operations near Sudbury, and by the long-range transport of airborne pollutants (Jeffries 1984; McNicol et al. 1987).

Twenty small (1.9–7.8 ha) headwater lakes were chosen for intensive sampling of aquatic insects that are important waterfowl food. They were chosen to include lakes with and without fish, because fish predation may have a significant impact on waterfowl foods (Bendell and McNicol 1987) including snails (Merrick et al. 1991). Benthic samples were taken from those lakes twice in 1985, between 19 June and 7 July, and between 23 July and 2 August. On each occasion, samples were taken at 10 randomly selected sites in water < 1.0 m deep. A layer of substrate 0.5 m long by 0.29 m wide was removed with a D-

TABLE 1. Water chemistry and distribution of gastropod species in visually searched lakes, scored 1-10 for the number of sites in which they were found, or B if found in benthic samples only. Lakes are ranked by pH values (summer 1985). Ca^{2+} (mg/L) and alkalinity (µeq/L) values are averages of fall 1984 and 1986 values. * indicates a fishless lake.

Lake	247*	299*	920*	005	905	409	333	016*	199*	527	197	410	922*	530*	404
Latitude	46° 54’	46° 58’	46° 51’	46° 48’	46° 51’	46° 57’	46° 55’	46° 53’	46° 52’	46° 59’	46° 51’	46° 58’	46° 57’	46° 59’	46° 56’
Longitude	80° 50’	80° 52’	80° 49’	80° 51’	80° 52’	80° 35’	80° 46’	80° 49’	80° 47’	80° 39’	80° 47’	80° 37’	80° 51’	80° 38’	80° 38’
pH	7.5	7.3	7.2	7.1	6.8	6.8	6.7	6.5	6.1	5.8	5.6	5.4	5.3	5.2	5.1
Ca^{2+}	7.0	8.9	6.2	6.8	4.8	7.8	3.9	3.5	4.1	1.9	4.2	2.9	2.9	3.0	2.2
alkalinity	389	648	210	322	100	227	143	92	69	9	0	7	0	6	0
Valvatidae															
Valvata lewisi morph *ontariensis* F. C. Baker		B													
Lymnaeidae															
Fossaria parva (Lea)		3													
Pseudosuccinea columella (Say)		1						8	2						
Bulimnea megasoma (Say)				1											
Physidae															
Physella gyrina (Say)	10	10	5		5		10	2	10						
Planorbidae															
Gyraulus deflectus (Say)		2	B	2					2						
Gyraulus parvus (Say)					7										
Promenetus exacuous (Say)	4	2		1											
Helisoma anceps (Menke)	4			1	4	3	10	6							
Planorbella campanulata (Say)				1											
Planorbella trivolvis (Say)	2	2				1									
Ancylidae															
Ferrissia sp.	7	7	7	1	9	2	3	8	B		6			4	

framed net, and sieved through 1 mm^2 screens. Macroinvertebrates, including gastropods, were removed and later identified and counted. This sampling procedure was also followed in a separate study, conducted in the same area in the summers of 1988 and 1989 (McNicol and Wayland 1992), which provided further information on pH tolerances of certain gastropod species. Between June and mid-July, ten benthic samples were collected once from eight additional lakes with pH under 5.0, 12 with pH 5.0–5.5, and 10 with pH between 5.5 and 6.0.

We found that benthic sampling did not effectively sample gastropods occurring at low densities in small oligotrophic lakes. Other studies have sampled gastropods in submerged vegetation (McKillop and Harrison 1972; McKillop 1985; Pip 1987). However, there was little submerged aquatic vegetation in our study lakes, and gastropods were often associated with woody detritus. Therefore, a more intense survey was undertaken between 20 August and 2 September, 1985. Those lakes chosen for further study were 15 of the 20 previously sampled lakes with pH>5.0. We had no realistic expectation of finding gastropods in the most highly acidic lakes. Ten 5 m sections of shoreline were randomly selected around each lake. The substrate, detritus and vegetation in the littoral zone in each sector, to a depth of 0.5 m, were visually searched by two persons until it was judged that all gastropods had been found and removed, or until 0.5 hr had passed.

The pH of surface water was determined using a portable pH meter during July 1985. In November 1984 and October 1986, surface water samples were taken for more complete chemical analysis, including pH, alkalinity, major ions, and nutrients, following procedures outlined by McNicol et al. (1987). Statistical analyses were performed using average values of fall determinations of alkalinity, total phosphorous, and calcium ion (Ca^{2+}) concentrations.

Species nomenclature follows Burch (1982). The study lakes are unnamed and are referenced here by number.

Results

Eleven species of pulmonate gastropods were found among 11 of 15 lakes sampled with the visual search technique (Table 1). A single prosobranch, *Valvata lewisi*, was the only species found solely in benthic samples from those lakes.

Using the visual search technique, 39 occurrences of species in lakes were recorded (Table 1). Benthic sampling was less effective, as only 21 occurrences of species in lakes were scored from benthic samples, of which three were not found by the visual technique. Benthic sampling commonly found *Helisoma anceps* and *Gyraulus deflectus*, but often failed to find *Physella gyrina*, a species more likely to be found by sweeping vegetation. However, neither technique adequately recorded the most widespread gastropod found in visual searches of the study lakes, a fresh-water limpet, *Ferrissia* sp.

A total of 1519 gastropods were collected by visual searches. Almost half (49%) were from lake 333, where high densities of gastropods, especially *Helisoma anceps*, made it impossible to collect all individuals in a site within the 0.5 hr sampling period. Therefore, more gastropods probably occurred in that lake than in all others combined. Lake 333 had Ca^{2+} levels lower than in most lakes with gastropods (Table 1), but had the highest total phosphorous concentrations (Figure 1).

Overall, gastropod densities were low. The average number of gastropods found in visual searches of lakes with pH>6.0, other than lake 333, was only 1.7 per metre of shoreline.

Between three and eight species of gastropods occurred in each of nine lakes with pH>6.0, and always included *Ferrissia*. It was the only gastropod occurring below pH 6.0, where it occurred in two of six lakes. Other species which characterized the gastropod fauna were the tadpole snail, *Physella gyrina*, and the ramshorn snail, *Helisoma anceps*. At least one of them occurred on each lake above pH 6.0, and together they comprised 71% of all gastropods collected by visual searches.

The number of gastropod species in visual searches increased from 3.6 per lake in five lakes between pH 6.0 and 7.0, to 5.5 per lake in four lakes with pH>7.0; but those differences were not significant (p>0.05, Mann-Whitney test). In lakes with pH>6.0, the $\log_e$-transformed number of gastropods per lake in visual searches was not significantly correlated (p>0.10) with pH (r=0.22), or the related chemical variables, Ca^{2+} concentration (r=0.45) and alkalinity (r=0.12). However, there was a significant correlation between mean total phosphorous concentrations and the $\log_e$-number of gastropods in visual searches (r=0.73, n=9, p<0.05) (Figure 1). Among lakes with pH>6.0, four lakes with fish did not differ from five without fish (Table 1), in either the number of gastropods found (t-test, $\log_e$-transformed data, t=0.44, p>0.10), or species composition.

Gastropods were not found in any benthic samples from 13 lakes with pH<5.0. In benthic samples taken in 1988-1989 from 12 lakes with pH 5.0–5.5, only *Ferrissia* was found at pH 5.5. In contrast, gastropods were found in benthic samples from six of ten lakes with pH between 5.5 and 6.0. *Amnicola limosa* was found in four of those lakes, *Gyraulus deflectus* in three, and *Ferrissia* in one. *Physella gyrina* was taken by sweep net sampling at pH 5.8.

Discussion

Intense visual searches of 15 small headwater lakes showed that gastropod distribution was limited by acidity below pH 6.0. Above pH 6.0, gastropod numbers were positively correlated with total phosphorous concentrations, which suggested a relationship to food resources.

Total phosphorous is the most important indicator of lake nutrient status and productivity, and is the most important limiting factor for the growth of algae, especially in oligotrophic lakes (Wetzel 1983). Algae and detritus were found to be the most important food items of British gastropods, and eutrophic detritus was better for growth than oligotrophic detritus (Reavell 1980). In general, gastropods have been observed to be more abundant and to have greater species richness in eutrophic compared to oligotrophic lakes (Russell-Hunter 1978). However, studies that have related gastropod abundance and diversity to water chemistry have not measured total phosphorous (Macan 1950; Aho 1966, 1978; Williams 1970; Dussart 1976; Økland 1983). North American gastropod studies (McKillop and Harrison 1972; McKillop 1985; Pip 1987; Jokinen 1991) have compared among study sites on and off the Precambrian shield and along a gradient in Ca^{2+} concentrations and alkalinity, and probably productivity, but have also not measured total phosphorous.

Økland (1983) sampled gastropods in about 1000 Norwegian lakes, including many that had become acidified, and found the greatest decline in abundance and species richness occurred below pH 6.0. In the Sudbury area and the Adirondack Mountains (Jokinen 1991), the minimum pH at which many species can be found is between pH 5.5 and 6.0. In south-central Ontario, recruitment failure of *Amnicola limosa* occurred when lake pH fell below 5.8 (Shaw and Mackie 1989).

Low pH is associated with low calcium ion concentrations, and Økland (1983) believed that either could explain the absence of gastropods. Aho (1966, 1978) and Økland (1983) found significant correlations between the diversity and abundance of gastropods, and Ca^{2+} concentration; but only among lakes with Ca^{2+} concentrations < 7.0 mg/l, which reflects the inclusion of acidic and very calcium-poor lakes in their data. However, Shaw and Mackie (1990) found that the minimum Ca^{2+} concentration for the development of *Amnicola limosa* was < 1.1 mg/l, which is lower than in most acidified lakes. Several common Ontario species have been recorded at Ca^{2+} concentrations between 2.0 and 3.0 mg/l (Rooke and Mackie 1984). In the Sudbury area, gastropods were often absent at such concentrations, and their absence was solely explained by low pH.

Macan (1950) presented statistically unanalysed data on gastropod abundances in water bodies that were similar in size to our Wanapitei study lakes, and also covered a similar range of Ca^{2+} concentration and alkalinity. Regrettably, Macan (1950) does not provide pH values. Gastropods were present in all water bodies, except those where Ca^{2+} concentrations was <3.0 mg/l. A correlation analysis of Macan's data showed no evidence of relationships between the $\log_e$-number of gastropods caught per hour in 1946 and the mean Ca^{2+} concentration ($r=0.05$) or mean alkalinity ($r=0.17$) of each water body where gastropods occurred ($n=33$, $p>0.10$). In contrast, McKillop and Harrison (1972), Dussart (1976), and McKillop (1985) covered a greater range of Ca^{2+} concentrations, including non-acidic soft waters and hard waters with Ca^{2+} concentrations > 40.0 mg/l, and found significant relationships between Ca^{2+} concentrations and gastropod species diversity or abundance. Dillon and Benfield (1982) found that the abundance of pulmonate snails, including *Helisoma anceps* and *Physella* spp., in streams was positively correlated with alkalinity, which they suggested was positively related to food resources for pulmonates.

The distributions of gastropod species suggest that they tolerate a wide range of chemical conditions (Aho et al. 1981). In Ontario, McKillop and Harrison (1972) found 14 species among nine hard-water stations ($Ca^{2+} >40$ mg/l), but twelve of those also occurred among seven soft-water stations (Ca^{2+} <5 mg/l). Similarly, in Manitoba, McKillop (1985) found 16 species among 11 hard-water stations ($Ca^{2+} >40$ mg/l), and 13 of those also occurred among six soft-water stations ($Ca^{2+} <10$ mg/l). Few species are likely to be found uniquely associated with hard waters.

Bendell and McNicol (1991) also sampled leeches in the Sudbury area, including lakes visually searched for gastropods. Leeches and gastropods shared a similar distribution and abundance with respect to lake pH. All lakes above critical pH values supported several species of both groups, which disappeared below critical values over a narrow range of pH. In both groups, the most widespread species in non-acidic lakes were the species that occurred at the lowest pH, and there was no evidence of a relationship between abundance and lake pH, where pH was above critical values.

Our data suggest that the response of gastropods and leeches to acidification is poorly described by a dose-response model which assumes proportional declines in populations for each decline in pH. The figures of Eilers et al. (1984) [reproduced in Mills and Schindler 1986] suggest a steady decline in species numbers over a broad range of pH. However, a better model is provided by assuming minimal pH thresholds above which populations do not respond to changes in pH, but below which they disappear over a narrow range of pH. Models predicting declines in species richness from declines in pH were developed by Schindler et al. (1989) and

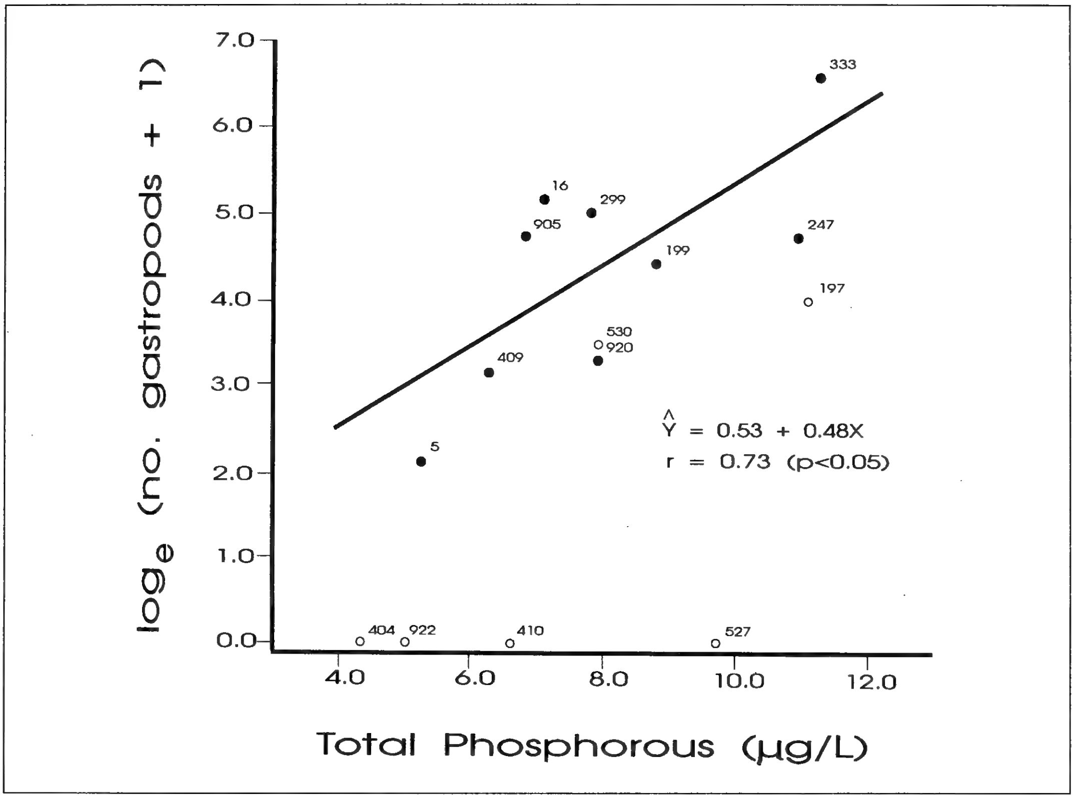

Figure 1. Log_e-transformed number of gastropods found in visual searches versus mean total phosphorous concentrations (µg/l). The linear regression is calculated for lakes with $pH > 6.0$, indicated by solid circles. Lakes with $pH < 6.0$ are represented by open circles, and had no gastropods or only *Ferrissia*. Numbers beside points refer to lake numbers.

Minns et al. (1990), based on Eilers et al.'s (1984) data, but they may overestimate the loss of species as pH declines from 7.0 to 6.0, and underestimate losses due to declines from pH 6.0 to 5.0.

Although gastropods are among the most acid-sensitive organisms, they are affected at pH values similar to those that affect certain fish species (Mills and Schindler 1986; Matuszek et al. 1990). The evidence presented here suggests that gastropods of small headwater lakes will not respond directly to changes in alkalinity or Ca^{2+} concentrations, and that monitoring gastropods will not provide an early warning of acidification above pH 6.0, and before other sensitive organisms are affected. Gastropod densities are low in most Precambrian shield lakes. Species are often missed in sampling programs, and may be more difficult to monitor than other acid-sensitive groups. Our data suggest that low densities of gastropods in small non-acidic oligotrophic lakes are better accounted for by low nutrients and food resources than by low alkalinity or Ca^{2+} concentrations.

Acknowledgments

We wish to thank Kim Fillman for field assistance. Jane Topping of the Canadian Museum of Nature helped in the identification of specimens. Analysis of water samples was done at the Great Lakes Forestry Centre LRTAP laboratory in Sault Ste. Marie. Helpful comments were provided by an anonymous reviewer. This study was funded by the Long Range Transport of Airborne Pollutants (LRTAP) program of Environment Canada.

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Received 20 May 1992
Accepted 4 January 1994

Population Composition and Perching Habitat of Wintering Bald Eagles, *Haliaeetus leucocephalus*, in Northcentral Michigan

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Bowerman, William W., IV, Teryl G. Grubb, Allen J. Bath, John P. Giesy, Jr., Gary A. Dawson, and R. Kenneth Ennis. 1993. Population composition and perching habitat of wintering Bald Eagles, *Haliaeetus leucocephalus,* in northcentral Michigan. Canadian Field-Naturalist 107(3): 273–278.

From 15 November 1989 to 15 February 1990, biweekly aerial surveys of the Au Sable, Manistee, and Muskegon rivers, Michigan, detected 54 adult and 33 immature Bald Eagles (*Haliaeetus leucocephalus*) with a high of 19 between 1-15 January. Adults peaked prior to immatures and appeared to leave earlier. Thirteen deciduous and four coniferous species were identifed among 55 perch trees. Adults perched nearly equally in coniferous (43%) and deciduous trees (57%), whereas immatures used mostly deciduous perches (85%, P = 0.034). Coniferous perches were taller (23.2 m vs. 18.9 m, P = 0.029), in denser stands (577.6 stems/ha vs. 408.9, P = 0.017) and on terrain that had a greater mean slope (40.6% vs. 19.9%, P = 0.008) than deciduous trees. Perch DBH was greater than both nearest-tallest DBH (P = 0.003) and surrounding stand DBH (P < 0.001). Distance from perch trees to potential human disturbance varied with tree type, between structures and roadways, and was greatest on the more densely populated Muskegon River.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, winter, habitat, perching, population, Michigan.

Bald Eagle, *Haliaeetus leucocephalus*, numbers on wintering grounds are governed by food availability, habitat suitability, and proximity of human disturbance (Vian and Bliese 1974; Stalmaster and Newman 1978). Although wintering eagles have been recorded along the Au Sable, Manistee, and Muskegon rivers in the northern lower peninsula of Michigan (National Wildlife Federation 1984, 1988; Figure 1), details of population size and factors influencing it were unknown. The purpose of this study was to determine the numbers and age composition of Bald Eagles wintering on these rivers and describe the associated perching habitat.

Study Area

Within the study area defined by the three rivers (Figure 1), terrain was flat to rolling with occasional hills and an elevational range of 200 to 400 m. Vegetation was predominantly continuous mixed-forest, consisting of White (*Pinus strobus*), Red (*P. resinosa*), and Jack Pine (*P. banksiana*), aspens (*Populus grandidentata* and *P. tremuloides*), oaks (*Quercus rubra* and *Q. nigra*), maples (*Acer rubrum* and *A. saccharum*), and White Birch (*Betula papyrifera*). The area was rural and sparsely populated but supported year-round recreational activity.

Methods

A pilot and two observers conducted surveys every two weeks from 15 November 1989 through 15 February 1990, with a Cessna 172* fixed-wing aircraft flown 60-150 m above ground level at 130-190 km/hr. Each river was flown once during a survey period, and the east-west direction of travel was reversed every survey. The three rivers were flown on as nearly consecutive days as weather and scheduling would permit. We flew directly over the rivers to permit simultaneous viewing of both shorelines, and just offshore along the perimeter of the 11 included hydroelectric reservoirs. During aerial surveys, eagles were classified as adults (≥ 4 years old) or immatures (< 4 years) by plumage characteristics (McCollough 1989). Eagle perch locations were plotted on United States Geological Service 7.5 minute quadrangle maps. Each perch area was also photographed to facilitate relocation on the ground.

Within three weeks of the flights we measured perch trees to determine species, crown class (dominance or codominance in relation to surrounding trees), diameter at breast height (DBH, cm), and height (m). Tree height was measured with clinometer or altimeter. Percent slope of the perch substrate was also determined with clinometer when slope exceeded

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*Use of trade names does not imply endorsement by the USDA Forest Service or Michigan State University to the exclusion of other potentially suitable products or services.

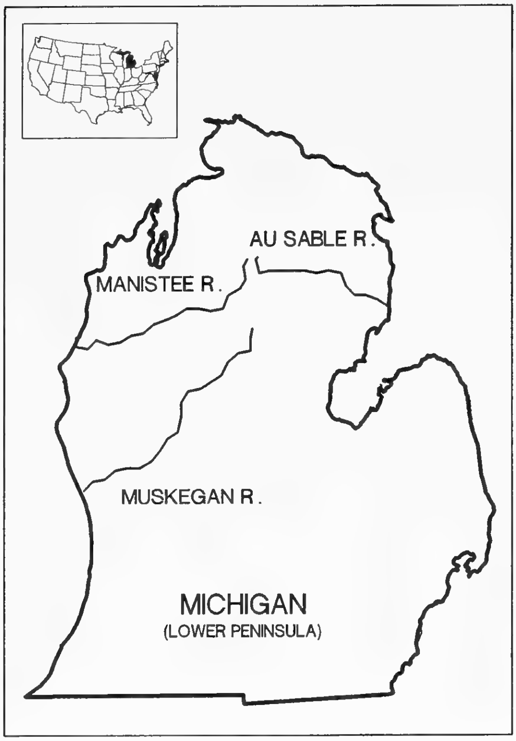

FIGURE 1. Location of the Au Sable, Manistee, and Muskegon rivers in the northern lower peninsula of Michigan.

10%. DBH was measured with a standard DBH tape. Distances from perches to potential disturbance by humans, defined as roadways (primary roads, secondary roads, snowmobile trails) or structures (buildings, power plants, transmission lines) were measured with a 33 m tape or calculated from maps.

We characterized perch surroundings through measurements of two additional habitat features. We recorded DBH and height of the nearest-tallest tree to compare perch trees with potential alternate perches (Chester et al. 1990). To characterize the perch stand, a 132-m^2 area was centered on each perch tree with the point-centered quarter method (Cottam and Curtis 1956) and the DBH's of trees $\geqslant$ 10.16 cm within this area were recorded for calculating mean DBH and stand density.

Statistical analyses were performed using SPSS/PC+ Version 4.0 (Norusis/SPSS Inc. 1990a-b). We tested quantitative data (DBHs, heights, distances, and densities) for normality with the Kolmogorov-Smirnov one sample test, and then used either parametric t-test's and ANOVA, or nonparametric binomial, Mann-Whitney *U* and Kruskall-Wallis' tests for further analyses, as appropriate. We also used crosstabulation summaries with Chi-square tests among variables to evaluate patterns or nonrandom distributions.

Results

Numbers and Age Composition

Between 15 November and 15 February we recorded 87 Bald Eagles (54 adults and 33 immatures, Figure 2): 28 on the Au Sable River (19,9), 31 on the Manistee (21,10), and 28 on the Muskegon (14,14). The overall ratio of adults to immatures was 1.6:1, but varied among rivers with the two northern rivers, Au Sable and Manistee, being 2.1:1 and the Muskegon, 1:1. Adults equalled or outnumbered immatures in all but the final survey period. The greatest number of eagles (19) was observed between 1-15 January. Adult peaks (11) were during 1-15 December and 16-31 January and preceded the peaks for immatures (9) during 1-15 January and 1-15 February. On the Au Sable River, adults were present throughout the study period, while immatures were absent during two survey periods. Adults outnumbered immatures on the Manistee River on all but the last survey; whereas on the Muskegon, immatures equalled or outnumbered adults on all but the second survey.

Perching Habitat

In measuring the 55 perch trees recorded during our surveys (Table 1), we identified 13 deciduous and four coniferous species (Table 2). Deciduous trees were used twice as frequently as coniferous trees (P = 0.015). However, coniferous perch trees were taller (23.2 m vs. 18.9 m, P = 0.029), in denser stands (577.6 stems/ha vs. 408.9, P = 0.017) and on terrain that had a greater mean slope (40.6% vs. 19.9%, P = 0.008) than deciduous trees. Coniferous perches were also less variable in height with a coefficient of variation (s.d./mean X 100%) of 27.4% versus 35.7%. The proportion of coniferous and deciduous perches was similar between crown classes: dominant (37% and 63% respectively); codominant (31% and 69%, P = 0.639). Although the frequencies of coniferous perches and dominant crowns were nearly identical, only about a third of the conifers were dominant.

Adults perched nearly equally in coniferous (43%) and deciduous trees (57%), whereas immatures used mostly deciduous perches (85%, P = 0.034). We found no difference in crown class (P = 0.958) or stand density (P = 0.860) among perches used by adult and immature eagles. However, adult perch trees were taller (21.8 m vs. 17.7 m, P = 0.036) and on greater slopes (31.6% vs. 17.9%, P = 0.046) than immatures. There was no overall age class preference for perch species (P = 0.467), but of the 14 observations of *Pinus strobus* only one was of an immature.

The distribution of perch use among recorded species was not random (P < 0.001). The two most

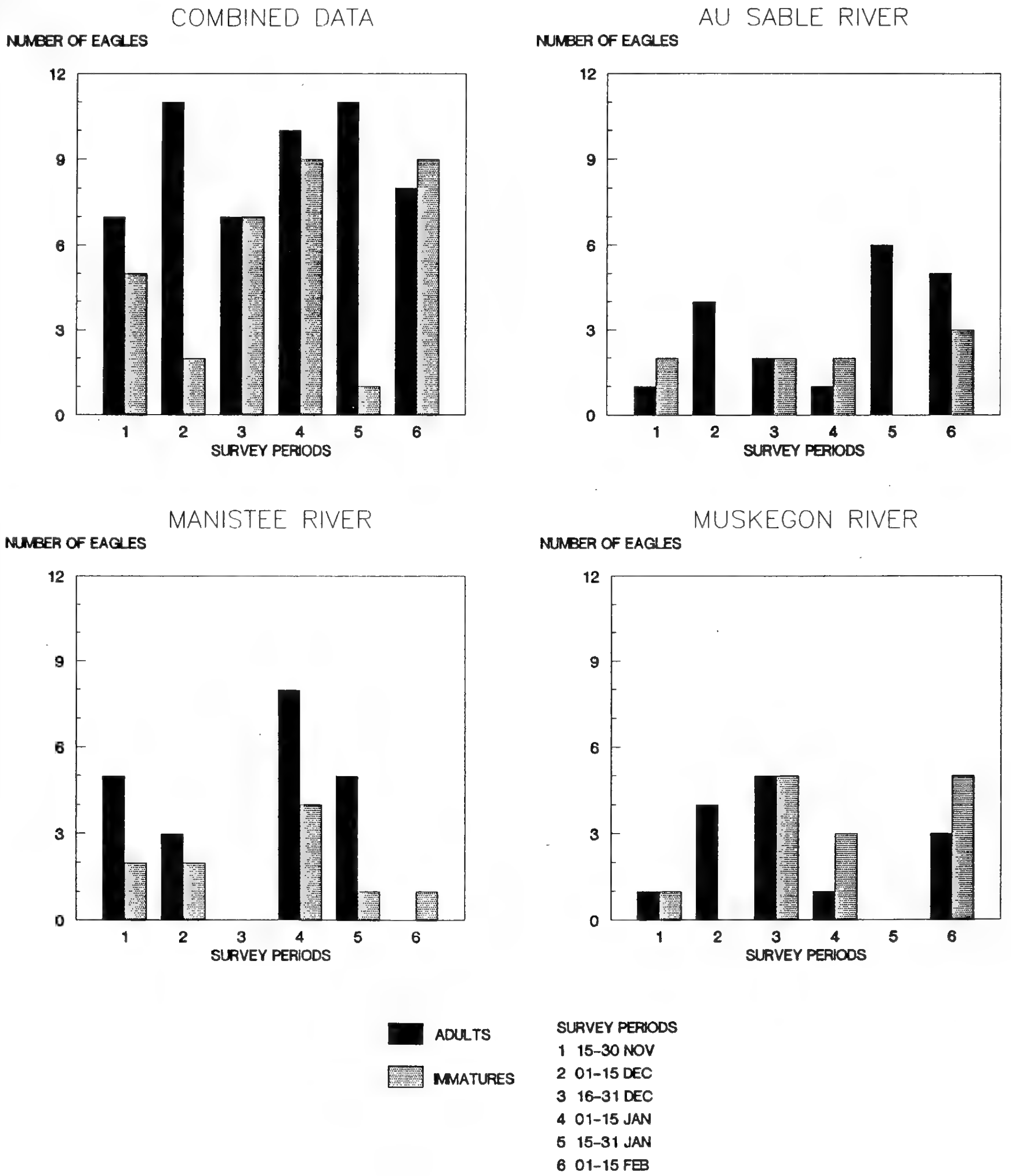

Figure 2. Summary of Bald Eagle numbers and age composition along the Au Sable, Manistee, and Muskegon rivers in northern Michigan, 15 November 1989 to 15 February 1990.

frequently used species were *Pinus strobus* and *Acer rubrum* (Table 2), which collectively were taller ($P = 0.043$) and had greater DBH ($P = 0.021$) than the remaining perch species; crown class ($P = 0.730$) and stand density did not vary ($P = 0.077$). Heights of the nearest-tallest trees, which averaged 5.5 m (s.d. = 3.5) from perches, were comparable to perch tree heights ($P = 0.815$). However, perch DBH was greater than both nearest-tallest DBH ($P = 0.003$) and surrounding stand DBH ($P < 0.001$). Nearest-tallest DBH was also greater than surrounding stand DBH ($P < 0.001$). Only tree type and crown class varied among rivers. The percent of deciduous perch tree use

TABLE 1. Habitat features of perch trees used by wintering Bald Eagles along the Au Sable, Manistee, and Muskegon rivers in northcentral Michigan, 15 November 1989 to 15 February 1990. (Data are presented as number of trees or mean measurements with standard deviations in parentheses.)

Habitat Feature	Au Sable River	Manistee River	Muskegon River	Totals
Total Perch Trees	14	22	19	55
Eagle Use				
Adults only	10	13	11	34
Immatures only	4	9	6	19
Both adults and immatures	0	0	2	2
General Features				
Tree species (number)	8	9	8	17
Coniferous trees	8	8	2	18
Deciduous trees	6	14	17	37
Dominant crowns	8	8	3	19
Codominant crowns	6	14	16	36
Perch Tree Measures				
DBH (cm)	48.8 (20.2)	39.2 (13.1)	54.1 (29.3)	46.8 (22.2)
Height (m)	21.4 (7.9)	18.4 (5.8)	21.8 (7.0)	20.3 (6.9)
Nearest-Tallest Tree				
DBH (cm)	36.1 (10.2)	33.4 (8.8)	43.7 (21.9)	37.6 (15.4)
Height (m)	18.2 (4.9)	19.9 (4.1)	22.9 (8.1)	20.5 (6.1)
Stand				
DBH (cm)	25.1 (7.2)	22.1 (7.0)	29.5 (11.7)	25.4 (9.4)
Density (stems/ha)	527.6 (310.2)	460.4 (269.4)	421.6 (224.2)	464.1 (264.2)
% Slope				
Mean	45	56	38	50
S.D.	(9.6)	(16.7)	(18.7)	(16.7)
N > 10%	9	19	4	32

increased across the Au Sable (42.9), Manistee (63.6), and Muskegon rivers (89.5, $P = 0.013$). The percent of codominant perch trees followed a similar pattern (42.9, 63.6, and 84.2, respectively; $P = 0.052$).

Distance from perch trees to potential human disturbance varied between structures and roadways, and with tree type. Deciduous perch trees were farther from human activity than conifers (655.0 m vs. 353.5 m, $P = 0.042$). Perches in the vicinity of structures were farther away (752.9 m vs. 455.2 m, $P = 0.026$) and in taller trees (22.4 m vs. 19.5 m, $P = 0.029$) than perches near roadways. Perches on the Muskegon River, a river more densely populated by humans, were almost twice as far from potential human disturbances than those along the Manistee (912.7 vs. 508.3 m, $P < 0.001$), and almost seven times farther than those on the sparsely populated Au Sable (132.4 m, $P < 0.001$). Roadways were the predominant human activity along the Au Sable and Manistee rivers, while along the Muskegon structures were the most frequent activity ($P < 0.001$).

Discussion

Numbers and Age Composition

The high proportion of adults, along with the timing of changes in population composition, are consistent with other studies in the Midwest which indicate immatures migrate earlier and travel further south than adults (Southern 1963, 1964; Sprunt and Ligas 1966). At wintering areas along the Mississippi River adults peak between mid-December and early-February, prior to leaving by mid-February; immatures typically peak after the adults and migrate later (Southern 1964; Vian and Bliese 1974). Immatures also exploit readily available food and often rely on different food sources than adults (Servheen 1975; Stalmaster and Newman 1978; Griffin and Baskett 1985). This would explain the greater proportion of immatures on the Muskegon River where eagles feed on mer-

TABLE 2. Perch tree species used by wintering Bald Eagles along the Au Sable, Manistee, and Muskegon rivers in north-central Michigan, 15 November 1989 to 15 February 1990. (Data are presented as number of trees or mean measurements with standard deviations in parentheses.)

Species	DBH (cm)	Height (m)	N	AuS R.	Man R.	Mus R.
Pinus strobus	50.6	25.3				
	(13.7)	(5.8)	14	5	7	2
Acer rubrum	52.5	18.0				
	(23.7)	(6.6)	8	0	1	7
Quercus alba	31.7	15.8				
	(9.9)	(6.2)	5	0	3	2
Acer saccharinum	54.8	23.2				
	(21.0)	(1.8)	4	0	0	4
Betula papyrifera	35.5	12.3				
	(8.0)	(2.6)	4	1	3	0
Populus spp.	30.2	17.3				
	(13.2)	(6.0)	4	0	4	0
Quercus rubra	46.5	18.2				
	(3.3)	(1.7)	3	2	1	0
Acer saccharum	27.2	16.8				
	(17.1)	(0.5)	2	1	1	0
Pinus resinosa	41.5	17.0				
	(0.0)	(0.9)	2	2	0	0
Populus deltoides	39.7	17.7				
	(0.1)	(3.0)	2	1	0	1
Acer negundo	50.8	19.9	1	0	0	1
Fraxinus spp.	34.6	22.6	1	0	0	1
Pinus banksiana	32.0	15.2	1	1	0	0
Robinia pseudoacacia	147.0	40.0	1	0	0	1
Tilia americana	49.0	25.2	1	0	1	0
Tsuga canadensis	37.8	15.5	1	0	1	0
Ulmus americana	99.1	32.9	1	1	0	0

gansers, *Mergus spp.*, Gizzard Shad, *Dorosoma cepedianum*, and Herring Gulls, *Larus argentatus*, at Muskegon Lake and on winter concentrations of waterfowl at the Muskegon State Game Area.

Perching Habitat

The patterns of habitat use we recorded may be as much a function of habitat availability as an indication of wintering Bald Eagle perch selection. The scope of this study did not permit an analysis of random sites for a statistical comparison of selected versus available habitat. However, our data are sufficient to characterize typical winter perching habitat along the Au Sable, Manistee, and Muskegon rivers, and in addition, to at least partially differentiate perch characteristics among age classes and the three rivers. Our results are consistent with the well documented tendency for Bald Eagles throughout their range to seek the highest available perches (Stalmaster and Newman 1979; Gerrard et al. 1980, Steenhof et al. 1980). Chester et al. (1990) also observed a higher proportion of daytime winter perching in leafless hardwoods than in pines and concurred with Stalmaster and Gessaman (1984) that this may be related to less obstructed flight paths, greater range of vision, and possible thermoregulatory advantage from solar radiation. The differences in distance to disturbance among rivers appeared inversely related to population density but may also have been influenced by the type of disturbance (structure vs. roadway) with its associated level of human activity (Grubb and King 1991).

Acknowledgments

C. Burns, P. Huber, and C. Schumacher assisted with aerial surveys. Ground surveys and habitat measurements were performed by S. Hogle, M. Keck, D. Pinzino, and P. Stefanek. P. Ungren, J. Trevoka; and T. Ulmer provided office and logistical support. This research was jointly funded by Consumers Power Company (Work Project Number 412E322) Hydroelectric Project Environmental Studies: Bald Eagle Studies, and the Huron-Manistee National Forest.

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Received 9 September 1992
Accepted 5 November 1993

Artificial Spawning and Rearing of the Copper Redhorse, *Moxostoma hubbsi* (Teleostei: Catostomidae)

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The Copper Redhorse, *Moxostoma hubbsi*, a threatened fish species endemic to southwestern Quebec, has been reproduced artificially. Intramuscular injection of Carp pituitary extract (CPE), dry fertilization, incubation at 20°C and rearing with a dry diet yielded good results. Small Copper Redhorse ate any mollusks that were offered to them including the Zebra Mussel (*Dreissena polymorpha*). Consequently, fish raised under artificial conditions could adapt rapidly if stocked in a natural environment.

Nous avons reproduit artificiellement le Suceur cuivré, (*Moxostoma hubbsi*), un poisson endémique au sud-ouest du Québec et actuellement désigné espèce menacée. La méthodologie suivante a donné de bons résultats: injection intramusculaire d'extrait d'hypophyse de Carpe (EHC), fécondation sèche, incubation à 20°C et alimentation sèche. Les jeunes suceurs obtenus ont rapidement accepté les différents mollusques qui leurs étaient offerts, incluant la Moule zébrée (*Dreissena polymorpha*). Cette adaptation rapide permet de croire au succès éventuel d'un programme d'ensemencement.

Key Words: Copper Redhorse, Suceur cuivré, *Moxostoma hubbsi*, reproduction, sucker, Catostomidae.

The Copper Redhorse (*Moxostoma hubbsi*) is endemic to southwestern Quebec where it occurs in some main tributaries of the St. Lawrence River near Montréal. Since its discovery and description by Legendre (1942), only one major study concerning its biology has been conducted (Mongeau et al. 1992). This work underscored the unique character of this species. Compared to other sympatric Redhorses, the Copper Redhorse has a long life span, a high growth rate and fecundity, and is a particularly late spawner. Furthermore, the Copper Redhorse feeds almost exclusively on molluscs (Mongeau et al. 1992); this alimentary behaviour is associated with its highly specialized pharyngeal apparatus capable of crushing bivalve shells (Eastman 1977). As pointed out by archeological research and past surveys, the Copper Redhorse was once more abundant in Quebec waters (Mongeau et al. 1986). At present, the only detectable population occurs in the Richelieu River. Due to its rarity, its restricted range, and the general degradation of its habitat, the Copper Redhorse is classified as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Mongeau et al. 1988). Further decline of redhorse populations may be prevented by the identification and protection of spawning sites and by the development of successful culture and stocking techniques.

This paper presents the methodology used for induction of ovulation, fertilization and rearing of Copper Redhorse larvae and juveniles. Eggs, larvae and juveniles will be described in a separate paper.

Methods

In June 1990, adult Copper Redhorse were captured by electrofishing in the Richelieu River downstream from the St-Ours lock where they are believed to spawn. On June 20, three females and two males were held in a floating cage (2 m long X 1 m large X 1 m deep) in order to minimize the stress imposed to broodfish already in very poor physiological condition when captured. Most fish caught had numerous external injuries and displayed a panic-shock behaviour characterized by body stiffening, loss of equilibrium and breathing failure at the time of capture.

At 12-hour intervals, each fish received three doses of approximately 3 mg/kg of Carp pituitary extract (CPE) dissolved in distilled water (maximum quantity of fluid injected in one fish: <1 ml). The hormone was administered underwater by an intramuscular injection anterior to the dorsal fin using a 3.0 ml syringe with a 38 mm 23-gauge needle. A scale was loosened in the area of injection in order to facilitate the procedure. During the experiment, the water temperature remained at approximately 19°C.

A second attempt to induce spawning was made, on 28 June, when the temperature had reached 23°C. Broodfish were still numerous on the spawning site and no males or females were running-ripe. Four females and four males were captured and transported in oxygenated water to the laboratory of the Ministère du Loisir, de la Chasse et de la Pêche du Québec and placed in a 500-litre tank. They were exposed to a natural day-light cycle and maintained in 18.5°C running water. The eight fish were injected with higher doses of CPE (Table 1) following the methodology described above.

Eggs were expelled by slight abdominal pressure and mixed for one minute with milt from two males, in a dry stainless steel bowl. The mixture was then covered with water and gently stirred for five minutes. Finally, the eggs were thoroughly rinsed and allowed to water-harden for one hour. Water from the incubator was used for the fertilization and rinsing of the eggs. The addition of de-adhesion material was not necessary. The eggs were incubated at 20°C in floating baskets (screening medium: Nitex 500 µm) placed along an artificial stream of 600-litre capacity supplied with dechlorinated water at a rate of 2.5 l/min. Photoperiod was 14 hours L/10 hours D. After yolk resorption, the larvae were transferred to recirculating water aquaria. Embryos, yolk-sac larvae, feeding larvae and juveniles were sampled periodically and preserved for the description of development. Larvae were offered both live and artificial diets.

Results

We observed that all the injected redhorses changed from a dark color pattern to a bright copper one approximately eight minutes after injection of CPE. All injected males responded positively by milt expulsion when gently pressed on the abdomen. The milt could be stripped 12 to 24 hours after the CPE injection. However ovulation was successfully induced in only one female (female #4, Table 1) in the course of the second attempt (laboratory condition). This female ovulated all her eggs 5.5 hours after a second dose of 15.2 mg/kg. Two strippings provided a total of 375 ml of water-hardened eggs. This experiment showed that Copper Redhorse's eggs are non-adhesive.

Mean egg diameter, after fertilization and water-hardening, was 2.81 mm (SE= ±0.01). Viability estimated 40 degree-days after fertilization (neurulation completed) was 70.6% and 77.3% respectively for the two strippings. A Chi^2-test indicated that viability was not significantly different between strippings. Yolk-sac larvae averaged 9.09 mm (SE= ±0.05) at hatching, which occurred between 89 and 127 degree-days after fertilization, peaking at 108 degree-days. Larvae began swimming to the surface between 12 and 16 days after fertilization; maximum swim-up was at 15 days. Yolk absorption was nearly complete at 15 days when embryos started exogenous feeding. Total length at this stage of development averaged 13.11 mm (SE= ±0.03). During embryonic development, mortality was very low. The eggs did not become infected by fungi despite the lack of antifungal treatment.

TABLE 1. Carp pituitary extract (CPE) injections into sexually mature Copper Redhorses kept under laboratory conditions.

Fish	Weight (kg)	Dose (mg/kg)	Schedule (time; date)(1)
Female #1	4.90	12.2	12:35; 30/06 18:35; 30/06
Female #2	4.04	14.8	12:50; 30/06 18:50; 30/06 00:50; 01/07
Female #3	3.80	12.6	13:10; 30/06 19:10; 30/06
Female #4	2.36	15.2	13:20; 30/06 19:20; 30/06
Male #1	3.74	6.6	13:20; 30/06
Male #2	3.94	6.3	13:50; 30/06
Male #3	3.52	7.1	19:25; 30/06
Male #4	2.88	8.6	19:40; 30/06

(1) Time and date of each CPE injection.

Larvae were fed *Artemia* nauplii or ground trout chow until they attained a total length of 30 mm. Later, the fish were given a diet of sinking pellets (Tetra TabiMin and Hikari Lionhead) occasionally supplemented with chopped tubifex worms. Under these laboratory conditions, growth rate remained constant (Figure 1). On 19 January 1991 (196 days after hatching), average total length was 50.8 mm (SE= ±1.4). On 28 April 1991, 41 juveniles (Total length: 79.3 mm (SE= ±1.0)) were transferred into a tank containing gastropods of different size. Within one hour, all molluscs less than 4 mm were eaten by the young Copper Redhorses. Dissection

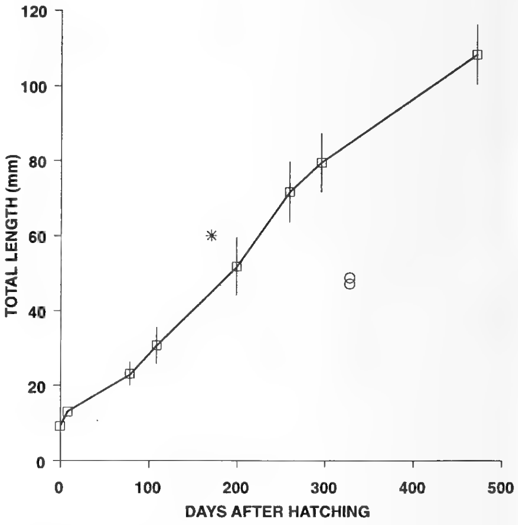

FIGURE 1. Growth of young Copper Redhorses reared under laboratory conditions. Vertical lines represent standard deviation. The circles are the length of juveniles captured on 31 May 1965 (Jenkins 1970). The star indicates the estimated length of the fish at the formation of the first annulus (January first) (Mongeau et al. 1992).

confirmed that molariform teeth were already well developed on the pharyngeal arch. On 22 October 1991, the fish had an average length of 108.4 mm (SE= ±2.1) and ate the few small (less than 8 mm) Zebra Mussels (*Dreissena polymorpha*) that were offered to them. These fish had a mouth width of 6.66 mm (SE= ±0.20).

Discussion

This experiment was not designed to evaluate the best method to induce spawning. However, since all six males reacted positively, CPE is surely suitable for Copper Redhorse. Although CPE enhanced ovulation in only one of seven females injected, we think that low success with females is not linked to the type of hormone used. The female that reacted positively was the smallest and appeared in better health as indicated by lack of lesions and brighter color. In a study on the effect of bleached mill effluent on the pituitary-gonadal axis, Van Der Kraak et al. (1992) compared the responsiveness of White Sucker (*Catostomus commersoni*) to a superactive GnRH analog. GnRH failed to induce ovulation in all contaminated females while it was possible to collect roe from all the reference females, and all males regardless of the site of capture. A high concentration of heavy metals has been identified as a possible cause of egg retention in White Sucker (McFarlane and Franzin 1978); 50% of the female population resorbed their eggs after the spawning season in a contaminated site. Recent surveys in the Richelieu River showed a high degree of contamination by heavy metals and PCBs in various species of fish (Goulet and Laliberté 1982a, 1982b; Paul and Laliberté 1989). During our field work, no spontaneous passage of reproductive products from the urogenital pore was observed in the more than 40 Copper Redhorses manipulated. This observation must be emphasized since our field work overlapped the entire spawning period. It is possible, therefore, that the responsiveness of fish to CPE in the present study may have been decreased by environmental contaminants.

Dry sinking pellets supplemented by occasional live food apparently yielded good growth in our juvenile Copper Redhorses. Jenkins (1970) reports two young specimens captured in the Richelieu River on 31 May 1965 (CU 52916) that measured 47.2 mm and 48.9 mm in total length (38.1 mm and 39.5 mm standard length). Using back calculation on scales, Mongeau et al. (1992) estimated a total length of 60 mm at the formation of the first annulus. Furthermore, specimens reared with such an artificial diet would feed on molluscs when such a prey was offered. The expression of this instinctive behavior is of prime importance for an eventual propagation program. We presume from this observation that fish raised under artificial conditions would adapt rapidly if stocked in a natural environment, thus increasing their chances of survival.

This study contributes a further description of the development of the species and has permitted the identification of spawning activity in the Richelieu River (Chambly Basin; La Haye et al. 1992; Gendron and Branchaud 1991). Unfortunately, all the observations reported by La Haye et al. (1992) and our findings reinforce the hypothesis that reproduction in this species is compromised. In spite of intensive sampling, La Haye et al. (1992) found less than 100 eggs in the Chambly Basin spawning ground. Now, major effort must be placed on the establishment of a propagation plan to help restore the Copper Redhorse.

Acknowledgments

We thank Pierre Dumont, of the Ministère du Loisir, de la Chasse et de la Pêche du Québec, who initiated this research; his colleagues Jean Leclerc, Yves Chagnon and Gilles Roy who participated in field and laboratory work; Philip Spear, Réjean Fortin and Alice Hontela of the Université du Québec à Montréal who have reviewed this manuscript; and Perry Anderson of Concordia University who allowed us to conduct this research in his laboratory. We are also grateful to the staff of St-Ours lock for their collaboration. This study received the financial support of the Ministère du Loisir, de la Chasse et de la Pêche du Québec.

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Received 16 November 1992
Accepted 19 October 1993

An Arctic-Alpine Flora at Low Elevation in Marble Canyon, Kootenay National Park, British Columbia

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A total of 169 vascular plant species reported for Marble Canyon in Kootenay National Park, British Columbia. The canyon is situated in the lower subalpine zone at 1490 m above sea level and at least 800 m below treeline, yet it contains an unusually rich assemblage of alpine plants. It is suggested that the abundance of alpine species at this low altitude is made possible by the cold microclimate produced by the glacially-fed stream flowing through this deep and narrow canyon.

Key Words: Alpine, flora, canyon, Kootenay National Park, British Columbia.

The vascular flora of the four National Parks in the Rocky Mountains of western Canada was thoroughly documented in a series of studies during the early 1980s. Vascular plant checklists compiled during these studies give a total of 844 and 749 taxa for Banff and Jasper National Parks respectively (Holland and Coen 1982), 754 taxa for Yoho National Park (Kuchar 1978), and 677 taxa for Kootenay National Park (Achuff et al. 1984). These studies provided an ecological land classification for each park but did not specifically focus on unusual or localized habitats with a small areal extent. The present study reports on the flora of such an unusual habitat, located in the cold microclimate surrounding Marble Canyon in Kootenay National Park, British Columbia. The primary objective was to assess the uniqueness of the canyon's flora in terms of its concentration of arctic-alpine species at a relatively low altitude in the region.

Site Description

Marble Canyon (Figures 1, 2) is located next to the Banff-Windermere Parkway at 51°11'N, 116°08'W and an altitude of 1490 m. The canyon is near the lower altitudinal limit of the lower subalpine zone (Achuff et al. 1984) and the adjacent forest is dominated by Engelmann Spruce (*Picea engelmannii*), Subalpine Fir (*Abies lasiocarpa*), and Lodgepole Pine (*Pinus contorta*). Mountains in the area reach an altitude of up to 3175 m and the alpine zone (vegetation above treeline) begins at between 2200 and 2400 m.

The canyon extends upstream from the parkway about 500 m to along Tokumm Creek and reaches a maximum depth of 36 metres below the waterfall at its northwestern end. The bedrock forming the canyon walls consists of limestone and dolomite belonging to the Cathedral Formation from the Middle Cambrian period. Marble Canyon is a major tourist attraction in the park, and there is a self-guided walking trail with seven bridges crossing the canyon. The canyon and its flora are protected under the Canadian National Parks Act.

Marble Canyon is only 6 km west of the continental divide and has a moderately heavy snowfall. Snow depth at the canyon reaches an average maximum of 124 cm in March or early April (water equivalent of 358 mm) and snow typically remains on the ground until late May or early June (British Columbia Ministry of Environment 1985). There is no weather station at Marble Canyon, but at Lake Louise, Alberta, located about 30 km north of Marble Canyon at a similar altitude of 1534 m (Figure 1), mean annual temperature is -0.4°. Mean daily maximum and minimum temperatures at Lake Louise are 21° and 3° respectively in July, and -8° and -22° in January. Mean annual precipitation is 684 mm with 418 cm of snowfall (Environment Canada 1982a, 1982b).

Methods

This study was conducted in the summers of 1981-1983, while I was employed as a seasonal park naturalist in Kootenay National Park, and collections were completed under a collection permit from the Canadian Parks Service in 1992. The species reported here occur within 20 m of Marble Canyon or along the Potholes Trail, which extends ca. 300 m downstream from the canyon below the junction of Tokumm Creek and the Vermilion River (Figure 1). The size and number of collections was limited due to the small number of individuals present for many species, and in some cases, plants were photographed, rather than collected. Plant specimens are housed in the Kootenay National Park herbarium at Radium Hot Springs, British Columbia. Except where otherwise noted, nomenclature follows Moss

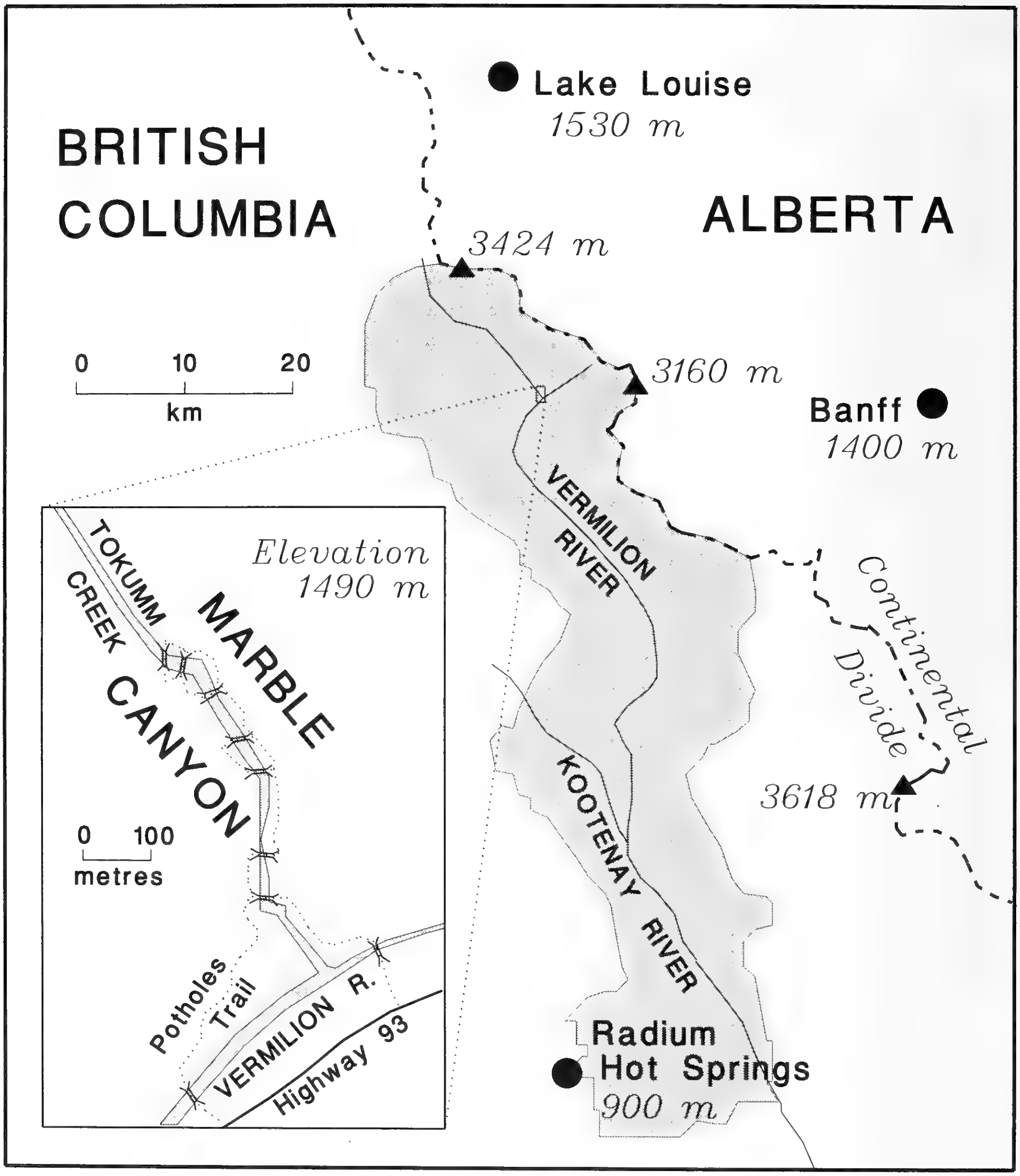

FIGURE 1. Map of the study area, showing Marble Canyon (inset) and Kootenay National Park (shaded area). The position of the Potholes Trail (inset) is approximate.

(1983). Common names are given according to Moss (1983) where possible; otherwise, common names are those listed by Alberta Energy/Forestry, Lands and Wildlife (1992).

Those species encountered at Marble Canyon which were suspected to occur elsewhere mainly at high altitudes (>2000 m) were selected for examination of their altitudinal distribution. The recorded altitude of herbarium collections was noted for specimens housed at the Northern Forestry Centre (CAFB, Johnson et al. 1985), the University of Alberta (ALTA) and the University of Calgary (UAC). This analysis was restricted to collections from the Rocky Mountains and foothills of British Columbia and Alberta, between 49°30' N and 53°00' N latitudes.

FIGURE 2. View of Marble Canyon in Kootenay National Park, British Columbia.

Results and Discussion

The flora of the Marble Canyon area includes an unusually rich assemblage of alpine plant species, considering that the canyon is situated at least 800 m below treeline. Of the 169 species of vascular plants recorded (Appendix), I considered 20 to be alpine because regionally, they otherwise occur at an average altitude of >2000 m. One additional species, *Arenaria longipedunculata* (Sandwort) has been collected very rarely in the Rocky Mountains, but was considered to be alpine based on its overall geographic distribution. These 21 alpine (including arctic-alpine) plant species are listed separately in Table 1. To my knowledge, thirteen of these species have not been collected elsewhere in the region at such a low altitude as Marble Canyon (1490 m).

The two most notable alpine plants recorded are *Draba lonchocarpa* (Whitlow-grass) and *Saussurea nuda* var. *densa* (Dwarf Saw-wort), which occur at an average altitude of >2300 m in the region (Table 1). The list also includes *Pinus albicaulis* (Whitebark Pine), which normally grows near timberline, and *Salix reticulata* ssp. *nivalis* (Snow Willow), a dwarf shrub that attains a height of <1 cm. The most abundant of the alpine plants is *Dryas octopetala* var. *hookeriana* (White Dryad), which forms extensive mats along the edge of the canyon and on ledges within the canyon. *Saxifraga oppositifolia* (Purple Saxifrage) is an arctic-alpine species that occurs as far north as Ellesmere Island. At Marble Canyon, it is restricted to growing on the vertical walls of the canyon, rather than its more usual habitat on mountain slopes and tundra. It is attached at one point, and dangles down into the canyon like a hanging garden. One of the hanging Purple Saxifrages had attained a length of >1 m in the early 1980s, but erosion has apparently caused its detachment and disappearance since then.

Ten additional species occur at Marble Canyon which are also found near or above treeline (>2400 m) but which are also common at lower altitudes (mean altitude of herbarium specimens 1800-2000 m). These include *Epilobium clavatum*, *Astragalus alpinus*, *Vaccinium scoparium*, *Anemone parviflora*, *Rhododendron albiflorum*, *Senecio lugens*, *Salix vestita*, *Saxifraga aizoides*, *Polygonum viviparum* and *Arctostaphylos rubra* (common names are given in the Appendix).

Most of the alpine plants noted were concentrated near the edge of the canyon, where microclimatic conditions are often much cooler than in the adjacent spruce-fir forest. On a sunny, summer day between 10:00 and 13:30 MDT (3 August 1981), air temperature in the forest increased from 16–24°C, while air temperature in the canyon, 10 m below the second bridge, was only 8–14°C. Similarly, on a warm (18–21°C) autumn afternoon (17 September 1982, 16:30-18:30 MDT), the temperature of the air surrounding *Cassiope tetragona* (White Mountain Heather) plants growing at the edge of the canyon

TABLE 1. Altitudinal distribution of alpine plant species found in or near Marble Canyon, based on herbarium collections from the region (Rocky Mountains and foothills between latitudes 49°30' and 53°00').

Species	Altitude (m) mean	SD	range	N*	N<1500 m**
Saussurea nuda var. *densa*	2325	172	1829-2685	36	0
Draba lonchocarpa	2313	183	1905-2931	51	0
Salix reticulata ssp. *nivalis*	2263	241	1726-2591	23	0
Arnica angustifolia	2243	237	1341-2500	31	1
Saxifraga oppositifolia	2230	263	1311-2718	43	1
Juncus drummondii	2220	171	1737-2591	32	0
Erigeron humilis	2216	200	1692-2685	46	0
Veronica alpina	2195	216	1676-2555	25	0
Phyllodoce glanduliflora	2174	211	1702-2743	42	0
Pinus albicaulis	2157	203	1720-2438	17	0
Dryas octopetala ssp. *hookeriana*	2154	305	1219-2646	50	2
Cassiope tetragona ssp. *saximontana*	2147	163	1615-2374	43	0
Phleum commutatum	2138	271	1585-2591	21	0
Poa alpina	2132	294	1280-2685	90	3
Carex atrosquama	2103	268	1067-2499	73	1
Trisetum spicatum	2089	321	1372-2743	27	1
Solidago multiradiata	2086	305	1280-2652	78	5
Gentianella propinqua	2057	347	1311-2835	54	5
Carex macloviana	2054	288	1510-2530	16	0
Cassiope mertensiana	2035	229	1524-2591	28	0
Arenaria longipedunculata	(1800)	—	—	1	0

*Number of herbarium specimens examined with altitude of collection reported.

**Number of herbarium specimens collected at altitudes <1500 m.

was only 8–12°C. Thus it appears that the alpine plants of Marble Canyon may often experience daily maximum temperatures that are 8–10°C colder than in the adjacent forest.

The cool microclimate appears to be caused by the large volume of cold (<8°C), glacially fed waters that flow through the bottom of the canyon. At the upper end of the canyon, spray from the 36-m waterfall induces additional cooling of the air because of rapid evaporation and latent heat loss. This should also dramatically reduce the peak maximum summer temperatures in the alpine plant habitats. In northern Europe, the distribution of several alpine plant species, including *Cassiope tetragona*, *Saxifraga oppositifolia*, and *Dryas octopetala* was found to be restricted to areas where peak maximum summer temperatures do not exceed 24°–27°C (Dahl 1951).

Studies on the floras of the upper Great Lakes also suggest the importance of microclimate in determining the distribution of alpine plants. Given and Soper (1981) noted 48 species of arctic-alpine plants that have a disjunct distribution along the coast of Lake Superior. Twelve of these species also occur in Marble Canyon (see Appendix), although only four of these fit my more restrictive definition of "alpine". The four species are *Poa alpina*, *Phleum commutatum* (*P. alpinum* L.), *Trisetum spicatum*, and *Arenaria longipedunculata* (*A. humifusa* Wahl.). Morton and Venn (1984) also provided a list of 20 arctic species in the flora of Manitoulin Island in Lake Huron. In both cases, most of the arctic-alpine plants are concentrated near the shoreline, where the cold Great Lake waters exert a strong cooling effect on the surrounding air during the spring and summer, and where persistant coastal fog reduces the amount of solar radiation. However, several of the arctic-alpine species, notably *Arenaria longipedunculata* (*A. humifusa*), occur in cold microsites along the floors of canyons northwest of Lake Superior. In these situations, the cold microclimate is produced by the presence of late-season ice and shading by the canyon walls (Given and Soper 1981). These features should also contibute to the cold microclimate in Marble Canyon, although vascular plants are generally absent from the deepest and narrowest sections of Marble Canyon, probably because of insufficient light.

At Marble Canyon, some of the alpine plants are probably also favoured by the moister conditions found near the falls, and in areas that are continuously moistened by seepages emanating from the canyon walls. The cool, moist limestone habitats in Marble Canyon also support the growth of ferns (Appendix), notably *Cystopteris fragilis* (Fragile Fern), and a diverse moss flora of approximately 100 species (D.H. Vitt and E.H. Hogg, personal observations).

A total of 28 alien species were recorded for Marble Canyon. These are mainly weeds of European origin which thrive in the disturbed habitats near the roadside and along the trails. Several were introduced by trail reclamation activities in the early 1980s. Four of the aliens are new records for Kootenay National Park, including *Thlaspi arvense* (Stinkweed), *Galeopsis tetrahit* (Hemp Nettle), *Lamium amplexicaule* (Dead Nettle) and *Trifolium repens* (White Clover).

This study also adds nine new native species to the flora of Kootenay National Park, giving a total of at least 690 taxa. The new records include *Cryptogramma stelleri*, *Arenaria longipedunculata*, *Arnica lonchophylla*, *Aster puniceus*, *Ranunculus sceleratus*, *Carex microptera*, *Danthonia californica*, *Festuca saximontana*, and *Juncus longistylis* (for common names see Appendix).

Acknowledgments

I thank Larry Halverson, Ian Jack and my colleagues in Kootenay National Park for their encouragement and support of this study. I also thank J. D. Johnson, C. C. Chinnappa, and R. J. Bayer, curators of CAFB, ALTA and UAC respectively, for providing access to herbarium collections. Helpful comments on the manuscript were made by J. D. Johnson of the Northern Forestry Centre in Edmonton.

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Received 25 January 1993
Accepted 22 October 1993

APPENDIX. List of vascular plant species for Marble Canyon and vicinity, Kootenay National Park, British Columbia.

Scientific name	Common name[4]	Collection number[7]
PTERIDOPHYTA		
EQUISETACEAE (Horsetail Family)		
Equisetum arvense	Common Horsetail	MC74
Equisetum scirpoides	Dwarf Scouring Rush[5]	MC51
LYCOPODIACEAE (Club-moss Family)		
Lycopodium annotinum	Stiff Club-moss	
Lycopodium complanatum	Ground Cedar	
OPHIOGLOSSACEAE (Adder's-tongue Family)		
Botrychium lunaria	Moonwort	
POLYPODIACEAE (Fern Family)		
Cryptogramma stelleri	Rock Brake	MC67
Cystopteris fragilis	Fragile Fern[5]	MC52
SELAGINELLACEAE (Little Club-moss Family)		
Selaginella densa	Prairie Selaginella	MC94
Selaginella selaginoides[1,2]	Spiny-edged Little Club-moss	MC27
SPERMATOPHYTA		
GYMNOSPERMAE		
CUPRESSACEAE (Cypress Family)		
Juniperus communis	Ground Juniper	
PINACEAE (Pine Family)		
Abies lasiocarpa	Alpine Fir	
Picea engelmannii	Engelmann Spruce	
Pinus albicaulis	White-bark Pine	MC95
Pinus contorta	Lodgepole Pine	
ANGIOSPERMAE		
Monocotyledoneae		
CYPERACEAE (Sedge Family)		
Carex atrosquama	Dark-scaled Sedge[5]	MC75
Carex capillaris[1]	Hair-like Sedge[5]	MC17
Carex concinna[2]	Beautiful Sedge[5]	MC76, 77
Carex disperma	Two-seeded Sedge[5]	MC18, 21
Carex gynocrates[2]	Northern Bog Sedge[5]	MC65
Carex macloviana	Thick-spike Sedge[5]	MC78
Carex microglochin	Short-awned Sedge[5]	MC19
Carex microptera	Small-winged Sedge[5]	MC79
Carex norvegica	Norway Sedge[5]	MC80
Carex scirpoidea[1,2]	Rush-like Sedge[5]	MC 20, 22, 23
Kobresia simpliciuscula	Simple Bog-sedge[5]	MC81
GRAMINEAE (Grass Family)		
**Agrostis stolonifera*	Hair Grass	MC 1
Bromus inermis ssp. *pumpellianus*	Northern Awnless Brome	MC 2
Calamagrostis canadensis	Bluejoint	MC 3
Calamagrostis purpurascens[1]	Purple Reed Grass	MC 4

APPENDIX. *Continued.*

Scientific name	Common name[4]	Collection number[7]
Danthonia californica	California Oat Grass[5]	MC 5
Deschampsia cespitosa	Tufted Hair Grass	MC 6
Elymus innovatus	Hairy Wild Rye	MC 7
Festuca rubra	Red Fescue	MC 8
Festuca saximontana	Rocky Mountain Fescue[5]	MC 9
Glyceria striata	Fowl Manna Grass	MC10
Hordeum jubatum	Foxtail Barley	
Oryzopsis asperifolia	White-grained Mountain Rice Grass[5]	MC11
Phleum commutatum (_P. alpinum_ L.[1])	Mountain Timothy	MC82
*_Phleum pratense_	Timothy	MC61
Poa alpina[1,2]	Alpine Bluegrass	MC13
*_Poa annua_	Annual Bluegrass	
*_Poa compressa_	Canada Bluegrass	MC68
Poa palustris	Fowl Bluegrass	MC14
*_Poa pratensis_	Kentucky Bluegrass	MC15
Trisetum spicatum[1]	Spike Trisetum	MC16
IRIDACEAE (Iris Family)		
Sisyrinchium montanum	Blue-eyed Grass	
JUNCACEAE (Rush Family)		
Juncus balticus	Wire Rush	MC25
Juncus drummondii	Drummond's Rush[5]	MC83
Juncus longistylis	Long-styled Rush[5]	MC26
JUNCAGINACEAE (Arrow-grass Family)		
Triglochin palustris	Slender Arrow-grass	MC24
LILIACEAE (Lily Family)		
Stenanthium occidentale	Bronze-bells	MC46
Tofieldia pusilla	False Asphodel	
Zygadenus elegans	White Camas	
ORCHIDACEAE (Orchid Family)		
Habenaria hyperborea	Northern Green Orchid	
Listera borealis	Northern Twayblade	
Dicotyledoneae		
BETULACEAE (Birch Family)		
Betula glandulosa	Dwarf Birch	MC31
Betula occidentalis	Water Birch	
BORAGINACEAE (Borage Family)		
*_Lappula squarrosa_	Blue-bur	MC66
CAMPANULACEAE (Bluebell Family)		
Campanula rotundifolia	Harebell	
CAPRIFOLIACEAE (Honeysuckle Family)		
Linnaea borealis	Twin-flower	
Lonicera involucrata	Bracted Honeysuckle	
Lonicera utahensis	Red Twin-berry	
Viburnum edule	Low-bush Cranberry	MC45
CARYOPHYLLACEAE (Pink Family)		
Arenaria longipedunculata (_A. humifusa_ Wahl.[1])	"Alpine" Sandwort[6]	MC84
*_Cerastium vulgatum_	Mouse-ear Chickweed	
Minuartia dawsonensis	Dawson Sandwort	CAFB 840836
*_Stellaria longipes_	Long-stalked Chickweed	MC69
CHENOPODIACEAE (Goosefoot Family)		
*_Chenopodium album_	Lamb's-quarters	
Chenopodium capitatum	Strawberry Blight	

APPENDIX. *Continued.*

Scientific name	Common name[4]	Collection number[7]
COMPOSITAE (Composite Family)		
Achillea millefolium	Common Yarrow	
Agoseris aurantiaca	False Dandelion	
Anaphalis margaritacea	Pearly Everlasting	
Antennaria pulcherrima	Showy Everlasting	
Antennaria rosea ssp. _pulvinata_[3]	Rosy Everlasting[5]	MC70
Arnica angustifolia	Alpine Arnica[5]	MC44
Arnica cordifolia	Heart-leaved Arnica[5]	
Arnica lonchophylla	Spear-leaved Arnica[5]	
Aster ciliolatus	Lindley's Aster	CAFB 840895
Aster conspicuus	Showy Aster	CAFB 840897
Aster puniceus	Purple-stemmed Aster	
Aster sibiricus	Arctic Aster[5]	
Aster subspicatus	Leafy-bracted Aster[5]	MC62
*_Chrysanthemum leucanthemum_	Ox-eye Daisy	
*_Cirsium arvense_	Canada Thistle	
Erigeron elatus	Tall Fleabane[5]	MC64
Erigeron humilis	Purple Fleabane[5]	P
*_Matricaria matricarioides_	Pineapple-weed	
Petasites palmatus	Palmate-leaved Coltsfoot	MC85
Petasites sagittatus	Arrow-leaved Coltsfoot	
Saussurea nuda var. _densa_	Dwarf Saw-wort[5]	P
Senecio lugens	Black-tipped Groundsel[5]	
Senecio pseudaureus	Thin-leaved Ragwort[5]	
Solidago multiradiata	Rocky Mountain Goldenrod[5]	MC47, 48
Taraxacum cf. _ceratophorum_[1]	Northern Dandelion[5]	P
*_Taraxacum officinale_	Common Dandelion	
CORNACEAE (Dogwood Family)		
Cornus canadensis	Bunchberry	
CRUCIFERAE (Mustard Family)		
*_Capsella bursa-pastoris_	Shepherd's-purse	
Draba lonchocarpa	"Spear-fruited" Whitlow-grass[6]	MC86
*_Sisymbrium altissimum_	Tumbling Mustard	
*_Thlaspi arvense_	Stinkweed	
ELAEAGNACEAE (Oleaster Family)		
Shepherdia canadensis	Canadian Buffalo-berry	
EMPETRACEAE (Crowberry Family)		
Empetrum nigrum[1]	Crowberry	MC37
ERICACEAE (Heath Family)		
Arctostaphylos rubra	Alpine Bearberry	MC32
Arctostaphylos uva-ursi	Common Bearberry	
Cassiope mertensiana	Western Mountain-heather[5]	MC33
Cassiope tetragona ssp. _saximontana_	White Mountain-heather[5]	MC34
Gaultheria hispidula	Creeping Snowberry	
Ledum glandulosum	Glandular Labrador Tea	MC54
Ledum groenlandicum	Common Labrador Tea	MC35
Menziesia ferruginea	False Azalea[5]	
Phyllodoce glanduliflora	Yellow Heather	MC36
Rhododendron albiflorum	White-flowered Rhododendron	
Vaccinium myrtillus	Low Bilberry	MC39
Vaccinium scoparium	Grouse-berry	MC40
GENTIANACEAE (Gentian Family)		
Gentianella propinqua	Felwort[5]	MC38
GROSSULARIACEAE (Gooseberry Family)		
Ribes lacustre	Bristly black current	

APPENDIX. *Continued.*

Scientific name	Common name[4]	Collection number[7]
LABIATAE (Mint Family)		
*_Galeopsis tetrahit_	Hemp Nettle	
*_Lamium amplexicaule_	Dead Nettle	MC58
*_Prunella vulgaris_	Heal-all	
LEGUMINOSAE (Pea Family)		
Astragalus alpinus	Alpine Milk Vetch[5]	MC87
Hedysarum sulphurescens	Yellow Hedysarum[5]	
Lathyrus ochroleucus	Cream-coloured Vetchling[5]	MC88
*_Medicago lupulina_	Black Medick	
*_Medicago sativa_	Alfalfa	
*_Melilotus alba_	White Sweet Clover	
*_Melilotus officinale_	Yellow Sweet Clover	
Oxytropis monticola	Late Yellow Locoweed	MC89
*_Trifolium hybridum_	Alsike Clover	
*_Trifolium pratense_	Red Clover	
*_Trifolium repens_	White Clover	
*_Vicia cracca_	Tufted Vetch[5]	
LENTIBULARIACEAE (Bladderwort Family)		
Pinguicula vulgaris[1,2]	Common Butterwort	P
ONAGRACEAE (Evening Primrose Family)		
Epilobium angustifolium	Fireweed	
Epilobium ciliatum	Northern Willowherb[5]	MC50
Epilobium clavatum	"Alpine Club" Willowherb[6]	MC90
PARNASSIACEAE (Grass-of-Parnassus Family)		
Parnassia fimbriata	Fringed Grass-of-Parnassus	MC56
PLANTAGINACEAE (Plantain Family)		
*_Plantago major_	Common Plantain	
POLYGONACEAE (Buckwheat Family)		
Polygonum viviparum[1]	Bistort	MC43
PYROLACEAE (Wintergreen Family)		
Moneses uniflora	One-flowered Wintergreen	
Orthilia secunda	One-sided Wintergreen	
Pyrola asarifolia	Common Pink Wintergreen	
Pyrola chlorantha	Greenish-flowered Wintergreen	
RANUNCULACEAE (Crowfoot Family)		
Anemone parviflora[1]	Small Wood Anemone[5]	MC41
Ranunculus scleratus	Cursed Crowfoot	MC59
ROSACEAE (Rose Family)		
Amelanchier alnifolia	Saskatoon	
Dryas drummondii	Yellow Dryad	
Dryas octopetala ssp. _hookeriana_	White Dryad	MC42
Fragaria virginiana	Wild Strawberry	
Geum aleppicum	Yellow Avens	
Potentilla fruticosa	Shrubby Cinquefoil	
Rosa acicularis	Prickly Rose	MC91
Rosa woodsii	Wild Rose	MC92
Rubus idaeus	Wild Red Raspberry	
Spiraea lucida	White meadowsweet	
RUBIACEAE (Madder Family)		
Galium triflorum	Sweet-scented Bedstraw	MC93
SALICACEAE (Willow Family)		
Populus balsamifera	Balsam Poplar	
Populus tremuloides	Aspen	
Salix farriae	Farr's Willow[5]	MC55

APPENDIX. *Concluded.*

Scientific name	Common name[4]	Collection number[7]
Salix glauca	Smooth Willow[5]	MC29
Salix reticulata ssp. *nivalis*	Snow Willow[5]	MC28
Salix scouleriana	Scouler's Willow[5]	MC53
Salix vestita	Rock Willow[5]	MC30
SAXIFRAGACEAE (Saxifrage Family)		
Mitella nuda	Bishop's-cap	
Saxifraga aizoides	Yellow Mountain Saxifrage[5]	P
Saxifraga oppositifolia	Purple Saxifrage	P
SCROPHULARIACEAE (Figwort Family)		
Castilleja miniata	Common Red Paintbrush	
Pedicularis bracteosa	Western Lousewort[5]	MC49
Veronica alpina	Alpine Speedwell[5]	
VIOLACEAE (Violet Family)		
Viola renifolia	Kidney-leaved Violet	

[*] Alien (introduced) species.

[1] Species classed as arctic-alpine at Lake Superior (Given and Soper 1981).

[2] Species classed as arctic-alpine on Manitoulin Island, Lake Huron (Morton and Venn 1984).

[3] Nomenclature according to Bayer (1989).

[4] Common names according to Moss (1983) except where otherwise noted.

[5] Common name following the checklist from Alberta Energy/Forestry, Lands and Wildlife (1992).

[6] Common name suggested by the author (EHH) for species lacking common names from the above sources.

[7] The author's collections (MC) are located in the Kootenay National Park Herbarium at Radium Hot Springs, B.C. Other collections are at CAFB (Edmonton, Alberta). "P" denotes species photographed only.

Regional Use, Selection, and Nesting Success of Wood Ducks, *Aix sponsa,* Using Nest Boxes in Ontario

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Richardson, Michael, and Richard W. Knapton. 1993. Regional use, selection, and nesting success of Wood Ducks, *Aix sponsa,* using nest boxes in Ontario. Canadian Field-Naturalist 107(3): 293–304.

Duck nesting-box surveys in 1990 and 1991 in Ontario on the use of nest boxes by Wood Ducks and other species provided information on 1808 nest boxes, of which 1678 were analysed. There were 510 (31%) reported nesting attempts by Wood Ducks, of which 303 were successful, 87 unsuccessful, and 106 unknown. Nest box use showed strong regional variation; lowest in northern Ontario, highest in the Sudbury area and eastern Ontario. Density of breeding Wood Duck populations and availability of suitable nesting cavities probably explain this variation. Clutch size was about 10.5 eggs, and did not differ between successful and unsuccessful nests. Only five of 15 dump nests reported were successful, with a mean clutch size of 18.8 eggs. Nest boxes placed in swamps and around sewage lagoons had the highest occupancy rates. Nest boxes placed about 2.5 m above ground, highly visible and with a clear flight path to the nest hole were preferred over higher or more concealed boxes. Nest-box distance to water did not affect occupancy or nesting success. Nest-boxes with smaller entrance holes were occupied more than those with larger holes; average area of entrance hole of occupied boxes was 63 cm^2. Clumped boxes were used less than expected, but had higher nesting success.

Key Words: Wood Duck, *Aix sponsa*, nest boxes, survey, nesting success, dump nests, nest box placement and dimensions.

This report summarizes the use of nest boxes, selection preference, and nesting success by Wood Ducks *Aix sponsa* in Ontario, from data provided by the *Duck Nesting-Box Survey*. Results from the 1990 and 1991 breeding seasons are presented.

Wood Ducks and other secondary cavity nesting ducks, such as Common and Barrow's Goldeneyes *Bucephala clangula, B. islandica*, Bufflehead *B. albeola*, and Hooded Merganser *Lophodytes cucullatus*, cannot create their own nest holes and therefore must use existing cavities as nest sites. Much time, effort and money has been expended in nest-box construction and placement to promote the establishment of nesting populations of these species, especially the Wood Duck, the second-most commonly shot duck in Ontario (Boersma 1990). In a study of 4000 Wood Duck nest boxes between 1963 and 1971, H. G. Lumsden (personal communication) found that Wood Ducks used only 8.4% of available nest boxes. Nest-box use by Wood Ducks has been shown to vary considerably according to flyway and latitude (review in Soulliere 1990a). The *Duck Nesting-Box Survey* was undertaken to determine the extent of nest-box use in Ontario, and to investigate nesting success and selection preferences.

Wood Ducks are thought to have been generally threatened with extinction in the early part of the 20th century, although there were probably scattered pockets of abundance (Bellrose 1990). Since then, the Wood Duck has recovered across much of its range (review in Bellrose 1990) with many populations continuing to slowly expand (Sauer and Droege 1990). This is partly attributable to the elimination of hunting from 1918 to the 1940s. Numbers had recovered sufficiently to allow limited shooting throughout all states in the Atlantic Flyway by 1942, in Ontario by 1945, in Quebec by 1950, and throughout the remainder of Canada, with restricted bag limits, during the late 1950s.

Widespread habitat loss for cavity-nesting ducks, especially wetland drainage (Snell 1987), has occurred across eastern Canada (Erskine 1972). Large-scale loss of natural cavities has been cited as a major factor limiting populations of many secondary cavity-nesters (e.g., von Haartmann 1957); in fact, some secondary cavity-nesters, such as Purple Martin *Progne subis*, now appear to be dependent on artificial nest sites (Jackson and Tate 1974; Erskine 1979). For several years, the Ontario Ministry of Natural Resources (OMNR) has provided financial support to groups through the Community Wildlife Involvement Program (CWIP) to build and erect nest boxes for Wood Ducks. Similarly, other groups such as Ducks Unlimited Canada, the Ontario Federation of Anglers and Hunters, and the Federation of Ontario Naturalists have also encouraged people to build and erect nest boxes. Nest boxes have been credited with playing an important role in the recovery of the Wood Duck by replacing lost nest sites; however, Bellrose (1990) estimated that young born in nest boxes comprise only 4–5%

(132 000–165 000) of the juvenile fall population (3.3 million) of Wood Ducks east of the Great Plains.

Wood Duck preferences for nest-site, nest-box and entrance-hole dimensions, and construction style have been major topics of study (e.g., Bellrose et al. 1964; McLaughlin and Grice 1952). The recommended location for nest boxes for Wood Ducks is at the edge of deciduous forests in close proximity to wetlands that provide suitable food and cover for breeding adults and subsequent habitat for ducklings (Bellrose 1976; Cadman et al. 1987). Also, characteristics of locations of natural cavities and nest boxes have been studied in relation to use and nest success of Wood Ducks: for example, cavity orientation and distance to water (Gilmer et al. 1978; review in Haramis 1990), visibility and vegetation (Wenner and Marion 1981), height (Bellrose et al. 1964), and cavity density (Haramis and Thompson 1985).

Methods

Data were collected through the *Duck Nesting-Box Survey*, a cooperative project of the OMNR and the Long Point Bird Observatory (LPBO). Volunteers throughout Ontario were asked to monitor nest boxes during the 1990 and 1991 breeding seasons. Each participant received an information kit, containing instructions for participants, a survey form with an example of the correct method of completing the form, and a return envelope. Specific instructions explained how use by various species and the fate of the nest could be determined by characteristics of the nest and eggs.

The following information was requested for each nest box: species in nest box, number of eggs laid, number of eggs hatched, number of eggs or young lost to predators, presence of emergent or floating vegetation at the water's edge nearest the nest box, shortest distance from nest box to water in May, height of nest box above ground, area around nest box with vegetation more than 1 m high, habitat in which nest box was placed, a subjective assessment of how visible the nest box was, whether nest boxes were solitary or clumped, and type of nest box used. Dimensions and construction details of the nest box were also requested, including dimensions and shape of the nest box and entrance hole, type of material used for construction, interior and exterior colour, and type of predator guard used, if any. Measurements requested were the interior width, depth, and height, and distance from base of the entrance hole to bottom of the nest box. Floor area and volume were calculated (99% of the nest boxes reported were "upright wooden" rectangular boxes). Dimensions and shape of the entrance hole were also determined; the area of the entrance hole was calculated as that of a circle, a half-circle, or an ellipse. Most nest boxes were checked one to three times annually, although some were checked only after nesting was complete.

Completed forms were returned to LPBO, where data were coded and entered into computer files. Nest-box use and site characteristics were included in the analysis for the first year the nest box was reported. "Use" was divided into three categories: nest box not used, nest box used by Wood Duck, or nest box used by other species (see Appendix A). A nest box was considered to have been used if there was evidence of eggs or young, and was considered successful if there was evidence that at least one young left the nest box. In this study, a potential source of error was that most nests were not followed from initial occupation to fledging of the young. Nests with unknown success have been separated from those with a known outcome. The number of young hatched may be overestimated since checks were made before hatching.

For analysis purposes, the province was divided into six regions. The southwestern region included all counties and regional municipalities southwest of Bruce, Simcoe and York counties; the south-central region included the counties of Victoria, Durham, Peterborough, Northumberland, Hastings and Prince Edward; the eastern region included all counties east of Renfrew and Lennox & Addington; the central region included Muskoka, Haliburton, and Parry Sound Districts and Algonquin Provincial Park; the Sudbury region included Nipissing, Timiskaming, Sudbury and Algoma Districts; and northern Ontario included all land north of the Sudbury region.

Data were analyzed using SPSS. All variables were found to be non-normally distributed, thus non-parametric techniques were chosen for analysis (Sokal and Rohlf 1969). Goodness-of-fit tests (G^2) were used to analyse the distribution of class data. Dunn's Multiple Comparison Test, based on Kruskal-Wallis rank sums, was used to find significant differences between specific categories.

Results

Approximately 100 volunteers provided results for 1808 nest boxes (Table 1). The use of 158 nest boxes was unknown (due to accessibility problems), while 28 nest boxes were used twice in one season, providing 1678 nest opportunities in 1650 nest boxes. Nest boxes were not used by any species in 741 reports (44%). Wood Ducks occupied 510 nest boxes (30%) (Table 2), and several other species occupied the remaining 427 nest boxes (25%) (see Appendix A).

Regional Use of Nest Boxes

Northern Ontario had low nest box use: 34 (16%) of 216 boxes (Table 1). Four (2%) were occupied by Wood Ducks and each nest was unsuccessful (Table 2). Other species occupied 30 boxes (14%) with a high success rate (26 of 27, 96%).

TABLE 1. Nest box distribution by region and use.

	Region						
Nest boxes	Northern Ontario	Sudbury region	Central Ontario	Eastern Ontario	South central Ontario	South western Ontario	Total
Reported	308	156	27	573	166	606	1836
Use unknown	92	0	0	34	0	32	158
Not used	182	41	11	150	94	263	741
Used	34	115	16	389	72	311	937

Highest nest-box use was in the Sudbury region (74%) and in eastern Ontario (72%) (Table 1). Wood Ducks used 97 (62%) of 156 boxes in the Sudbury region; only 18 (12%) were used by other species (Table 2). Ninety percent (37 of 41) of Wood Duck nests reported were successful, whereas nesting success of nest boxes used by other species was lower (7 of 14, 50%). In eastern Ontario, Wood Ducks used 239 (44%) of 539 nest boxes and nesting success was high (76%, 158 of 208); other species used 150 nest boxes (28%), with a slightly lower nesting success of 69% (69 of 101) (Table 2).

Sixteen (59%) out of only 27 nest boxes reported were used in central Ontario (Table 1). Seven of 27 (26%) were used by Wood Ducks and 9 (33%) by other species. Four of 7 (57%) Wood Ducks and 6 of 9 other species (67%) were successful. South-central Ontario also had relatively low nest box use (43%) (Table 1); Wood Ducks used 42 (25%) and other species 30 (18%) of 166 nest boxes. Again, nesting success was higher for Wood Ducks (71%, 29 of 41) than for other species (35%, 10 of 29) (Table 2). In southwestern Ontario, 54% of the nest boxes were used; Wood Ducks occupied 121 (21%) nest boxes and other species used a higher proportion (190, 33%) (Table 1). Nesting success was high for Wood Ducks (75 of 103, 73%), and lower for other species (83 of 129, 64%) (Table 2).

In summary, 937 nest boxes (56%) were used, 518 (73%) of which were successful (Tables 1, 2). Wood Ducks occupied 510 boxes, of which 303 (75%) were successful, and other species occupied 427 boxes, of which 201 (65%) were successful.

Clutch size

Clutch size in Wood Ducks did not differ between successful (9.5 ± 3.5, n = 198) and unsuccessful (11.2 ± 7.1, n = 58) nests (Mann-Whitney $|z| = 1.0$, $P=0.4$). Wood Duck clutch size is generally 8–15 eggs (Godfrey 1986), and clutches larger than 15 eggs are assumed to be "dump nests" (clutches in which more than one hen contributed eggs; Clawson et al. 1979). When dump nests were eliminated from the analysis, average clutch size again did not differ significantly between unsuccessful (8.6 eggs ± 4.0, n = 48) and successful nests (9.3 eggs ± 3.2, n = 193) (Mann-Whitney $|z|=0.8$, $P=0.4$). The mean number of young which left the nest was 8.1 ± 3.4 (n = 200).

Five of the 15 dump nests were successful. Clutch sizes of unsuccessful dump nests were; 16, 20, 21 (2x), 23, 25 (3x), and 32 (2x). Clutch size and number of eggs hatched of successful dump nests were: 16 eggs, 2 hatched; 17 eggs, 16 hatched; 18 eggs, 12 hatched; 21 eggs, 19 hatched; 22 eggs, 4 hatched. The two clutches in which only two and four young hatched may have suffered partial predation.

TABLE 2. Nest box distribution by region and use by Wood Ducks and other species.

	Region						
Nest boxes	Northern Ontario	Sudbury region	Central Ontario	Eastern Ontario	South central Ontario	South western Ontario	Total
Wood Duck:							
Total	4	97	7	239	42	121	510
Fate Unknown	0	56	0	31	1	18	106
Unsuccessful	4	4	3	50	12	28	101
Successful	0	37	4	158	29	75	303
Other species:							
Total	30	18	9	150	30	190	427
Fate Unknown	3	4	0	49	1	61	118
Unsuccessful	1	7	3	32	19	46	108
Successful	26	7	6	69	10	83	201

Characteristics of Nest-Box Sites

Emergent Vegetation

Emergent vegetation included those plants which root and project through the water to the surface (floating plants) or above it (emergents). The proportion of unused nest boxes was significantly higher in areas with emergent vegetation (411 of 693, 59%) than in areas where emergent vegetation was absent (108 of 247, 44%) (G^2=17.2, P<0.001, Table 3).

Nest boxes in areas without emergent vegetation were used significantly more often than those with emergent vegetation by both Wood Ducks (G^2=7.5, P=0.006) and other species (G^2=15.2, P<0.001, df=1). Nesting success, however, was not affected by the presence or absence of emergent vegetation. Nesting success for Wood Ducks was 75% (47 of 63) in areas with no emergent vegetation and 86% (108 of 136) in areas with emergent vegetation (G^2=0.3, not significant), and for other species it was 63% (42 of 67) and 55% (63 of 114), respectively (G^2=0.7, not significant).

Average Distance to Water

Measures of the shortest distance from the nest box to water in May (Table 4) were similar for unused boxes, those used by Wood Ducks, and those used by other species (Kruskal-Wallis H =2.2, P=0.3). Nest boxes used successfully were not significantly further from water than those used unsuccessfully by Wood Ducks (Mann-Whitney $|z|$=1.7, P=0.08) or by other species (Mann-Whitney $|z|$=0.1, P=0.4).

Area Covered with Vegetation taller than 1 m

The percent of the area around a nest box covered in vegetation taller than 1 m, was estimated to the nearest 5% (Table 4). Unused nest boxes occurred in areas with a greater percentage of tall vegetation than those used by Wood Ducks or other species (Kruskal-Wallis H=30.9, P<0.001). However, successful nest boxes of Wood Ducks occurred in areas of a greater percentage of tall vegetation than nest boxes used unsuccessfully (Mann-Whitney $|z|$=2.7, P=0.006). This same tendency was also found for other species (Mann-Whitney $|z|$=3.3, P=0.001).

Nest Box Height

Mean height above ground or water of nest box used by Wood Ducks (2.4 m) was the same as that of unused nest boxes (2.4 m) but significantly lower than that of other species (2.8 m) (Table 4, Kruskal-Wallis H=5.8, P=0.05, Dunn α=0.05). Nest boxes used successfully by Wood Ducks were lower than nest boxes used unsuccessfully, but not significantly so (Mann-Whitney $|z|$=1.8, P=0.07). No significant differences were found between the height of nest

TABLE 3. Nest box use in relation to the presence or absence of emergent vegetation.

Nest box use		Emergent vegetation absent	Emergent vegetation present
not used		108	411
Wood Duck:	total used	65	146
	unknown	2	10
	unsuccessful	16	28
	successful	47	108
"other species"	total used	74	136
	unknown	7	22
	unsuccessful	25	51
	successful	42	63

TABLE 4. Nest box use as a function of average distance to water, percent of area covered in vegetation taller than 1 m, and nest box height.

Nest box use		Distance to water (m) mean ± S.D. (n)	Percent of area in vegetation (%) mean ± S.D. (n)	Height of nest box (m) mean ± S.D. (n)
not used		2.6 ± 16.2 (457)	36.8 ± 30.4 (308)	2.4 ± 1.0 (697)
Wood Duck	total used	2.7 ± 8.5 (229)	29.1 ± 31.4 (153)	2.4 ± 1.5 (348)
	unsuccessful	1.4 ± 2.4 (42)	22.2 ± 35.6 (37)	3.5 ± 2.5 (57)
	successful	2.8 ± 9.3 (174)	31.8 ± 29.8 (108)	2.2 ± 1.2 (213)
"other species"	total used	6.3 ± 14.1 (210)	25.1 ± 32.7 (138)	2.8 ± 2.5 (350)
	unsuccessful	4.8 ± 11.3 (75)	14.1 ± 26.1 (52)	3.2 ± 2.5 (99)
	successful	8.0 ± 16.7 (113)	29.0 ± 33.8 (70)	2.9 ± 2.9 (184)

box and nesting success in other species (Mann-Whitney $|z|=1.4$, $P=0.2$).

Use over Water and Ground

Unused nest boxes comprised 49% of 367 nest boxes over water and 53% of 529 boxes over ground (Table 5, $G^2=1.3$, not significant). Wood Ducks used 95 boxes over water and 134 boxes over ground, and other species used 94 and 116, respectively. Nesting success of Wood Ducks was significantly greater over ground (86%) than over water (73%) ($G^2=4.6$, $P=0.04$). The location of nest boxes above water or ground did not affect nesting success in other species ($G^2=1.9$, $P \approx 0.18$).

Habitat

Nest boxes were assigned to one of six habitats described in the kit; marsh, swamp, bog, deciduous forest, mixed deciduous forest, and "other habitats" (Table 6). "Other habitats" incuded sewage lagoons, river banks, and man-made ponds.

Use of boxes by all species differed significantly among habitats ($G^2=167.5$, $P<0.001$). Unused nest boxes occurred most frequently in marshes and slightly more often than expected in bogs and forests. Nest boxes in swamps and "other habitats" appeared to be most attractive (Table 6). The number of nest boxes used by Wood Ducks differed significantly with the number of unused nest boxes in each habitat ($G^2=146.9$, $P<0.001$). Wood Ducks used fewer nest boxes in marsh, bogs, and forests than expected, more nest boxes in swamps than expected (observed=84, expected=62), and over three times the number in "other habitats" (observed=153, expected=46).

Similarly, use of nest boxes by other species differed significantly among habitats ($G^2=106.7$, $P<0.001$). Nest boxes in marshes were used about 40% more often than expected (observed=52, expected=135), and in bogs about 60% (observed=26, expected=45). "Other habitats" were used about three times more often than expected (observed=122, expected=45). Expected and observed use of nest boxes in deciduous and mixed deciduous forests was approximately equal.

Nesting success of Wood Ducks did not differ among habitats ($G^2=5.2$, $P \approx 0.5$). For other species, nesting success varied considerably with habitat ($G^2=37.5$, $P<0.001$); higher than expected numbers of unsuccessful nests occurred in marshes and bogs, whereas successful nests occurred most frequently in swamps and mixed deciduous forests.

Nest box visibility

Nest box visibility, reported on 65% of returned forms, differed significantly between unused and used nest boxes (Table 7; $G^2=38.3$, $P<0.001$). "Clearly visible" nest boxes were most frequently

TABLE 5. Nest box use over water and ground.

		Not used	Wood Duck	Other species
Over water	total used	178	95	94
	unknown		6	9
	unsuccessful		24	39
	successful		65	46
Over ground	total used	279	134	116
	unknown		7	13
	unsuccessful		18	36
	successful		109	67

TABLE 6. Nest box use as a function of habitat.

Nest box use		Habitat					
		Marsh	Swamp	Bog	Deciduous forest	Mixed deciduous forest	"Other" habitats
Not used		217	98	73	39	58	72
Wood Duck	total used	69	84	27	8	9	153
	unknown	1	4	3	0	5	2
	unsuccessful	10	20	4	3	0	39
	successful	58	60	20	5	4	112
"other species"	total used	52	88	26	20	34	122
	unknown	3	7	3	1	8	61
	unsuccessful	27	18	26	8	2	25
	successful	22	63	7	11	24	36

TABLE 7. Nest box use and nesting success as a function of visibility.

		Nest box visibility				
Nest box use		Unknown visibility	"Clearly visible"	"Mostly visible"	"Mostly hidden"	"Well hidden"
not used		197	210	198	133	3
Wood Duck	total used	270	125	49	56	10
	unknown		7	4	7	0
	unsuccessful		36	8	4	4
	successful		82	37	45	6
"other species"	total used	126	135	72	84	10
	unknown		16	8	27	0
	unsuccessful		43	13	28	6
	successful		76	51	29	4

occupied, and were used significantly more often than expected by Wood Ducks ($G^2=33.9$, $P<0.001$) and by other species ($G^2=21.8$, $P<0.001$).

Nesting success of Wood Ducks and of other species was affected by visibility (Wood Duck: $G^2=13.2$, $P\approx0.005$; other species: $G^2=13.9$, $P\approx0.005$). Successful Wood Ducks nests occurred in "mostly visible" and "mostly hidden" boxes in numbers higher than expected, while nests in "clearly visible" boxes were less successful than expected. For other species, "mostly visible" nest boxes were more successful, whereas "mostly hidden" nest boxes were less successful than expected.

Nest box clumping

A nest box was considered clumped if it was within 10 m of another nest box. Clumped nest boxes were used less than expected (observed=21, expected=43), and solitary nest boxes more than expected (observed=205, expected=183), by Wood Ducks (Table 8; $G^2=9.2$, $P\approx0.003$). Nesting success of Wood Ducks was higher in clumped nest boxes ($G^2=3.8$, $P=0.05$), a result which is probably a function of sample size. The use of nest boxes by other species was not affected by clumping ($G^2=0.7$, $P\approx0.4$), nor was nesting success ($G^2=0.6$, $P\approx0.45$).

TABLE 8. Nest box use as a function of clumping.

Nest box use		Clumped	Solitary
not used		104	445
Wood Duck	total used	21	205
	unknown	2	12
	unsuccessful	1	51
	successful	18	142
"other species"	total used	41	248
	unknown	6	37
	unsuccessful	15	72
	successful	20	139

Nest box dimensions

There was considerable variation in sizes of nest boxes, hence the relatively large standard deviations associated with each of the three dimensions in Table 9. "Other species" included small passerines using small boxes, and ducks (Hooded Mergansers and Common Goldeneye), flying squirrels *Glaucomys* spp., American Kestrels *Falco sparverius* and Eastern Screech-Owls *Otus asio* using considerably larger boxes.

Floor Area

Average floor area of nest boxes used by Wood Ducks was significantly larger than the average of those used by other species (Dunn $a=0.001$) or unused nest boxes (Dunn $a=0.01$), and floor area of unused nest boxes was larger than that of other species (Dunn $a=0.05$) (Table 9: Kruskal-Wallis $H=29.3$, $P<0.001$). Average floor area of successful Wood Ducks nests was larger than that of unsuccessful nests (Mann-Whitney $|z|=3.6$, $P=0.001$). Floor area of nest boxes used successfully by other species was larger than that of those used unsuccessfully (Mann-Whitney $|z|=2.3$, $P=0.02$).

Volume

Average total volume of nest boxes used by Wood Ducks was significantly greater than that of unused nest boxes or those used by other species (Table 9; Kruskal-Wallis $H=38.4$, $P<0.001$, Dunn $a=0.001$). Average volume of successful nest boxes was significantly greater than that of unsuccessful nest boxes for Wood Ducks (Mann-Whitney $|z|=4.2$, $P<0.001$) and for other species (Mann-Whitney $|z|=2.1$, $P=0.03$).

The volume below the entrance hole was significantly larger for nest boxes used by Wood Ducks than for unused nest boxes or for those used by other species (Table 9; Kruskal-Wallis $H=41.1$, $P<0.001$; Dunn $a=0.001$). Nest boxes used successfully had significantly greater volumes below the entrance hole than those used unsuccessfully by Wood Ducks (Mann-Whitney $|z|=3.4$, $P=0.008$). This relationship

TABLE 9. Nest box use as a function of nest box dimensions

Nest box use		Floor area (cm^2) mean ± S.D. (n)	Total volume (cm^3x10^3) mean ± S.D. (n)	volume below entrance (cm^3x10^3) mean ± S.D. (n)
not used		748 ± 319 (656)	35.8 ± 17.9 (656)	25.4 ± 12.2 (656)
Wood Duck	total	821 ± 340 (329)	42.0 ± 19.5 (328)	30.3 ± 14.6 (329)
	unsuccessful	612 ± 192 (56)	28.1 ± 8.8 (56)	20.5 ± 5.8 (56)
	successful	790 ± 349 (203)	39.6 ± 18.3 (202)	26.8 ± 11.2 (203)
"other species"	total	663 ± 220 (274)	32.5 ± 14.2 (274)	24.1 ± 11.4 (261)
	unsuccessful	632 ± 214 (78)	30.3 ± 13.7 (78)	22.8 ± 10.0 (78)
	successful	668 ± 211 (159)	33.4 ± 13.4 (159)	34.6 ± 10.9 (146)

was marginally significant for other species (Mann-Whitney $|z|=1.8$, $P=0.076$).

Entrance hole dimensions

The average area of the entrance hole was significantly larger in unused nest boxes than in those used by other species or Wood Ducks (Table 10: Kruskal-Wallis $H=34.4$, $P<0.001$, Dunn $a=0.001$). Size of the entrance hole in nest boxes used successfully by Wood Ducks was larger than in those used unsuccessfully (Mann-Whitney $|z|=3.2$, $P=0.001$). Average size of the entrance hole in successful and unsuccessful nest boxes did not differ for other species (Mann-Whitney $|z|=0.01$, not significant).

TABLE 10. Nest box use as a function of entrance hole dimensions.

Nest box use		Nest box entrance hole area (cm^2) mean ± S.D. (n)
not used		67.0 ± 17.5 (635)
Wood Duck	total used	63.6 ± 23.5 (331)
	unsuccessful	63.7 ± 11.8 (55)
	successful	68.6 ± 26.5 (203)
"other species"	total used	65.4 ± 11.6 (287)
	unsuccessful	64.6 ± 9.8 (77)
	successful	64.6 ± 11.4 (163)

TABLE 11. Nest box use as a function of predator control.

Nest box use		No predator guards	Predator guards
not used		567	170
Wood Duck	total used	198	276
	unknown	69	10
	unsuccessful	24	60
	successful	105	206
"other species"	total used	194	213
	unknown	55	54
	unsuccessful	32	69
	successful	107	90

Predator guards

All types of predator guards were grouped to consider their effect on nesting success (Table 11). Nest boxes with predator guards were used significantly more often than those without ($G^2=178.9$, $P<0.001$). However, predator guards did not affect nesting success of Wood Ducks ($G^2=0.6$, $P\approx0.45$), and predator guards appeared to have had a negative effect on success of other species ($G^2=13.1$, $P<0.001$).

Discussion

Wood Ducks used 31% of the reported nest boxes in Ontario. This is considerably higher than the usage found by Lumsden in the 1960s (personal communication) and more similar to other studies (reviewed by Bellrose 1990; Soulliere 1990a). Increased use is likely due to currently larger and expanding populations of Wood Ducks, which may be preferentially using nest boxes (Sauer and Droege 1990). Ongoing surveys of breeding waterfowl by the Canadian Wildlife Service in southern Ontario indicate Wood Duck numbers doubled in the last 17 years (Dennis et al. 1989). Furthermore, female Wood Ducks show strong fidelity for the site where they were born, or where they previously bred successfully. Studies have shown Wood Duck numbers increase rapidly in an area after the introduction of hand-reared ducks or the placement of nest boxes (Doty and Kruse 1972; Doty et al. 1984). Hence, those Wood Ducks born in nest boxes may use nest boxes preferentially when adults.

Regional Trends

Nest box use by Wood Ducks and other species showed strong regional trends. Use in northern Ontario was low, whereas all areas from the Sudbury region south showed higher rates of use. Use of nest boxes by Wood Ducks was highest in the Sudbury region and eastern Ontario.

Northern Ontario had low overall nest box use (34 of 216, 16%). This lack of use was probably due to a combination of an ample supply of natural cavities and a low density in northern Ontario of species using nest boxes. Many cavity-nesting species reported using nest boxes are not common or show patchy distributions in northern Ontario; for example, House Wrens, *Troglodytes aedon,* and House Sparrows, *Passer domesticus,* do not have dense breeding populations away from urban centres. European Starlings *Sturnus vulgaris*, which comprised the largest component of other species in southern Ontario, were not reported to have used nest boxes in the north. Starlings may have declined in northern Ontario; in the early 1970s, Lumsden (1976) reported up to 42 pairs annually using nest boxes put up for Common Goldeneye near Elk Lake (44°44'N, 80° 20'W) [Sudbury District], whereas in the 1980s such use had dropped to zero (H. G. Lumsden, personal communication).

Of those boxes used, Wood Ducks occupied only four (<2%, Tables 1, 2). Wood Ducks are a relatively scarce breeding species north of a line extending from Temagami to Batchawana Bay. In the 1930s, Baillie and Harrington (1936) considered the Wood Duck a rare breeding species even in southern Ontario. The Atlas of the Breeding Birds of Ontario (Cadman et al. 1987) indicated scattered areas of breeding in northern Ontario, and the species may still be expanding, or re-establishing, in parts of its historical range. Of an estimated Ontario breeding population of 155 000 birds, only 10 000 occurred in northwestern Ontario, the remaining 145 000 mostly breeding south of 47°N (Dennis 1990).

The northern extent of Wood Duck breeding populations in northern Ontario may be limited by cavity availability. Most trees containing a suitable-sized cavity for Wood Ducks are ≥ 30 cm diameter at breast height (Soulliere 1990b), and many northern coniferous forests may not provide suitable nests as most trees there are too small. Interestingly, increasing Wood Duck populations in Ontario have been correlated with increasing populations of Pileated Woodpeckers *Dryocopus pileatus* and Beavers *Castor canadensis* (Cringan 1971).

Nest box use was greatest in the Sudbury region and eastern Ontario. High use in the Sudbury region may be a result of a lack of large trees immediately around Sudbury. Air-borne and other pollutants have caused much vegetation to die, and only in the last 20 years has vegetation been re-established. Currently, few trees remain which are large enough to contain a cavity of suitable size for Wood Ducks or Hooded Mergansers; hence, any nesting cavity would be desirable. High use in eastern Ontario may also be attributed to a lack of suitable natural cavities. Much of this area is abandoned farmland in various stages of forest regeneration. Many trees are still relatively young, providing few suitable nest cavities for species requiring large cavities. The number of boxes used by both Wood Ducks and other species, particularly Hooded Mergansers and Starlings, indicated a locally large breeding population of cavity-nesting birds.

South-central and south-western Ontario showed lower nest box use than the Sudbury region or eastern Ontario. Reasons for this are not clear, although Wood Ducks are not abundant throughout all of southern Ontario, particularly the extreme southwest, and Hooded Mergansers are very localized away from the Canadian Shield. The proportion of nest boxes used by other species such as Starlings, House Wrens, and House Sparrows increased from eastern to southwestern Ontario, probably reflecting regional trends in abundance.

Clutch size and dump nests

Clutch size in Wood Ducks did not differ significantly between successful and unsuccessful nests, indicating clutch size was not related to success. When dump nests were eliminated from analysis, clutch size still did not differ significantly between unsuccessful and successful nests. Although 10 of 15 dump nests failed, a mean of 10.6 eggs hatched (out of 18.8 mean clutch size), higher than for successful non-dump nests (9.5 eggs laid, 8.1 eggs hatched). Clawson et al. (1979) also found that dump nesting in Missouri sometimes played a beneficial role as it was more productive, in terms of number of young contributed per nest, than non-dump nests. Thus, dump nests were partially compensatory by being more productive.

The frequency of dump nests is density-dependent, and it occurs when there is intra-specific competition for nest sites (Clawson et al. 1979; Haramis and Thompson 1985; Erskine 1990). Dump nests occurred primarily in eastern Ontario, an area of high nest-box use and probably high Wood Duck populations during the breeding season. In the present study, 28 nest boxes were re-used, often following removal of a starling nest, although Wood Ducks also used single nest boxes more than once in a season. Wood Ducks breeding in Ontario are unlikely to have second broods as the incidence of this decreases with increasing latitude (Fredrickson and Hansen 1983; Moorman and Baldassarre 1988).

Nest Placement and Nesting Success

Nest-box distance to water did not affect selection by Wood Ducks or other species. An optimum distance to water was not determined as most nest boxes were within a few metres of water. Furthermore, occupancy of nest boxes was not significantly affected by the placement of the nest box above water or ground (Table 5). However, nesting success of nest boxes above ground was higher than those placed over water in this study, a result difficult to explain as the initial movement of ducklings from the nest is probably the most dangerous and vulnerable period in the life of a Wood Duck

(Leopold 1951). Ball et al. (1975) suggested duckling mortality is directly attributable to amount of overland travel. Wood Ducks likely nest as close to water as possible, and Grice and Rogers (1965) proposed that the distance from the nest box to water be less than 0.8 km, to reduce duckling mortality.

More unused nest boxes occurred in areas with a greater percentage of tall vegetation than those used by Wood Ducks or other species. This may be because dense vegetation obscures the visibility of the nest box; previous studies indicated non-visible nest boxes were avoided (Wenner and Marion 1981). "Clearly visible" nest boxes were used by Wood Ducks and other species most frequently and more often than expected. The visibility of nest boxes may play a role in nest box selection by virtue of the orientation of an opening (in the case of boxes placed in forests) and presence of a clear flight path to the box. However, nest boxes used successfully by Wood Ducks and other species occurred in areas with a greater percentage of tall vegetation than those used unsuccessfully. Presumably there is an optimum range of visibility, above which the nest box will not be occupied, and below which nesting success is reduced.

Proportionately more boxes were used in areas with no emergent vegetation. Although the presence of emergent vegetation may have discouraged use, nesting success of Wood Ducks and other species did not differ significantly whether emergent vegetation was present or absent in the area. The presence of emergent vegetation was only described for the area immediate to the nest box, and not for the water body as a whole. Broods are highly mobile and probably move to preferred habitats once they leave the nest. Hence, percent cover of emergent vegetation of the water body would be more important than that near individual boxes.

The range of heights of nest boxes was not large enough to determine an optimum height, although this study's data suggested that lower nests may be more attractive to Wood Ducks. Nest boxes used successfully by Wood Ducks and other species were closer to the ground than those used unsuccessfully. Past studies have encouraged nest-box placement considerably higher than 2-3 m. Bellrose (1976) recommended a height range of 4 to 7 m above ground. The CWIP field manual suggests that Wood Ducks prefer nest boxes placed 4.5 to 6 m above ground over those at 3 m. Bowers and Atkins (1990) found significantly greater number of nest initiations by Wood Ducks at lower nest box height (2 m) than at higher heights (3.8 m or 5.6 m). High nest sites are probably selected as much by their orientation to a canopy opening, allowing a clear flight path and the cavity to be easily found initially, and not height *per se*. Lower nest sites seem to be desirable if they are visually accessible, hence in open areas nest boxes placed only a few metres above water or ground are readily accepted.

Habitat played an important role in nest box use (Table 6). Boxes placed in swamps and "other habitats" were used by both Wood Ducks and other species considerably more often than would be expected. Proportionately few boxes were used in marshes or forests. Sewage lagoons were the primary "other habitat" reported. Sewage lagoons often have their perimeters cleared of trees and are in relatively unwooded areas, which may make any nest sites offered attractive. Wood Duck ducklings feed on aquatic insects and other invertebrates, and sewage lagoons often provide a plentiful source of invertebrates, and thus a particularly suitable site to raise young. They may also be attractive as they are often ringed with cattails which offer excellent protective cover.

Placing nest boxes closer than 10 m between boxes discouraged nest box use (Table 8), particularly for Wood Ducks. Although Wood Ducks are not considered to be territorial when nesting, closely spaced nest boxes are not desirable.

Nest box dimensions

Floor area, total volume and volume below the entrance hole were greater for boxes used by Wood Ducks than those used by other species or unused nest boxes. Soulliere (1990b), summarizing studies of Wood Duck use of natural cavities, concluded that suitable tree cavities were those with entrances of ≥ 9 x 9 cm in diameter, bases > 13 x 18 cm, and inside heights ≥ 23 cm. These values are considerably smaller than the dimensions of nest boxes investigated in this study; for example, basal area of successful nest boxes for Wood Ducks was 790 cm^2.

Entrance-hole dimensions influenced nest box use. Each cavity-nesting species has a particular preference of entrance size (Gauthier 1988; Lumsden et al. 1980; Lumsden et al. 1986); for Wood Ducks, this is the smallest entrance through which females can move easily (Soulliere 1990b). Wood Ducks used nest boxes with smaller entrance holes than were found in boxes used by other species or in unused nest boxes (Table 10). The average area of entrance holes used by Wood Ducks was about 63 cm^2, corresponding to an oval 10.2 x 7.6 cm^2. The recommended size of entrance hole is 10 x 8 cm^2, a size which effectively excludes Raccoons, *Procyon lotor*, the primary nest box predators, yet allows entrance by most female Wood Ducks.

Nest boxes without predator guards were underutilized, possibly because these boxes had been used in previous years and suffered depredation. Wood Ducks appear to have some memory for undesirable nests and as such many unused nest boxes, particularly those without predator guards, may be selected against (Haramis 1990). However, predator guards did not seem to affect nesting success.

Conclusions

Regional location of nest boxes played an important role in the use of nest boxes by Wood Ducks. Eastern Ontario and the Sudbury region were the two areas where the best results were obtained, with the rest of southern Ontario, possibly excluding the Canadian Shield, being potentially suitable.

Nest box use was affected by habitat. Swamps are likely the favoured natural habitat of Wood Ducks but sewage lagoons are a particularly attractive site for nest box programs. Forested areas and bogs were not found to be particularly acceptable sites for nest boxes.

This study suggested that nest boxes built with a floor area of 800 cm^2 (28 x 28 cm) and as tall as 50 cm would be more acceptable to Wood Ducks than to starlings and other passerines. Entrance hole size should be an oval 10 cm x 8 cm. Nest boxes erected on stakes should be placed about 2.5 m above ground (or water), and high visibility must be assured. Wood Ducks use forest stands with approximately 0.1 to 5.5 suitable cavities per hectare (Gilmer et al. 1978), and as such four nest boxes per hectare should be a maximum density in order to minimize competition and dump nesting. A final recommendation from participants is to move a nest box that is not used after two years if other boxes in the area are being used. Boxes located in trees should be oriented so that the entrance hole is in the general direction of the nearest water body with a clear flight path.

Acknowledgments

The *Duck Nesting-box Survey* was made possible by funding from a number of organizations and the help of many volunteers. Coordinators' positions were funded through the Ontario Environmental Youth Corps (OMNR). The Community Wildlife Involvement Program (OMNR) provided funds for information kits, publications, mailings, and office supplies. LPBO provided overall management, office space and equipment. Numerous newspapers, magazines and CBC radio helped by advertising the project. Laurel Whistance-Smith and Margaret McLaren (OMNR) acted as our Wildlife Policy Branch contacts. Rosa Riihimacki co-ordinated the survey in 1990. Special thanks to Margaret McLaren, Laurel Whistance-Smith, Mark Stabb, Harry Lumsden, and David Hussell for their help with the initial design and implementation of the project. The Public Information Centre (OMNR) answered many calls concerning the project, mailed kits, and collected completed surveys. We thank Michael Bradstreet, Tony Erskine, David Hussell and Harry Lumsden for helpful comments on versions of this manuscript. This paper is a contribution of the Long Point Bird Observatory, and is publication 93–04 of the Long Point Waterfowl and Wetlands Research Fund.

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Received 27 January 1993
Accepted 6 December 1993

APPENDIX. Nest box distribution by region and species.

		Region[1]						
Species	Use category	NOR	SUD	CEN	EAS	SOC	SOW	Totals
Wood Duck	total	4	97	7	239	42	121	510
	unknown	0	56	0	31	1	18	106
	unsuccessful	0	4	3	50	12	18	87
	successful	4	37	4	158	29	85	317
Hooded Merganser	total	1	4	4	46	2	7	64
	unknown	0	0	0	0	0	0	0
	unsuccessful	0	1	1	21	0	0	23
	successful	1	3	3	25	2	7	41
Common Goldeneye	total	9	3	0	0	0	0	12
	unknown	3	0	0	0	0	0	3
	unsuccessful	0	0	0	0	0	0	0
	successful	6	3	0	0	0	0	9
European Starling	total	0	4	2	38	20	60	124
	unknown	0	3	0	35	1	6	45
	unsuccessful	0	0	1	1	18	30	50
	successful	0	1	1	2	1	24	29
Eastern Screech-Owl	total	0	0	0	0	0	28	28
	unknown	0	0	0	0	0	15	15
	unsuccessful	0	0	0	0	0	6	6
	successful	0	0	0	0	0	7	7
American Kestrel	total	0	0	1	0	2	7	10
	unknown	0	0	0	0	0	0	0
	unsuccessful	0	0	0	0	0	0	0
	successful	0	0	1	0	2	7	10
Flying Squirrel	total	0	2	2	6	1	0	11
	unknown	0	1	0	1	0	0	2
	unsuccessful	0	1	2	0	1	0	4
	successful	0	0	0	5	0	0	5
other species	total	20	5	0	60	5	88	178
	unknown	0	0	0	13	0	40	53
	unsuccessful	1	5	0	10	0	10	26
	successful	19	0	0	37	5	38	99

[1] Regions are as follows: NOR = Northern Ontario, SUD = Sudbury, CEN = Central Ontario, EAS = Eastern Ontario, SOC = South-central Ontario, SOW = South-western Ontario

Distribution and Movements of Greater Snow Geese, *Chen caerulescens atlantica*, During Fall Staging in the St. Lawrence Estuary, Quebec

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Maisonneuve, Charles, and Jean Bédard. 1993. Distribution and movements of Greater Snow Geese, *Chen caerulescens atlantica*, during fall staging in the St. Lawrence estuary, Quebec. Canadian Field-Naturalist 107(3): 305–313.

Fall staging of neck-banded Greater Snow Geese, *Chen caerulescens atlantica*, along the St. Lawrence estuary in September-November 1985–1987 was characterized by a high rate of inter-site movement. A high proportion of these movements, many of them between the neighbouring Montmagny and Cap Saint-Ignace refuges, were made by only a few individuals. Age and sex had no influence on the mobility of birds, but status had an effect in 1987 when pairs were more mobile than families. In spite of this high mobility, individual birds had a tendency to use the same primary staging sites from year to year. Although some consistent patterns exist in distribution and site faithfulness, selective management of the Greater Snow Goose population during fall staging may be impeded by the behavioral flexibility of geese in response to factors like disturbance, hunting pressure and food availability.

Key Words: Greater Snow Goose, *Chen caerulescens atlantica*, distribution, migration, movements, Québec, staging.

The entire population of the Greater Snow Goose, *Chen caerulescens atlantica*, stops along the St. Lawrence River estuary, Québec, for five to seven weeks during spring and fall migrations. Due to hunting pressure, most geese concentrate in five federal National Wildlife Refuges (NWR) (no-hunting areas) located on the south shore, and in Cap Tourmente National Wildlife Area (NWA) on the north shore where hunting is restricted during fall. Some of the islands between these two areas are also used by staging geese. A recent population expansion from 25 000 geese in 1965 to 400 000 in 1989 (Gauvin and Reed 1987; Reed 1990) has led to intensive use of the refuges with detrimental effects on the vegetation (Giroux and Bédard 1987). Knowledge of the factors influencing goose distribution and movements within the estuary is essential for sound management of the population and for conservation of the intertidal marshes.

In Canada Geese, *Branta canadensis*, many studies have demonstrated the existence of subflocks that use particular areas and remain faithful to them within and over the years (Raveling 1969; Kennedy and Arthur 1974; Koerner et al. 1974; Raveling 1979; Zicus 1981; Craven et al. 1985). Such areas can thus be managed independently. Although it has been shown that high hunting pressure along the St. Lawrence does not seem to speed up the southward migration of particular Greater Snow Goose subflocks (Maisonneuve and Bédard 1992), the existence of discrete managable subflocks within the estuary has never been demonstrated.

In this study, we examined the influence of various factors on the dynamics of distribution and site-faithfulness of neck-banded Greater Snow Geese during their fall stopover. Our objectives were to (1) characterize utilization of staging sites and movements between them, (2) investigate the effects of age, sex and status on site-faithfulness, and (3) investigate the existence of subflocks possibly facing various levels of hunting pressure.

Study Area and Methods

From 1982 to 1987, 2150 Snow Geese were captured during spring staging along the St. Lawrence, and marked with yellow plastic serially coded neckbands and standard United States Fish and Wildlife Service aluminum leg bands. Fall observations were carried out from September to November 1985-1987. Details on the study area, terminology, capture, banding, and sighting techniques are as given by Maisonneuve and Bédard (1992).

Seven observers made daily visits to the refuges and other sites normally frequented by Snow Geese in fall. At each site, goose counts were carried out and these values were summed for the entire season (goose-days). Observers also noted individual neckbands and assigned birds to one of several status categories: (1) solitary, (2) paired, (3) member of a family unit including one or two white-plumaged parent(s) and one or several approximately 3-month-old gosling(s), (4) member of an old family unit including one or two white-plumaged parent(s), one or several white-plumaged subadult birds (and, in only one case, one or several 3-month-olds as well), or (5) unknown.

For the study of goose movements within the estuary, individuals sighted on fewer than three occasions were excluded. The analyses thus were based on observations of 300, 475, and 805 marked birds in 1985, 1986 and 1987, respectively.

A mobility index (I) was calculated for each marked individual:

$$I = d/n$$

where d is the number of movements between sites recorded for the individual, and n is the maximum number of movements that individual would have made if it had changed site on each successive sighting. This index varies from 0, for birds having used only one site, to 1 for birds observed at different sites on each sighting. These indices were used in comparing yearly variations in goose mobility, and in determining the effects of age, sex and status on mobility of birds. Comparisons of mobility index distributions between two samples were made with the Mann-Whitney test, and the Kruskal-Wallis test was used when more than two samples were compared. When the latter revealed significant differences between samples, Noether's multiple comparison test was used to determine which samples differed.

Site-fidelity and philopatry (as distinguished by Myers 1984: 303) analyses were based on utilization of primary staging sites, determined as the site where the majority of observations of an individual were made (Raveling 1979). General philopatry between spring and fall staging sites was determined by comparing fall primary site use to area of capture in spring, the latter being divided in two categories: upper estuary (area where geese are concentrated in fall) and others (areas where no refuges exist and where no fall concentrations occur). Chi-square contingency tests were used for statistical analyses of proportions.

Results

General Use of the Estuary

Typically, Snow Geese arrived in the St. Lawrence estuary in late September and increased steadily to peak numbers by mid-October, this peak being slightly earlier in 1986 (Figure 1). For each year, daily fluctuations in numbers of marked individuals roughly followed total numbers of geese counted (Figure 1). Levels of use in the estuary as a whole were roughly the same from year to year (Table 1). When compared to 1985, the number of goose-days was higher at every site in 1986 except Montmagny and Cap Tourmente; the increase was greater at Ile-aux-Oies. A decrease in goose-days was noted from 1986 to 1987 at all sites except Montmagny, Saint-Vallier and Ile-aux-Oies. During that period, goose-days also increased markedly at two refuges created in 1986, l'Islet-sur-Mer and Rivière Trois-Saumons.

Each year, regular use of the Cap Saint-Ignace NWR began four to five days after the flock at the neighbouring Montmagny NWR, located only 10 km upstream, exceeded 10 000 geese. Geese often completely deserted the Cap Saint-Ignace NWR, but this phenomenon never occurred at Montmagny. In late fall, geese always abandoned the Cap Saint-Ignace NWR before the Montmagny NWR was totally deserted.

Movements

Nearly 70% of the marked individuals observed each year were located on more than one site (Table 2). This proportion of mobile birds was significantly higher in 1986 than in other years (χ^2, df = 2, $P < 0.05$). Each year, the proportion of sedentary geese was highest at Cap Tourmente and Montmagny. No marked individual ever frequented exclusively the Cap Saint-Ignace NWR, although some birds restricted their presence to Ile-aux-Oies in 1986 and 1987.

In all, 212, 375, and 571 marked individuals made 530, 1108 and 1222 movements in 1985, 1986 and 1987, respectively. In 1985 and 1986, nearly half of all movements occurred between Montmagny and Cap Saint-Ignace, this proportion falling to 20% in 1987 (Figure 2). Many birds (54, 87 and 45 in 1985, 1986 and 1987, respectively) made all of their movements between these two adjacent sites.

In some years, most of the movements noticed were made by a few individuals. Only 13% of the birds having made at least five movements made 28% of these movements in 1985, while 18% and 11% of the movements noticed in 1986 and 1987 were ascribable to only 8% and 11% of the marked individuals, respectively. However, 68%, 58% and 26% of these movements occurred between Montmagny and Cap Saint-Ignace in 1985, 1986 and 1987, respectively. If movements between these two sites were excluded, only 11 and 13 individuals made more than four movements in 1986 and 1987, while no marked individual did so in 1985.

Again if movements between Montmagny and Cap Saint-Ignace were excluded, 67% of all movements occurred before 13 October 1985, the time at which 50% of all marked geese observed had reached the estuary. In 1986 and 1987, 52% and 78% of all recorded movements had been made by mid-season (3 and 10 October).

Mobility

Comparison of yearly mobility indices showed that geese were less mobile in 1986 than in other years (Kruskal-Wallis test, df = 2, $P = 0.0001$). Mobility of birds did not vary with age, sex or status in 1985 and 1986 (Table 3). In 1987, however, pairs

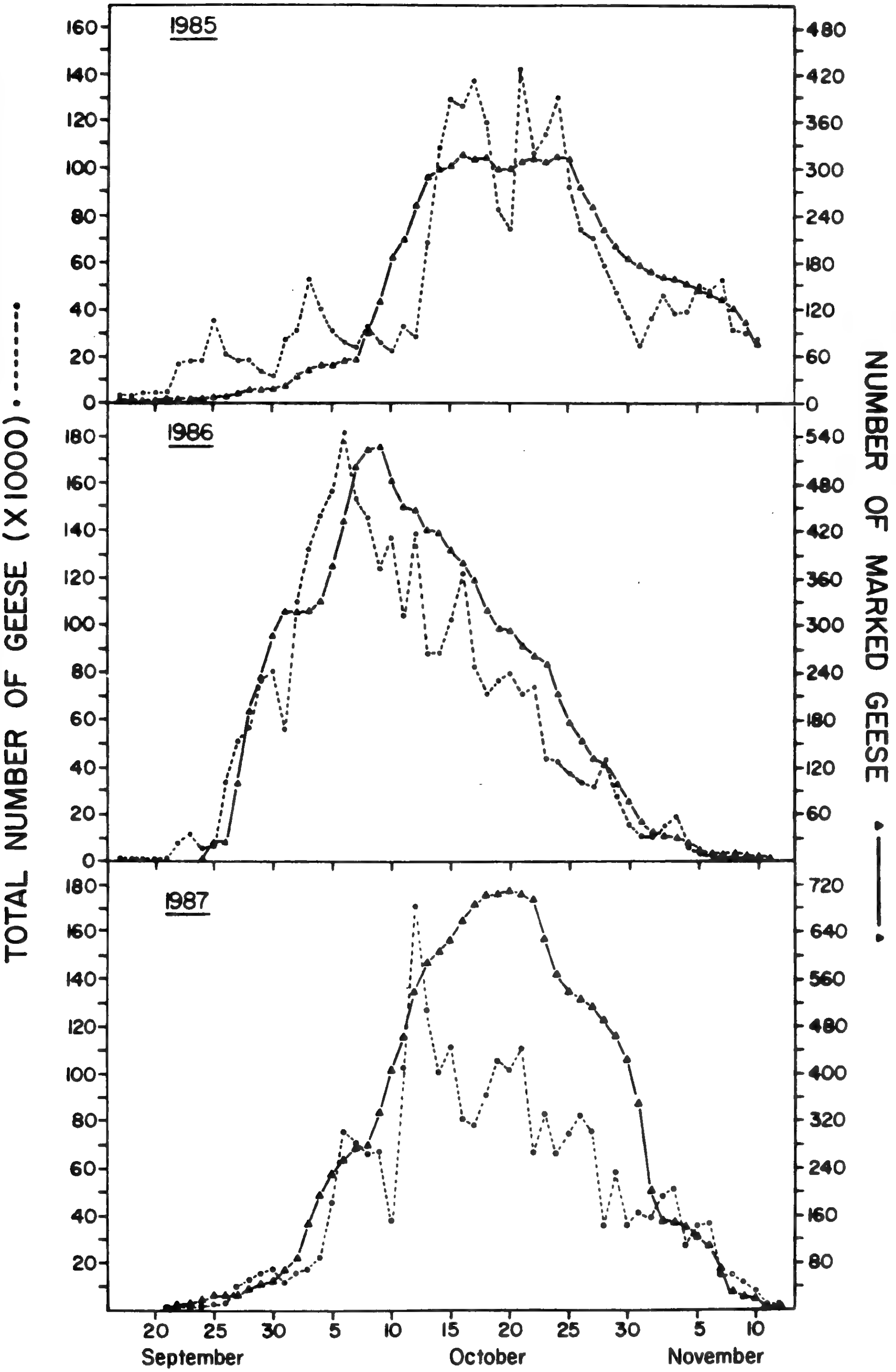

FIGURE 1. Goose use and number of neck-banded Greater Snow Geese observed during fall staging in the St. Lawrence estuary, 1985–1987.

TABLE 1. Fall use (goose-days) by Greater Snow Geese of major staging sites along the St. Lawrence estuary, 1985–1987.

Site	1985	1986	1987
Saint-Vallier	16 626	31 112	46 398
Montmagny	335 800	306 951	305 150
Cap Saint-Ignace	86 725	133 000	64 950
Ile-aux-Grues	277 254	737 000	485 825
Cap Tourmente	1 999 100	1 566 250	1 296 380
Ile-aux-Oies	18 851	331 245	333 195
L'Islet	0	0	8 604
Rivière Trois-Saumons	0	1 500	55 925
Total	2 734 355	3 105 558	2 596 427

without young were more mobile than individuals belonging to either new or old families. A difference in mobility was also observed between age categories, but Noether's multiple comparison test did not enable us to determine which categories were responsible for this difference. Although yearlings seemed less mobile than older birds, yearling sample was small and most of these birds were part of old families which were relatively sedentary.

Site Fidelity and Philopatry

Each year, nearly 70% of all observations were made on the primary sites of the neck-banded birds involved (Table 4). The Montmagny NWR was the preferred site in all three years (Table 5). Cap Tourmente came second in 1985 and 1986, but Ile-aux-Oies was preferred to the latter in 1987. In 1987, 63% of the neck-banded geese observed at the L'Islet and Rivière Trois-Saumons NWRs had Montmagny as primary site.

Yearlings had the same tendency as older birds to use the same primary site when returning the following year (1985 and 1986, n = 25 and 133, 1986 and 1987, n = 15 and 252, χ^2, df = 2, P > 0.25) or two years later (1985 and 1987, n = 17 and 91, χ^2, df = 2, $P > 0.25$).

In 1986 and 1987, males and females were equally faithful to their primary site of 1985 (1986, n = 76 and 82, 1987, n = 52 and 56, χ^2, df = 2, $P > 0.25$) but comparisons between the primary sites of 1986 and 1987 showed a higher philopatric tendency in females (n = 129 and 138, χ^2, df = 2, $P < 0.05$).

Among the neck-banded birds that were located in the estuary each year (n = 90), 64.4% used the same primary site during all three years, 22.2% changed site once, and only 13.3% changed site both years. Proportion of birds having used the same primary site during all three years did not differ between birds that were yearlings (n = 14) or > 1 year old in 1985 (n = 77) (χ^2, df = 2, $P > 0.5$). Sex also had no effect on philopatry (n = 44 and 46, χ^2, df = 2, $P > 0.75$).

During the three years, geese captured in the upper estuary had a higher tendency to use Montmagny as primary site than birds captured elsewhere (Table 6) (χ^2, df = 1-2, $P < 0.001$).

Discussion

A few staging sites in the St. Lawrence estuary were inaccessible to our crews; the Batture-aux-Loups-Marins reef is one of them (Adams 1945), but it probably never harbours more than a few thousand individuals. However, because of high hunting pressure, geese never stayed for long periods at these sites and flocks were forced to move to the refuges where our observers were posted. Recently, increasing flocks of Snow Geese have been observed during fall around Lac Saint-Pierre, located 150 km upstream of the study area. But lack of refuges and high hunting pressure there forced geese to remain on the lake. With restricted feeding opportunities, the flocks moved rapidly out of the

TABLE 2. Proportion of sedentary[1] and mobile[2] neck-banded Greater Snow Geese during fall staging in the St. Lawrence, 1985-1987, and distribution of the sedentary ones.

	1985		1986		1987	
	n	%	n	%	n	%
Sedentary						
Cap Tourmente	56	18.7	46	9.7	93	11.6
Montmagny	25	8.3	38	8.0	82	10.2
Saint-Vallier	4	1.3	2	0.4	4	0.5
Ile-aux-Grues	3	1.0	1	0.2	14	1.7
Ile-aux-Oies	0	0.0	13	2.7	40	5.0
Sub-total	88	29.3	100	21.0	234	29.1
Mobile	212	70.7	375	79.0	571	70.9
Total	300	100.0	475	100.0	805	100.0

[1] Always observed at the same site.
[2] Observed at more than one site.

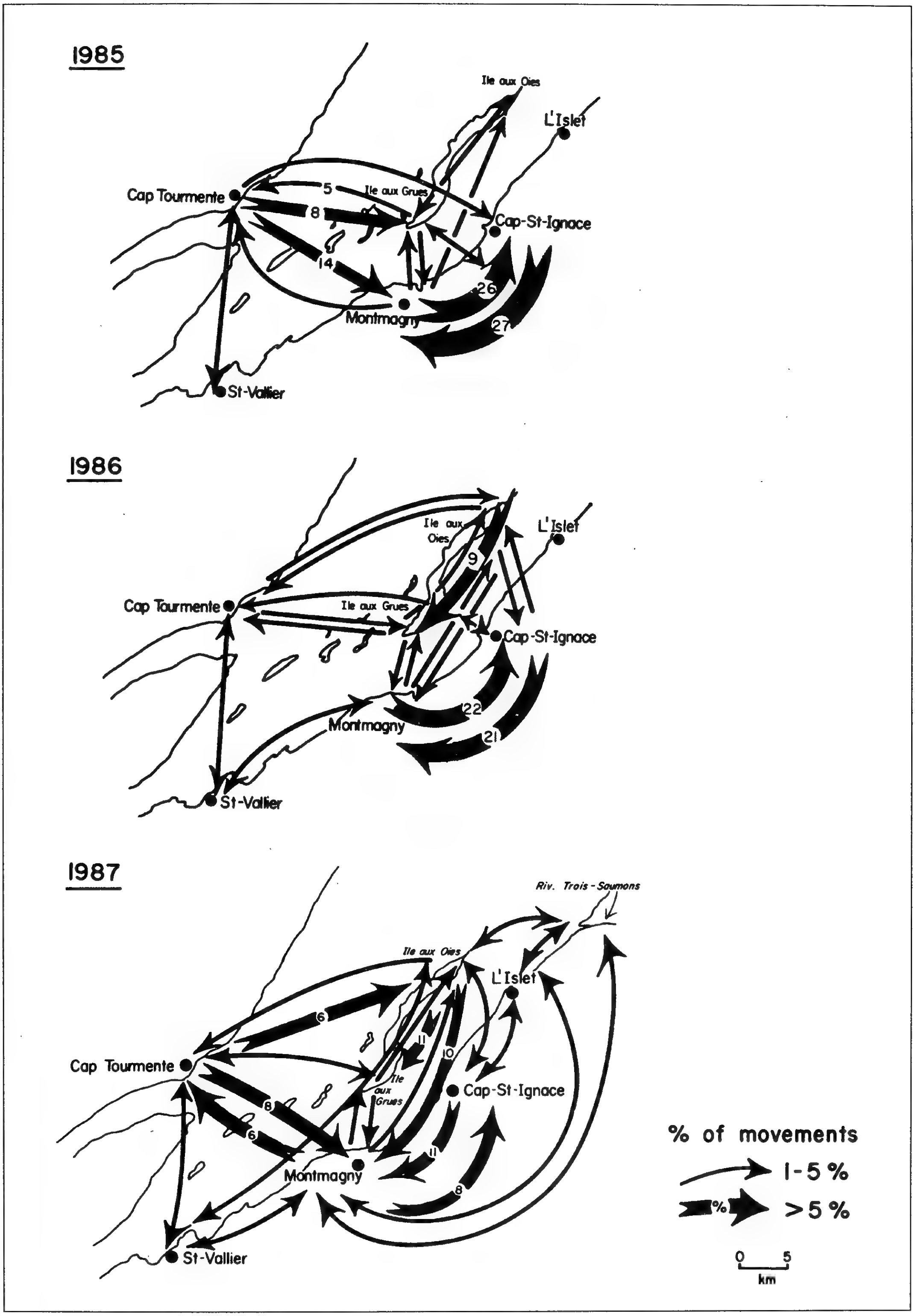

FIGURE 2. Distribution of Greater Snow Goose movements during fall staging in the St. Lawrence estuary, 1985–1987.

TABLE 3. Results of tests comparing distribution of mobility indices of neck-banded Greater Snow Geese of different age, sex and status categories.

Category	1985			1986			1987		
	n	Index	*P*	*n*	Index	*P*	*n*	Index	*P*
Sex[1]									
Male	106	0.40	> 0.5	104	0.26	> 0.5	405	0.44	> 0.5
Female	97	0.42		109	0.26		447	0.44	
Age[1]									
1 year	38	0.37	> 0.1	31	0.23	> 0.1	14	0.33	> 0.1
> 1 year	165	0.42		532	0.26		841	0.44	
Age[2,3]									
1 year	38	0.37	>0.1	31	0.26	> 0.1	14	0.33	< 0.05
2 years	15	0.47		66	0.28		24	0.44	
3 years				19	0.17		43	0.49	
4 years							18	0.41	
Status[2]									
Solitary	16	0.32	> 0.05	2	0.28	> 0.5	0		< 0.0005
Pair	35	0.34		110	0.27		189	0.39	
New family	13	0.24		0			39	0.26	
Old family	32	0.30		56	0.30		22	0.22	

[1] Mann-Whitney test.
[2] Kruskal-Wallis test.
[3] Totals used under "age" differ between tests because geese > 1 year-old also include individuals of unknown age.

area. The fact that 95% of the intervals between successive observations of marked individuals on the staging grounds spanned six days or less, in all three years of this study (Maisonneuve and Bédard 1992), confirmed the efficiency of our resighting efforts and indicated that the chances of missing a neck-collared bird were slight. Moreover, abundance of neck-banded birds sighted closely followed total numbers of Snow Geese observed along the estuary (Figure 1). Thus, we believe that our study, based on the behavior of neck-collared birds, gives an accurate description of the migratory habits of the entire flock.

The proportion of immatures within goose flocks may affect timing of their fall migration, movements and distribution because of the combination of higher energy demands by immatures and family-size related social rank (Lambeck 1990; Raveling and Zezulak 1991). The percentage of immatures noted during our study varied considerably from year to year: 19%, 2% and 27% in 1985, 1986 and 1987, respectively (Maisonneuve and Bédard 1992). Near-total reproductive failure occurred in 1986 as a result of late snowmelt and continued cold weather throughout the summer on the breeding grounds (A. Reed, Canadian Wildlife Service, personal communication). These conditions prompted failed breeders to join early migrating subadults (Maisonneuve and Bédard 1992), which explains the earlier peak in goose-use noted in that year (Figure 1). Furthermore, although more neck-banded geese were observed at more than one site in 1986, the

TABLE 4. Number of observations of neck-banded Greater Snow Geese[1] related to order of staging site use.

Site[2]	1985		1986		1987	
	n	%	*n*	%	*n*	%
1	1560	69.6	2880	66.6	3816	69.0
2	459	20.5	995	23.0	1156	20.9
3	185	8.3	316	7.3	428	7.7
4	33	1.5	110	2.5	114	2.1
5	5	0.2	26	0.6	18	0.3

[1] n = 300, 475 and 805 respectively in 1985, 1986 and 1987.
[2] 1 = primary site (most used site), 2 = secondary site, etc.

TABLE 5. Primary[1] fall staging sites located along the St. Lawrence estuary and numbers of neck-banded Greater Snow Geese found there most often in 1985-1987.

Site	1985		1986		1987	
	n	%	*n*	%	*n*	%
Montmagny	199	66.8	290	62.7	459	57.0
Cap Tourmente	92	30.9	117	25.3	134	16.6
Ile-aux-Oies	0	0.0	43	9.3	188	23.3
Saint-Vallier	4	1.3	2	0.4	4	0.5
Ile-aux-Grues	3	1.0	1	0.2	17	2.1
Cap Saint-Ignace	0	0.0	9	2.0	3	0.4
Riv. Trois-Saumons	0	0.0	0	0.0	1	0.1

[1]Site where an individual was seen most often.

mobility indices were higher in 1985 and 1987, indicating that individual birds made more movements per season in those years. Movements were also distributed more uniformly throughout the season in 1986, whereas mobility peaked before mid-season in 1985 and after mid-season in 1987. This latter high mobility in 1987 could be ascribable to rapidly depleted food stocks or increased hunting pressure at some sites used early in the season. For example, more than 70% of all movements recorded between Ile-aux-Oies and Ile-aux-Grues occurred after 22 October, indicating a probable food depletion in the agricultural fields of Ile-aux-Oies and a forced movement to Ile-aux-Grues. We cannot exclude the possibility that variations in hunting pressure through the season may affect movements and mobility of geese, but we think that reproductive success, through its effects on food availability, also has an indirect influence.

This hypothesis is further supported by the fact that, although age, sex and status of birds had no marked effect on mobility in 1985 and 1986, pairs without young were more mobile than families in 1987. Studies have shown goose families to be dominant over non-breeders (Lamprecht 1986; Black and Owen 1989; Grégoire and Ankney 1990) and some "family-poor" goose flocks have been reported to be more exploratory than others (Lambeck 1990). Thus, higher competition for food due to the relatively high percentage of immatures may have caused pairs to initiate more movements in 1987.

In spite of high numbers of movements recorded each year, the majority of neck-banded geese spent most of their time on a particular staging site during the season and had a tendency to use the same site year after year. Such site-tenacity during staging has been reported in other goose species (Nilsson and Persson 1991), tradition transferred within family groups being mentioned as the main factor for these patterns. This philopatry also seems to be maintained from spring to fall: our results indicated a higher site-faithfulness in individuals that were captured during spring in the upper St. Lawrence estuary as opposed to those captured elsewhere. We suggest that the latter have the same tendency to return to their site of capture in the fall, but the lack of adequate refuges and hunting pressure force them to converge on the upper estuary. Philopatry in geese captured at Montmagny and Cap Saint-Ignace (Maisonneuve and Bédard 1992) may also explain the higher use of Montmagny as primary fall staging site, as geese captured at Cap Saint-Ignace preferred Montmagny because of better conditions there (Giroux and Bédard 1988).

Although there was a relatively high use of the Cap Saint-Ignace NWR from year to year, none of the observed neck-banded geese used this staging site exclusively. This site seemed instead to harbour the overflow of geese originating from the neighbouring Montmagny NWR. As was observed by Giroux and Bédard (1988), Cap Saint-Ignace was used only after the flock at Montmagny had reached 10 000 birds, was often completely deserted and, at the end of the season, was abandoned earlier than

TABLE 6. Primary fall staging sites used by neck-banded Greater Snow Geese in relation to area of capture.

Year	Primary site	Area of capture	
		Upper estuary	Other
1985	Montmagny	114	82
	Cap Tourmente	21	62
	Total	135	144
1986	Montmagny	203	101
	Cap Tourmente	58	55
	Ile-aux-Oies	15	28
	Total	276	184
1987	Montmagny	304	162
	Cap Tourmente	67	65
	Ile-aux-Oies	67	121
	Total	438	348

Montmagny. The majority of yearly movements were made between these two sites (Figure 2) by a relatively small number of individuals. The lower use of the Cap Saint-Ignace NWR is ascribable to the proximity of hunter blinds and accrued disturbance there (Giroux and Bédard 1988).

Two other phenomena emphasized the close relationship between the Montmagny and Cap Saint-Ignace staging sites: (1) goose-day values in 1987 at the newly created L'Islet and Rivière Trois-Saumons NWRs were almost equal to the reduction observed at Cap Saint-Ignace in the same year (Table 1), and (2) the majority of neck-banded geese observed at these new refuges had Montmagny as primary site. Thus, the creation of these refuges has helped to accomodate the excess of geese originating from the Montmagny NWR.

It has been shown that factors such as food availability, disturbance and hunting pressure have more influence than sex, age (Craven et al. 1985), or status (O'Briain and Healy 1991) on fall distribution and movements of fall staging Canada Geese and Brent Geese (*Branta bernicla*). Previous studies on Greater Snow Geese have shown that choice of staging site along the St. Lawrence estuary is influenced by its location relative to neighbouring sites, its area and accessibility to geese under high hunting pressure (Giroux and Bédard 1986), the abundance of *Scirpus americanus* (Giroux and Bédard 1988), and human disturbance (Bélanger and Bédard 1989). Our study demonstrated that flock composition was the only other major factor influencing fall distribution and movements of Greater Snow Geese staging in the St. Lawrence estuary.

Except for high numbers of movements between the Montmagny and Cap Saint-Ignace NWRs, which were made by a few individuals, distribution patterns detected in this study reflected migratory homing to sites within the St. Lawrence staging grounds and a general lack of movement once geese were established there. Such consistent patterns of goose distribution may seem to represent ideal conditions for refuge-flock management, but selective management changes at any one of the staging sites and creation of new refuges are likely to influence goose use of neighbouring sites, particularly for the Montmagny and Cap Saint-Ignace complex.

Such migratory homing, leading groups of birds to always use the same location, may also incite to believe in the existence of stable subflocks within the Greater Snow Goose population. But there is growing evidence that goose breeding units are not maintained throughout their migrations. Studies on Canada Geese (MacInnes 1966; Trost et al 1981; Craven and Rusch 1983; Menkens and Malecki 1991) and Lesser Snow Geese (*Chen caerulescens caerulescens*) (Cooke et al 1975) indicate that associations of birds marked on the breeding grounds are not maintained after this season. Only Raveling (1979) has concluded otherwise. But, as Owen (1980) argued, the results of Raveling's study are based on a small sample and it is not mentioned if family relationships existed among the birds studied, thus influencing associations. Moreover, Tacha et al. (1988) have shown that Canada geese of the Mississippi Valley population associated with fall staging sites, specific refuges, or roosting sites within refuges located in the U.S.A. do not constitute subpopulations with discrete breeding distributions.

As discussed in this study, Greater Snow Geese demonstrate some behavioral flexibility in response to particular factors like disturbance, refuge location and food availability. Furthermore, fall staging in the St. Lawrence is characterized by a steady turnover (Maisonneuve and Bédard 1992), departing geese constantly being replaced by arriving ones. We believe that this turnover is a factor precluding the formation of stable subflocks in Greater Snow Geese, as reported in staging Bean Geese (*Anser fabalis*) (Nilsson and Persson 1991). This is further strengthened by the fact that, except for families, no continued association was ever observed between our neck-banded individuals during fall staging in the St. Lawrence (Maisonneuve and Bédard, unpublished data).

Patterns of site-faithfulness described in this study do not necessarily reflect continued associations of geese from specific nesting areas. If flock subunits exist on the breeding grounds, as was shown for the Lesser Snow Goose (Cooke et al. 1983), these may break up prior to or during the fall migration. Available evidence does not point to the existence of flock structure in wintering Lesser Snow Geese (Smithey et al 1973; Schroer and Chabreck 1975), and we think that associations of Greater Snow Geese using the same staging sites may not be maintained once these birds leave the St. Lawrence estuary.

Acknowledgments

Financial support was provided by Natural Sciences and Engineering Research Council of Canada, the Ministère de l'Éducation du Québec (FCAC program) and by the Ministère du Loisir, de la Chasse et de la Pêche du Québec. We wish to thank A. J. Erskine and an anonymous reviewer for helpful comments on the manuscript. We also are grateful to G. Picard and G. Rochette for participation in many phases of the project, L. Dumont for correcting the English text, numerous people who helped with the field work, and the Cap Tourmente National Wildlife Area for help and accommodation.

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Received 9 February 1993
Accepted 21 September 1993

Migration of Bonaparte's Gull, *Larus philadelphia*, in Southeastern Manitoba

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Taylor, Peter. 1993. Migration of Bonaparte's Gull, *Larus philadelphia,* in southeastern Manitoba. Canadian Field-Naturalist 107(3): 314–318.

Over 450 records of Bonaparte's Gulls in the Pinawa-Lac du Bonnet region of southeastern Manitoba were analysed and compared with broader regional patterns of occurrence. Spring migration of adults was brief (90% between 10 and 22 May); subadults migrated somewhat later, and sometimes lingered into the summer. Fall migration was more drawn-out (90% between 23 August and 14 October), with greater use made of sewage lagoons. The proportion of juveniles seen in fall flocks varied between 0 and about 85%, but was usually < 30%. Large flocks of Bonaparte's Gulls, almost all adults, often remained on Lake Winnipeg well after the main fall movement along the Winnipeg River. Such birds may contribute to a second migration wave reported for the lower Great Lakes. Observations on molt, and association of vagrant gulls with flocks of Bonaparte's Gulls, were summarized. A migration divide may exist in the western Prairie Provinces, between populations wintering on the Pacific and on the Atlantic and Gulf coasts.

Key Words: Bonaparte's Gull, *Larus philadelphia*, Manitoba, migration.

Braune (1989) described continental patterns in the fall migration of Bonaparte's Gulls, *Larus philadelphia,* in terms of Atlantic, Mississippi and Pacific flyways. She suggested that birds from the Prairie Provinces and farther north fly southeast to the Great Lakes, then via the Mississippi to the Gulf Coast. Two notable aspects of this migration in the Niagara River-eastern Lake Erie region are: (i) the occurrence of two distinct waves of birds, in August-September and November-December; and (ii) the scarcity (< 3%) of juveniles (Beardslee 1944; Braune 1989).

This article describes in detail the migration patterns of Bonaparte's Gull in southeast Manitoba on the basis of 17 years of observations on or near the Winnipeg River in the Pinawa-Lac du Bonnet area (Figure 1), and less systematic fall observations on Lake Winnipeg. These observations give some clues to possible origins of the two fall migration peaks in the Niagara/Lake Erie region.

The known nesting range of Bonaparte's Gull in Manitoba extends less far south than indicated by Braune (1989, after Godfrey 1986). There is no recent evidence of breeding southeast of Lake Winnipeg (Taylor 1985). Aerial observations by Koonz (1986) indicated that the breeding distribution in Manitoba east of Lake Winnipeg may extend south to about 51°N latitude. In adjoining regions of northwestern Ontario, the known breeding range extends south to about 52°N (Blokpoel 1987). Therefore, the observations discussed here refer entirely to migrants and non-breeding summer visitors (see Figure 1).

Methods

Observations of Bonaparte's Gulls along or near the Winnipeg River between Pinawa and Great Falls, Manitoba, were recorded from September 1975 to October 1992. Records normally included date, flock size, location, and sometimes notes on plumage and behaviour. Records were most complete and detailed for the periods 1978–1985 and 1988–1991, and the following discussion is based mainly on compiled observations from those 12 years. The observations totalled 459 records and 21 732 individuals, including repeat observations of the same flocks on different dates, which probably accounted for 30-50% of these totals. Less systematic records from inshore waters of the south basin of Lake Winnipeg, mostly between Patricia and Victoria beaches, are also discussed.

Results and Discussion

Figure 2 depicts total numbers of observations recorded in the 12-year compilation, arranged in a histogram by 10-day intervals. The figure includes information on flock sizes observed at three sewage lagoons (Pinawa, Lac du Bonnet and AECL Research's Whiteshell Laboratories). All three lagoon systems are within 1 km of the Winnipeg River.

Spring migration of adults

Adult Bonaparte's Gulls in breeding plumage passed swiftly through the study area in May (90% between 10 May and 22 May; median 13 May). Some individuals and flocks visited sewage lagoons to rest and feed, and others paused on the Winnipeg River and associated lakes, but many appeared to pass through the area without stopping.

Two spring observations of heavy migration occurred outside the 12 years of the main compilation. On the morning of 15 May 1976, about 10 low-

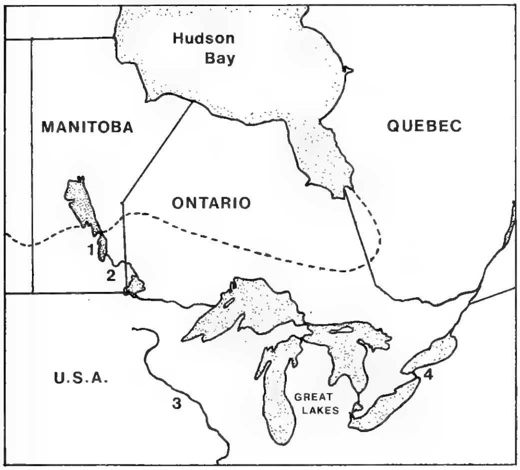

FIGURE 1. Central Canada and adjoining United States. Dashed line is the estimated southern limit of Bonaparte's Gull breeding range. Numbered features are: 1-Lake Winnipeg; 2-Winnipeg River; 3-Mississippi River; 4-Niagara River.

flying flocks of 20 to 40 Bonaparte's Gulls passed northward ovr Pinawa within an hour. On the morning of 10 May 1986 about 400 Bonaparte's Gulls, in flocks of 30 to 100 birds, arrived from the south and swirled down to rest at standing water in a field 3 km southeast of Whitemouth. Later on that morning, flocks totalling 570 birds migrated past Seven Sisters dam, flying west then north to follow the Winnipeg River, some of them pausing on Natalie Lake (the dam forebay).

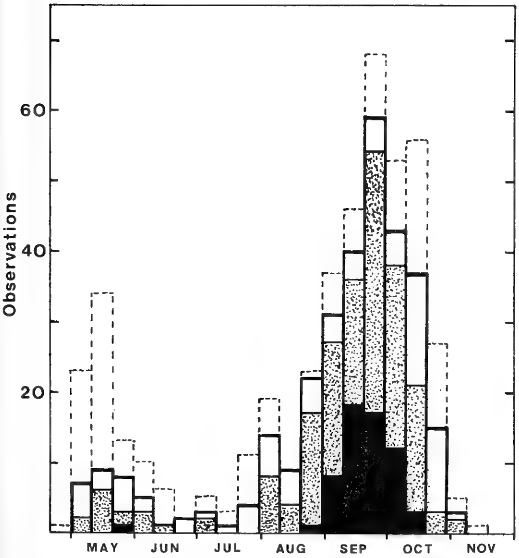

FIGURE 2. Records of Bonaparte's Gulls in Pinawa - Lac du Bonnet region, Manitoba, 1978-1985 and 1988-1991. Dashed outline = all records; solid outline = records at sewage lagoons. Flock sizes at sewage lagoons: >100 (black). 11-100 (stippled), <11 (open).

There are 13 other May records of actively migrating flocks of 8 to 100 birds (mean 41, most commonly 30 to 40 birds), usually heading north or northwest. These flocks sometimes flew extremely low, hugging the terrain within a few metres, when facing adverse winds. Small flocks of Common Terns, *Sterna hirundo*, sometimes migrated in similar fashion on the same dates as Bonaparte's Gulls. A concentration of 170 Bonaparte's Gulls fed on the Winnipeg River, 2 km downstream from Seven Sisters dam, 17 May 1990. The largest spring flock of adults at a sewage lagoon totalled 106 (plus one subadult) at the Whiteshell Laboratories, 13 May 1986. Nocturnal migration was recorded only on 19 May 1988, when Bonaparte's Gull calls were heard over Pinawa at 00:30.

Spring and summer subadults

Whereas a few subadult birds often associated with the mid-May flocks of adult Bonaparte's Gulls, flocks in which subadults predominated sometimes occurred between late May and mid-June. Those birds accounted for the "tail" on the spring migration peak in Figure 2. Numbers were usually low (< 30 birds), but higher counts were made in 1989: 115 (including only 5 adults) at the Lac du Bonnet sewage lagoons 29 May and 70 to 80 (1 adult) at the Pinawa lagoons 3–5 June. Small groups of subadults (usually 12 birds or fewer) were sometimes found along the Winnipeg River in June and July. About 50 lingered at the Lac du Bonnet lagoons, 16 June 1985. Similar summer records of yearling Bonaparte's Gulls were reported in extreme SE Manitoba and N Minnesota, and also in the Qu'Appelle Valley, Saskatchewan (Ferguson 1981; Janssen 1987; Callin 1980)

Fall migration

The fall migration of Bonaparte's Gulls along the Winnipeg River extended from late July to early November, with a peak between mid-September and early October (Figure 2). Heavier use was made of sewage lagoons in fall than spring (Figure 2), and lagoon flocks accounted for about 80% of fall observations. Ninety percent of the fall migrants seen in the 12-year compilation occurred between 23 August and 14 October (median, 22 September).

Flocks of over 100 Bonaparte's Gulls were recorded at sewage lagoons between 27 August and 15 October. Concentrations sometimes exceeded 200 birds, and the highest count was about 500, at the Pinawa lagoons 2–5 October 1983. The sewage lagoon flocks appeared to feed mainly on emerging insects or other minute prey on or near the water surface. They also engaged in aerial hawking for insects, sometimes (in August) in loose association with Black Terns, *Chlidonias niger*, swallows (Hirundinidae) and Common Nighthawks, *Chordeiles minor*. At dusk, the gulls usually flew to broad stretches of the nearby Winnipeg River to roost. The largest flock observed feeding on the River totalled about 200 birds, near the confluence of the Whitemouth River 10 September 1992. The few fall records of actively migrating flocks mostly involved fewer than 20 birds, heading south or east along the Winnipeg River.

Proportions of adult vs. immature (mostly first year) Bonaparte's Gulls were estimated for 85 observations of flocks of 40 or more birds, mostly in 1989–1992. Only five flocks consisted entirely of adults, but another 50 flocks had > 90% adults. An additional 24 flocks had between 70% and 90% adults, while immatures exceeded 30% in only six flocks. The highest proportions of immatures occurred in two flocks at the Pinawa lagoons: about 85% of 255 birds 11 October 1989, and 50% of 350 to 400 birds 29 September 1990. On the latter date, a flock of 250 birds at the Lac du Bonnet lagoons consisted mainly (> 90%) of adults. There thus appeared to be some partitioning of adult and juvenile birds during this drawn-out fall movement, but exclusively adult flocks were uncommon and exclusively immature flocks unknown, except for very small groups (< 10 birds). Adults predominated in most flocks.

Both adult and immature Bonaparte's Gulls showed evidence of molt during the fall migration. Adults observed in late July and early August usually had intact black hoods, but head molt was well advanced by mid-August. In most individuals, the hood was reduced to the black auricular spots of winter plumage by the end of August. Many adults showed obvious flight-feather molt (missing primaries) in the second half of August, and had a somewhat short-winged appearance in the first half of September as the outer primaries grew in. By October, adult molt appeared to be complete. In early August, most juveniles had extensive dusky markings on the wings and upper parts; by October, this was usually reduced to the carpal bars and terminal tail-band. Between mid-August and early October, as the postjuvenal molt progressed, a lot of individual variation in the extent of molt was observed.

Observations in the southern basin of Lake Winnipeg, mainly between Patricia Beach and Victoria Beach (Table 1), showed that large numbers of adult Bonaparte's Gulls often, but perhaps not annually, remained there long after the peak of the drawn-out migration along the Winnipeg River. Most spectacular was the total of 6500 birds estimated on 21 October 1990. Careful observation of several thousand birds on that date showed that over 99% were adults. Similarly, over 1000 birds observed closely in the Matlock-Hecla region 19 October 1991 included only 1–2% immatures.

TABLE 1. Late fall concentrations of Bonaparte's Gulls on Lake Winnipeg, south basin.

Date	Location*	Number
6 October 1982	East beaches	2000
31 October 1982	East beaches	800
5 November 1983	East beaches	2000+
1 November 1986	East beaches	1000
1 October 1988	East beaches	1000
30 October 1988	East beaches	2500
6 November 1988	East beaches	3000
28 October 1989	East beaches	3000
21 October 1990	East beaches	6500
27 October 1990	East beaches	"thousands"
3 November 1990	East beaches	"hundreds"
19 October 1991	West shore**	4100

Note: all dates but two were after the 95th percentile (14 October) of fall migration counts along the Winnipeg River. Records were compiled from field notes of D. Fast, R. F. Koes and P. Taylor.

*"East beaches" = Patricia, Grand and Victoria Beaches, including Grand Marais.

**"West shore" = Matlock to Hecla Island.

These late flocks on Lake Winnipeg divided their time between resting on undisturbed beaches or mudspits and feeding over the lake. Feeding flocks sometimes concentrated low over small areas on the lake, heading into the wind, dipping into the water, and peeling back when they reached the front of the flock (like a rolling flock of foraging blackbirds in reverse). This behaviour suggested large near-surface concentrations of small aquatic prey. It would be useful to know what prey species are utilised by the gulls in this important staging area.

Little is known about the departure of these large, late flocks of adult Bonaparte's Gulls from Lake Winnipeg. Clearly, they did not tarry along the Winnipeg River. Rudolf Koes (personal communication) observed a migrating flock of 50 Bonaparte's Gulls near Pinawa, 11 November 1982. Most of these late migrants probably leave Manitoba by a long-distance flight, perhaps to Lake Superior. These birds might contribute subsequently to the large November-December wave of Bonaparte's Gulls on the lower Great Lakes. The earlier migration of both adults and immatures may contribute to the earlier wave on the lower Great Lakes. The scarcity of immatures in the latter region, however, suggests that many of the birds that follow the Winnipeg River may subsequently take a more direct route to the Mississippi flyway, without moving as far east as Lake Erie (see Figure 1). The indirect route via the lower Great Lakes to the Mississippi, proposed by

TABLE 2. Vagrant gulls observed with Bonaparte's Gulls in the Pinawa-Lac du Bonnet region.

Date	Location	Identity	Reference
4 September 1977	Lac du Bonnet*	Adult Sabine's	Taylor (1978, 1985)
19-20 September 1982	Natalie Lake	Immature** Sabine's	Taylor (1985)
2-7 September 1987	Lac du Bonnet*	Immature Sabine's	MORC***
5 September 1988	Pinawa*	Immature Little	Taylor (1991)
6-7 September 1991	Lac du Bonnet*	Adult Sabine's	MORC
5-6 September 1992	Pinawa*	Adult Sabine's	MORC
7-8 August 1993	Winnipeg R. near Pinawa bridge	Immature Little	MORC

*Observed at sewage lagoons.

**All immatures were hatching-year birds.

***MORC = Description on file with Manitoba Ornithological Records Committee, c/o Manitoba Museum of Man and Nature, Winnipeg.

Braune (1989), seems improbable; a Great Lakes stopover by birds bound for the Atlantic coast is more logical (see Figure 1).

In Minnesota, fall migration of Bonaparte's Gulls extends from late July to late November with a peak in September (Janssen 1987), but no mention was made of a second peak. Nicholson (1981) referred to "variable peaks, mid-September to mid-October … [maximum] 100, 27 September 1980" at Manitoulin Island, Lake Huron. This suggested a similar but slightly later movement to that along the Winnipeg River in fall.

Whatever the relationship between movements in Manitoba and on the Great Lakes, Bonaparte's Gulls exhibited two distinct strategies in their migration out of Manitoba in fall. Immatures and some adults made a seemingly leisurely withdrawal while molting. However, large numbers of adults lingered on Lake Winnipeg until after flight-feather molt was complete, then made a late, direct departure from the province.

A possible migration divide?

Many waterbirds with broad continental breeding ranges display a "migration divide" between populations wintering on the Pacific and the Atlantic and/or Gulf coasts. Such divides have been documented, e.g., for Buffleheads *Bucephala albeola* in Alberta (Erskine 1972) and White-winged Scoters *Melanitta fusca* in Saskatchewan (Houston and Brown 1983). Salt and Salt (1976) referred to mass southwestward departure (towards the Pacific coast) of Bonaparte's Gulls from lakes in central Alberta in October. Thus, a migration divide likely exists for this species as well, in either Alberta or Saskatchewan. This differs from the broad patterns of migration in western Canada depicted by Braune (1989). There is little doubt, however, that fall migrants in the eastern half, at least, of the Prairie Provinces are bound for the Great Lakes or the Mississippi flyway.

Association of vagrant gulls with Bonaparte's Gulls

Many inland North American reports of Sabine's Gull *Xema sabini* and Little Gull *Larus minutus* refer to their association with Bonaparte's Gulls. Careful scrutiny of Bonaparte's Gull flocks in the Pinawa-Lac du Bonnet area since 1975 has turned up three adult and two immature Sabine's Gulls and two immature Little Gulls; most of these records were in early September (Table 2). Franklin's Gulls, *Larus pipixcan*, occurred abundantly in the Beausejour-Stead area, about 30 km west of Lac du Bonnet, but in most years they were scarce along the Winnipeg River. However, one or two immature Franklin's Gulls often associated with Bonaparte's Gull flocks at sewage lagoons in September. It is possible that such associations lead to some eastward vagrant occurrences of Franklin's Gull; e.g., on the lower Great Lakes.

Acknowledgments

I am grateful to R. F. Koes, W. H. Koonz and R. Zach for helpful comments; I also thank R. F. Koes for some of the information on fall flocking on Lake Winnipeg.

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Received 23 November 1992
Accepted 11 November 1993

Additions aux Boletaceae (Boletales) du Québec

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Lamoureux, Y., et P. Neumann. 1993. Additions aux Boletaceae (Boletales) du Québec. Canadian Field-Naturalist 107(3): 319–328.

À partir de récoltes récentes effectuées dans la région de Montréal, dix espèces de Boletaceae (Boletales, Basidiomycotina) sont ajoutées à la flore mycologique du Québec: *Boletus caespitosus* Peck, *B. hortonii* Smith & Thiers, *B. huronensis* Smith & Thiers, *B. lignicola* Kallenbach, *B. sensibilis* Peck var. *sensibilis* Smith & Thiers, *B. separans* Peck var. *subcaerulescens* (Dick & Snell) Smith & Thiers, *Gyroporus purpurinus* (Snell) Singer, *Leccinum griseum* (Quélet) Singer, *L. insolens* var. *brunneomaculatum* Smith, Thiers & Watling et *L. luteum* Smith, Thiers & Watling. Pour chacune de ces espèces, les auteurs présentent une description et une photographie, et discutent des confusions possibles avec les espèces apparentées.

Ten species of Boletaceae (Boletales, Basidiomycotina) are added to the mycological flora of Québec following recent collections in the Montréal region, namely: *Boletus caespitosus* Peck, *B. hortonii* Smith & Thiers, *B. huronensis* Smith & Thiers, *B. lignicola* Kallenbach, *B. sensibilis* Peck var. *sensibilis* Smith & Thiers, *B. separans* Peck var. *subcaerulescens* (Dick & Snell) Smith & Thiers, *Gyroporus purpurinus* (Snell) Singer, *Leccinum griseum* (Quélet) Singer, *L. insolens* var. *brunneomaculatum* Smith, Thiers & Watling and *L. luteum* Smith, Thiers & Watling. For each of these taxa, a description and a photograph are presented, and possible confusions with similar species are outlined.

Mots-clefs: Boletales, Boletaceae, *Boletus*, *Gyroporus*, *Leccinum*, Québec, macromycètes, additions.

La famille des Boletaceae (Boletales, Basidiomycotina) représente une partie importante de la flore des champignons charnus du Québec. La majorité des espèces fructifient en été et au début de l'automne; d'autres peuvent apparaître dès la fin du mois de mai ou tard à l'automne. La grande majorité des Boletaceae sont considérés comme des champignons ectomycorhiziens et leur capacité de s'associer aux arbres semble être restreinte à une ou quelques essences.

Dans l'est de l'Amérique du Nord, de nombreux auteurs ont porté une attention particulière aux Boletaceae durant les dernières décennies (Mazzer et Smith 1967; Pomerleau 1964; Pomerleau et Smith 1962; Smith 1966; Smith et Thiers 1964, 1966, 1967, 1968a, 1968b; Smith et al. 1966, 1967). Suite à ces études, quatre ouvrages majeurs, soit ceux de Snell et Dick (1970), de Smith et Thiers (1971), de Grund et Harrison (1976) et de Singer (1977), ont permis une meilleure compréhension des espèces nord-américaines. D'autres travaux sont ensuite venus clarifier le statut de certaines espèces et de nouvelles entités ont été décrites (Grund et Harrison 1974, 1975; Halling 1983; Redhead et Watling 1979; Smith 1973; Thiers 1976, 1979; Weber 1979; Wolfe 1979, 1981, 1983, 1986, 1987, 1988, 1990). Les clés de détermination des Boletaceae du Québec les plus complètes sont actuellement celles de la *Flore des Champignons au Québec* et de son supplément (Pomerleau 1980, 1984). Ces clés comprennent 85 espèces.

L'objectif de cet article est de faire état de la présence de quelques espèces de Boletaceae non incluses dans les ouvrages de Pomerleau (1980, 1984) ou dont la présence au Québec n'était pas certaine jusqu'à ce jour. Cette étude a été réalisée dans le but d'effectuer l'inventaire des macromycètes de la région de Montréal.

Présentation des espèces

Pour chacune des espèces traitées, nous présentons une description des caractères macroscopiques faite à partir de spécimens frais et une photographie. La largeur du stipe indiquée est celle telle que mesurée à l'apex. L'observation des caractères microscopiques a été faite dans le réactif de Melzer ou dans le KOH 5 %, sur le matériel frais ou après dessication. Nous indiquons à la suite de la description les collections étudiées, incluant le nom des localités où l'espèce a été récoltée, la date (année-mois-jour) de récolte de la collection, l'habitat et son numéro d'herbier. Nous résumons ensuite les caractères distinctifs de l'espèce et présentons une discussion sur les risques de confusion avec les espèces apparentées.

Les symboles LAM et CMMTL qui suivent les numéros des collections signifient que celles-ci ont été déposées respectivement dans l'herbier de Y. Lamoureux ou dans celui du Cercle des mycologues de Montréal. Un ou plusieurs spécimens de chaque espèce présentée ont été déposés à l'Herbier national de mycologie du Canada (Centre de recherches sur les terres et les ressources biologiques, Agriculture Canada, Ottawa, Ontario). La collection dont un échantillon a été déposé à l'Herbier national est suivie du symbole DAOM (Department Agriculture

FIGURE 1. *Boletus caespitosus* (*Lamoureux 1343*).

Ottawa Mycology) et de son numéro d'herbier. Toutes les collections ont été déterminées par Y. Lamoureux et l'identification des spécimens déposés à l'Herbier national a été confirmée par S. A. Redhead du Centre de recherches sur les terres et les ressources biologiques (Agriculture Canada, Ottawa).

Boletus caespitosus Peck, Torrey Bot. Club Bull. 27: 17. 1900. (Figure 1).

Pileus de 80-130 mm de diamètre; convexe, puis étalé; à marge régulière, un peu relevée à la fin; sec, plus ou moins subtomenteux, aréolé avec l'âge; brun rougeâtre au centre, vineux vers la marge. *Chair* ferme; d'épaisseur moyenne; jaunâtre dans le pileus, rougeâtre sous le pileipellis, blanchâtre à brunâtre dans le stipe, immuable; à odeur faible, à saveur acidulée. *Tubes* adnés, puis un peu déprimés; atteignant 12 mm de longueur à mi-rayon; jaune ocré; aux pores ronds ou un peu anguleux, de 1 mm de largeur, concolores, virant au brun-jaune au froissement. *Stipe* 70-90 x 14-32 mm; égal, parfois évasé dans le haut, à base rétrécie en pointe; ferme; plein; viscidule, finement furfuracé, non réticulé; brun-orange sur fond jaune, devenant noirâtre avec l'âge ou au contact, surtout vers la base. *Mycélium* jaune vif à la base du stipe. *Sporée* brun olive. *Basidiospores* 9-11 x 3,5-5 µm, elliptiques-fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 28-34 x 8-10 µm. *Pleurocystides* atteignant 58 x 12 µm, fusiformes. *Pileipellis* formé d'une couche compacte d'hyphes entremêlées, de 5-9 µm d'épaisseur.

Collection étudiée: Nicolet (46°16′47″N., 72°33′30″O.), 91-08-10, cespiteux ou grégaire sous *Quercus rubra*, *Fagus grandifolia* et *Acer saccharum*, *Lamoureux 1343* (CMMTL), (DAOM 213282).

B. caespitosus est caractérisé par son chapeau brun rougeâtre, ses tubes jaune ocré brunissant au froissement, sa chair immuable, son stipe brun-orange noircissant à la base et son mode de croissance cespiteux. Selon Snell et Dick (1970), il peut être confondu avec *B. auriporus* Peck, une espèce affine aux spores plus grandes et au mycélium blanc, qui croît dans les bois de chênes et de châtaigniers, du Québec jusqu'au nord de la Floride. Nous avons récolté une espèce proche (non identifiée) de *B. caespitosus* qui en diffère par son pileus plus pâle, son stipe sec et une odeur nette de *Scleroderma citrinum* Pers. [*Lamoureux 1724* (CMMTL)]. Snell et Dick (1970) indiquent que *B. caespitosus* a été récolté en Nouvelle-Écosse, en Virginie et en Caroline du Nord. Il semble très rare au Québec: nous ne l'avons observé qu'une seule fois

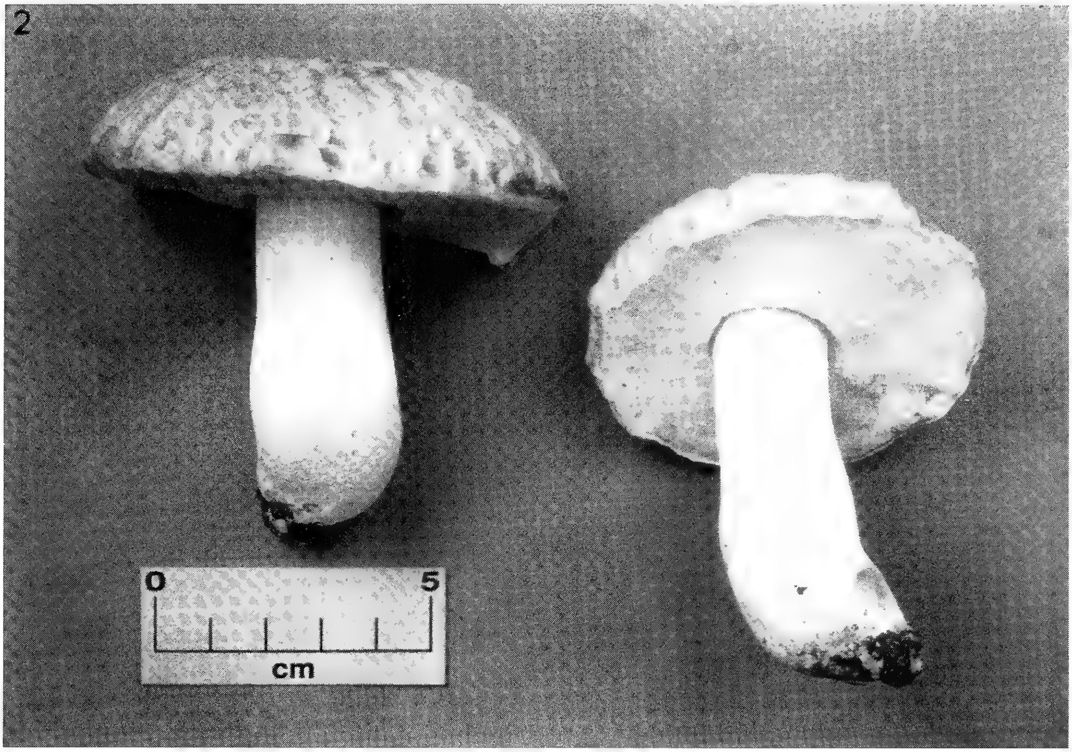

FIGURE 2. *Boletus hortonii* (*Lamoureux 1408*).

dans une mince bande de forêt feuillue, après une période de temps très chaud et sec.

Boletus hortonii Smith & Thiers, The Boletes of Michigan, p. 319. 1971. (Figure 2).

Pileus de 72-82 mm de diamètre; convexe, parfois un peu déprimé au centre; à marge un peu irrégulière, pruineuse; sec, glabre, profondément ridé-alvéolé; au pileipellis dépassant la marge de 1,5 mm; brun-orange, brun-rose ou ocre rosé. *Chair* ferme; épaisse (atteignant 14 mm d'épaisseur à mi-rayon); blanchâtre, jaunissant lentement mais vivement au-dessus des tubes à la coupe, brunie aux endroits infestés par les larves; à odeur faible, à saveur acidulée. *Tubes* déprimés; atteignant 10 mm de longueur à mi-rayon; jaunes; aux pores ronds et petits (2 par mm), concolores et immuables au froissement. *Stipe* 60-67 x 20-22 mm; égal, à base un peu épaissie; ferme; plein; sec, furfuracé, avec un fin réseau d'environ 10 mm de longueur produit par le prolongement des tubes dans la partie supérieure; jaune, jaune brunâtre vers le bas. *Sporée* brun olive. *Basidiospores* 11-15 x 3,5-5 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 28-30 x 8-10 µm. *Pleurocystides* atteignant 48 x 14 µm, fusiformes-ventrues. *Pileipellis* formé d'une couche d'articles courts et renflés surmontée d'éléments plus étroits atteignant 90 µm de longueur.

Collections étudiées: St-Bruno-de-Montarville (45°32′26″N., 73°19′30″O.), 91-08-18, sous *Tsuga canadensis*, *Quercus rubra* et *Fagus grandifolia*, *Lamoureux 1408* (CMMTL), (DAOM 213280), et 91-08-19, sous *Quercus rubra* et *Fagus grandifolia*, *Lamoureux 1412* (CMMTL).

B. hortonii se distingue par son pileus fortement ridé-alvéolé, son stipe et ses tubes jaunes, et sa chair blanchâtre jaunissant à la coupe. Smith et Thiers (1971) indiquent que la chair et les tubes peuvent parfois virer lentement et faiblement au bleu sur certains spécimens. Cette espèce peut être confondue avec *Leccinum rugosiceps* (Peck) Singer, au pileus semblable mais au stipe couvert de rugosités noirâtres à maturité (Smith et Thiers 1971), et avec *B. subglabripes* Peck, une espèce affine très commune dont le pileus est parfois un peu alvéolé, mais au pileipellis présentant des caractères microscopiques différents. *B. hortonii* semble rare au Québec: nous ne l'avons récolté qu'à deux endroits au Parc du Mont-St-Bruno. Phillips (1991) mentionne qu'il est plutôt rare en Amérique du Nord où il croît dans l'est du continent jusqu'au Michigan.

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FIGURE 3. *Boletus huronensis* (*Lamoureux 1178*).

Boletus huronensis Smith & Thiers, The Boletes of Michigan, p. 306. 1971. (Figure 3).

Pileus de 129 mm de diamètre; convexe; à marge régulière; sec, subtomenteux, finement fibrilleux par endroit; brun jaunâtre. *Chair* ferme; épaisse (atteignant 25 mm d'épaisseur près du stipe); jaunâtre, devenant un peu verdâtre au-dessus des tubes à la coupe, jaune vif après 30 minutes; à odeur un peu aigre-acidulée, à saveur douce. *Tubes* presque libres; atteignant 12 mm de longueur à mi-rayon; jaunes, bleuissant puis brunissant à la coupe; aux pores ronds et petits (2-3 par mm), concolores, devenant rapidement bleus au froissement. *Stipe* 110 x 30 mm; clavé et robuste; ferme; plein; sec, glabre à finement furfuracé de points bruns par endroit, non réticulé; jaune vif dans la partie supérieure et jaune brunâtre vers le bas. *Sporée* non obtenue, brun olive foncé selon Grund et Harrison (1976).

Basidiospores (par section des tubes) 12,5-17,5 x 4-5 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 28-30 x 8-10 µm. *Pleurocystides* atteignant 52 x 12 µm, fusiformes-ventrues. *Pileipellis* formé d'une couche d'hyphes entremêlées, de 5-7 µm d'épaisseur.

Collection étudiée: Chertsey (46°07′16″N., 73°50′04″O.), 90-08-26, sous *Picea* sp., *Betula papyrifera* et *Acer saccharum*, *Lamoureux 1178* (CMMTL), (DAOM 213281).

B. huronensis est caractérisé par sa grande taille, son port robuste, son pileus brun-jaune un peu tomenteux, ses tubes jaunes bleuissant au froissement, sa chair peu changeante à la coupe et son stipe jaune. Grund et Harrison (1976) mentionnent que *B. huronensis* est une espèce commune en Nouvelle-Écosse dans les forêts de conifères et qu'il a été identifié à tort sous le nom de *B. impolitus* Fries, une espèce européenne, pendant nombre d'années. Même si les caractères macroscopiques de *B. huronensis* concordent assez bien avec les descriptions européennes de *B. impolitus*, le spécimen récolté au Québec ressemble peu à ceux illustrés dans Phillips (1981) et Cetto (1970). De plus, Leclair et Essette (1969) mentionnent que les tubes de *B. impolitus* ne bleuissent jamais. Pour toutes ces raisons, il semble préférable d'utiliser le taxon nord-américain pour désigner cette entité. *B. huronensis* semble très rare au Québec; notre collection n'est constitué que d'un seul spécimen.

Boletus lignicola Kallenbach, Pilze Mitteleur 1: 57. 1929. (Figure 4).

Pileus de 50-120 mm de diamètre; convexe; à marge enroulée au début; sec, tomenteux-pelucheux; au pileipellis épais, dépassant la marge de 3 mm; brun-orange à rouille. *Chair* ferme; épaisse; jaune pâle, rougeâtre à la base du stipe, devenant rapidement bleue à la coupe; à odeur et saveur faibles. *Tubes* décurrents; atteignant 10 mm

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FIGURE 4. *Boletus lignicola* (*Lamoureux 690*).

de longueur à mi-rayon; jaunes; aux pores un peu anguleux, très petits au début, de 1 mm de largeur à maturité, concolores, bleuissant rapidement au froissement. *Stipe* 50-70 x 12-18 mm; un peu excentrique; égal, un peu flexueux; ferme; plein; sec, glabre, furfuracé dans la partie inférieure, non réticulé; brun rougeâtre, jaune vif à la base. *Sporée* non obtenue, olive selon Snell et Dick (1971).
Basidiospores (par section des tubes) 7-10,5 x 3-3,5 µm, fusiformes à elliptiques, lisses, jaunâtres dans le KOH. *Basides* 20-26 x 6-7 µm. *Pleurocystides* atteignant 52 x 12 µm, fusiformes-ventrues. *Pileipellis* formé d'hyphes entremêlées se terminant par des éléments peu différenciés.
Collections étudiées: Contrecoeur (45°58′30″N., 73°10′48″O.), 89-08-27, à la base d'une souche de *Pinus strobus*, *Lamoureux 690* (CMMTL), (DAOM 211900), et 90-09-01, dans le même habitat, *Lamoureux 422* (LAM).

B. lignicola est caractérisé par son pileipellis épais et fortement tomenteux, ses tubes jaunes, décurrents, bleuissant au froissement, sa coloration brun-orange. Il est proche de *B. hemichrysus* Berkeley et Curtis, une espèce semblable aux pores brun rougeâtre dans le jeune âge (Weber et Smith 1985), et de *B. sphaerocephalus* Barla, de coloration jaune soufre (Smith et Thiers 1971). *B. lignicola* est rare au sud du Québec où il ne semble croître que certaines années. Groves (1962) indiquent quelques collections réalisées en Ontario. Snell et Dick (1970) mentionnent qu'il a aussi été répertorié en Pennsylvanie, au Massachusetts, au Michigan, dans l'état de New York et en Nouvelle-Écosse.

Boletus sensibilis **Peck var.** ***sensibilis*** **Smith & Thiers, The Boletes of Michigan, p. 283. 1971. (Figure 5).**
Pileus de 60-115 mm de diamètre; convexe; à marge régulière ou un peu ondulée; sec, glabre à finement subtomenteux; rouge, pâlissant à jaune rosé vers la marge, bleuissant au froissement. *Chair* ferme; épaisse; jaune pâle, bleuissant rapidement à la coupe; à odeur faible mais nette de bouillon de poulet, à saveur faible. *Tubes* adnés, puis déprimés; atteignant 8 mm de longueur à mi-rayon; jaunes; aux pores ronds et petits (2-3 par mm), concolores, bleuissant rapidement au froissement. *Stipe* 50-91 x 12-37 mm; égal ou un peu aminci dans la partie centrale; ferme; plein; sec, glabre, non réticulé; jaune, teinté de rouge par endroit, bleuissant rapidement au toucher. *Sporée* brun olive.
Basidiospores 10,5-12 x 3,5-4,2 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 23-27 x

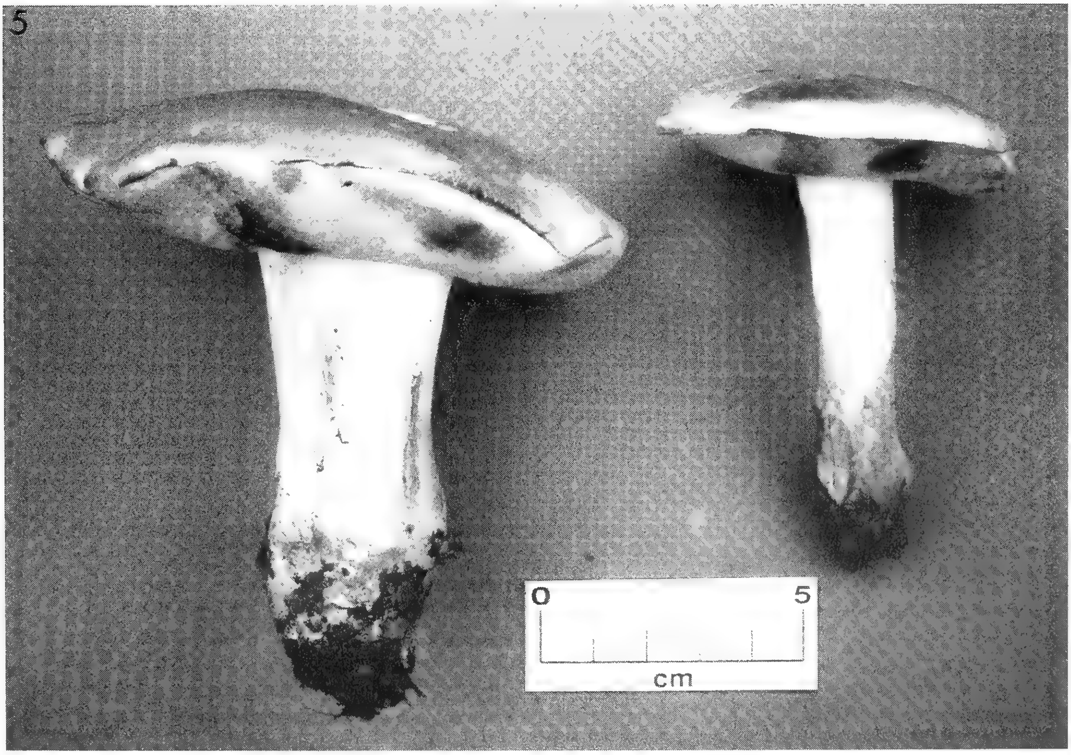

FIGURE 5. *Boletus sensibilis* var. *sensibilis* (*Lamoureux 960*).

FIGURE 6. *Boletus separans* var. *subcaerulescens* (*Lamoureux 1491*).

8-9 µm. *Pleurocystides* atteignant 50 x 14 µm, ventrues-acuminées. *Pileipellis* formé d'une couche d'hyphes entremêlées, de 4-7 µm d'épaisseur.
Collections étudiées: Ste-Ursule (46°16′46″N., 73°02′33″O.), 87-08-05, sous *Quercus rubra* et *Acer saccharum*, *Lamoureux 411* (LAM), (DAOM 213252), et 90-07-04, au même endroit, *Lamoureux 960* (CMMTL).

B. sensibilis se distingue par son chapeau rouge, ses tubes jaunes aux pores concolores, son stipe jaune rosé et par le bleuissement rapide de toutes les parties du basidiome au froissement. Selon Smith et Thiers (1971), le stipe est très finement réticulé à l'apex, un caractère que nous n'avons pas observé sur les spécimens récoltés au Québec. *B. sensibilis* fait partie d'un groupe d'espèces semblables qui bleuissent rapidement dont *B. carminipes* Smith et Thiers et *B. miniato-pallescens* Smith et Thiers, aux spores plus grandes, *B. pseudosensibilis* Smith et Thiers, au pileipellis contenant des cellules courtes et renflées, et *B. miniato-olivaceus* Frost, aux cystides vésiculeuses (Smith et Thiers, 1971). Parmi ces espèces, nous n'avons trouvé au Québec que *B. sensibilis*. Il semble plutôt rare sous les chênes ou les hêtres, du début de juillet à la mi-septembre, où il croît par temps chaud et pluvieux. Nous l'avons observé à Ste-Ursule, Rawdon, Mascouche et Ste-Marguerite-Station.

***Boletus separans* Peck var. *subcaerulescens* (Dick & Snell) Smith & Thiers, The Boletes of Michigan, p. 365. 1971. (Figure 6).**
Pileus de 82-105 mm de diamètre; convexe, parfois un peu déprimé au centre, irrégulièrement creusé par endroit; à marge un peu irrégulière; sec ou viscidule, glabre; brun rougeâtre à brun orangé, parfois ocré rosâtre. *Chair* ferme; épaisse; blanche, rougeâtre sous le pileipellis, immuable; à odeur et saveur faibles. *Tubes* adnés, puis déprimés; atteignant 14 mm de longueur à mi-rayon; jaunes; aux pores ronds et petits (2-3 par mm), concolores, bleuissant lentement au bleu au froissement, puis brunissant. *Stipe* 80-130 x 20-29 mm; égal, parfois renflé vers le bas; ferme; plein; sec, glabre, entièrement réticulé; ocré à brun rougeâtre, parfois blanc à la base, au réticulum concolore, plus pâle ou plus foncé. *Sporée* brun olive.
Basidiospores 12-17 x 4-5,5 µm, elliptiques-fusiformes, lisses, jaunes dans le KOH. *Basides* 28-30 x 8-10 µm. *Pleurocystides* nulles. *Pileipellis* composé d'hyphes se terminant par des éléments renflés, atteignant 20 µm de largeur.

Collections étudiées: Lachute (45°09′29″N., 74°18′11″O.), 89-09-04, sous *Picea* sp. et *Pinus sylvestris*, *Lamoureux 726* (CMMTL). Ste-Ursule (46°16′46″N., 73°02′33″O.), 91-08-09, sous *Quercus rubra* et *Fagus grandifolia*, *Lamoureux 1491* (CMMTL), (DAOM 213279).

B. separans var. *subcaerulescens* est caractérisé par son pileus dans les tons de brun, sa chair blanche et immuable, ses tubes bleuissant au froissement, et par son stipe réticulé. Snell et Dick (1970) le considèrent comme une variété de *B. edulis* Fries avec lequel il a une ressemblance assez marquée. Smith et Thiers (1971) ont préféré le considérer comme une variété de *B. separans* Peck à cause des caractères du pileipellis. Sa coloration et le bleuissement des tubes suggèrent qu'il s'agit probablement d'une espèce distincte. Il est sans doute assez répandu au Québec où on a dû le confondre avec *B. edulis*, car le faible bleuissement des tubes peut facilement passer inaperçu.

Gyroporus purpurinus **(Snell) Singer, Farlowia 2: 236. 1945. (Figure 7).**

Pileus de 15-52 mm de diamètre; convexe, puis étalé; à marge parfois irrégulière; sec, tomenteux, parfois craquelé et laissant voir la chair, rarement alvéolé vers le pourtour; pourpre vineux au début, pâlissant à vineux jaunâtre vers la marge en s'étalant. *Chair* plutôt fragile; 3-7 mm d'épaisseur à mi-rayon; blanche, immuable, orange-brun par les larves d'insectes; à odeur et saveur faibles. *Tubes* adnexés, puis déprimés; 3-6 mm de longueur à mi-rayon; blancs, puis jaunes; aux pores un peu anguleux, 1 mm de largeur à maturité, concolores, devenant plus jaunes au froissement. *Stipe* 23-50 x 4-9 mm; plus ou moins égal, souvent courbé vers la base; fragile; creux à maturité; sec, tomenteux, non réticulé; concolore au pileus dans le jeune âge, vineux sur fond jaunâtre à maturité. *Sporée* jaune.

Basidiospores 8,5-11 x 5,5-6,5 µm, elliptiques, lisses, presque hyalines dans le KOH. *Basides* 25-32 x 10-12 µm. *Cheilocystides* atteignant 45 x 8 µm,

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FIGURE 7. *Gyroporus purpurinus* (*Lamoureux 1410*).

fusiformes. *Pileipellis* formé d'hyphes se terminant par des éléments fusiformes atteignant 100 x 18 µm. *Collection étudiée*: St-Bruno-de-Montarville (45°32'26"N., 73°19'30"O.), 91-08-18, sous *Tsuga canadensis*, *Quercus rubra*, *Fagus grandifolia* et *Acer saccharum*, *Lamoureux 1410* (CMMTL), (DAOM 213283).

G. purpurinus est facilement reconnaissable par son pileus tomenteux, pourpre, son stipe concolore, creux à maturité, et sa sporée jaune. Les vieux spécimens perdent leur belle coloration et ils pourraient alors être confondus avec *G. castaneus* (Fries) Quélet, une espèce commune présentant un chapeau brun orangé dans le jeune âge. *G. purpurinus* semble très rare au sud du Québec où nous ne l'avons observé qu'une seule fois au Parc du Mont-St-Bruno. Snell & Dick (1970) mentionnent qu'il croît de l'état de New York jusqu'en Floride, et jusqu'au Minnesota vers l'ouest.

Leccinum griseum (Quélet) Singer, Röhrlinge II. In Pilze Mitteleuropas, p. 89. 1967. (Figure 8).

Pileus de 69 mm de diamètre; plus ou moins convexe; à marge régulière; non visqueux, glabre, irrégulièrement bosselé ou ridé-alvéolé; au pileipellis ne dépassant pas la marge; brun foncé. *Chair* peu ferme; mince; blanchâtre, devenant violacée puis noirâtre à la coupe; à odeur et saveur faibles. *Tubes* déprimés; longs de 12 mm pour 2-3 mm d'épaisseur de chair; ocrées; aux pores ronds et petits, concolores, devenant bruns au froissement. *Stipe* 112 x 11 mm; s'amincissant vers le haut, un peu flexueux; ferme; plein; sec, couvert de scabrosités noirâtres; crème. *Sporée* brun olive.

Basidiospores 13-16,5 x 5,0-7 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 28-30 x 9-11 µm. *Pleurocystides* atteignant 40 x 13 µm, fusiformes-ventrues, à contenu brunâtre. *Pileipellis* composé d'éléments renflés atteignant 30 µm de largeur.
Collection étudiée: L'Assomption (45°48'35"N., 73°28'10"O.), 90-07-22, sous *Tilia americana*, *Betula alleghaniensis* et *Populus deltoides*, *Lamoureux 1020* (CMMTL), (DAOM 213248).

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FIGURE 8. *Leccinum griseum* (*Lamoureux 1020*).

L. griseum est caractérisé par son pileus brun, alvéolé, sa chair devenant violacée à la coupe, et par son pileipellis celluleux. Il peut être confondu avec *L. scabrum* (Fries) S. F. Gray, à chair immuable, ou avec *L. snellii* Smith, Thiers & Watling, à chair rougissant à la coupe et au pileus non alvéolé, ces deux espèces étant assez communes au Québec. *L. griseum* semble plutôt rare au Québec où nous n'avons récolté qu'un seul spécimen dans une forêt de feuillus, en terrain humide. Smith et Thiers (1971) mentionnent qu'il est abondant par temps très pluvieux dans le sud-est du Michigan, en fin d'été et au début de l'automne, dans les vieilles forêts de feuillus.

Leccinum insolens var. *brunneomaculatum* Smith, Thiers & Watling, Lloydia 31: 259. 1968. (Figure 9).

Pileus de 48-107 mm de diamètre; convexe; à marge régulière; sec ou viscidule, glabre ou un peu fibrilleux; au pileipellis dépassant la marge dans le jeune âge; blanchâtre à crème rosâtre, se tachant de brun au froissement. *Chair* ferme; épaisse; blanchâtre, devenant violette puis finalement noirâtre à la coupe, parfois bleutée à la base du stipe; à odeur et saveur faibles. *Tubes* adnexées; 7 mm de longueur pour 9 mm d'épaisseur de chair à mi-rayon; blancs au début, puis brunâtres; aux pores ronds et petits (2-3 par mm), concolores, virant au jaune-brun au froissement. *Stipe* 105-127 x 12-30 mm; s'amincissant vers le haut; ferme; plein; sec, finement écailleux; blanchâtre, devenant violet puis noirâtre au contact, aux scabrosités devenant brunes puis noires avec l'âge. *Sporée* brun olive.

Basidiospores 11,5-15 x 4-5 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 27-29 x 8-10 µm. *Pleurocystides* atteignant 44 x 12 µm, fusiformes-ventrues. *Pileipellis* formé d'hyphes se terminant par des éléments plus courts et un peu renflés.

Collections étudiées: St-Didace (46°19′56″N., 73°15′28″O.), 88-09-06, sous *Picea* sp. et *Betula papyrifera*, *Lamoureux 311* (CMMTL), (DAOM 212242), 89-07-15, sous *Pinus resinosa*, *Picea* sp.

et *Polulus tremuloides*, *Lamoureux 576* (CMMTL), et 90-07-04, sous *Picea* sp., *Lamoureux 964* (CMMTL).

L. insolens var. *brunneomaculatum* se distingue par son pileus pâle se tachant de brun au toucher, sa marge débordante dans le jeune âge et sa chair devenant violette à la coupe. On pourrait le confondre avec *L. holopus* (Rostkovius) Watling, une espèce commune à chair immuable ou rougissante à la coupe, et au pileus à marge non débordante. *L. insolens* var. *brunneomaculatum* semble rare au Québec: nous ne connaissons qu'une seule station où il croît à chaque année dans une plantation de pins et d'épinettes. Smith et Thiers (1971) indiquent quelques collections effectuées au Michigan.

***Leccinum luteum* Smith, Thiers & Watling, Mich. Bot. 6: 114. 1967. (Figure 10).**

Pileus de 34-67 mm de diamètre; convexe, puis s'étalant; à marge régulière, parfois un peu craquelée; viscidule, glabre, irrégulièrement bosselé-crevassé, subhygrophane avec l'âge; au pileipellis ne dépassant pas la marge; jaune, devenant jaune brunâtre à maturité. *Chair* peu ferme; mince (3-5 mm d'épaisseur à mi-rayon); jaunâtre, devenant violacée à la coupe surtout dans le stipe, bleutée à la base du stipe; à odeur et saveur faibles. *Tubes* déprimés; de 9-17 mm de longueur à mi-rayon; crème, brunâtres avec l'âge; aux pores ronds et petits (2 par mm), concolores, brunâtres au froissement. *Stipe* 62-100 x 6-9 mm; s'amincissant un peu vers le haut; assez ferme; plein; sec, couvert de scabrosités pâles brunissant puis noircissant avec l'âge ou au contact; crème, puis jaunissant avec l'âge. *Sporée* brun olive.

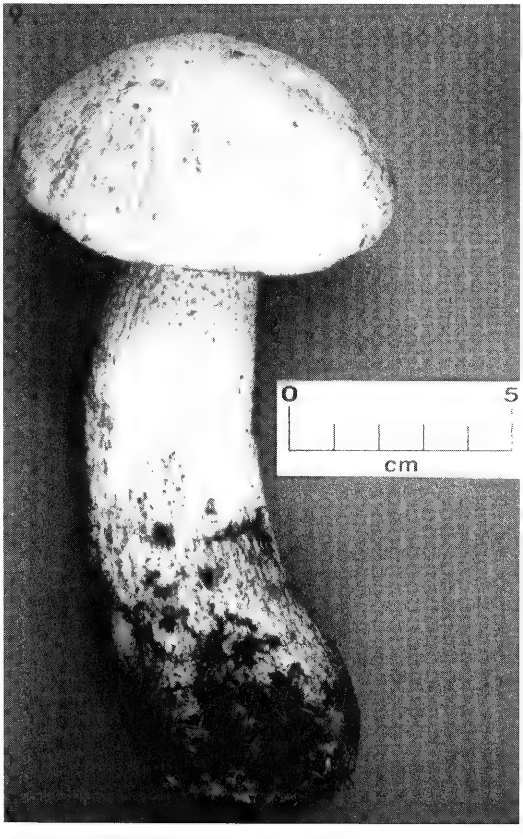

FIGURE 9. *Leccinum insolens* var. *brunneomaculatum* (*Lamoureux 576*).

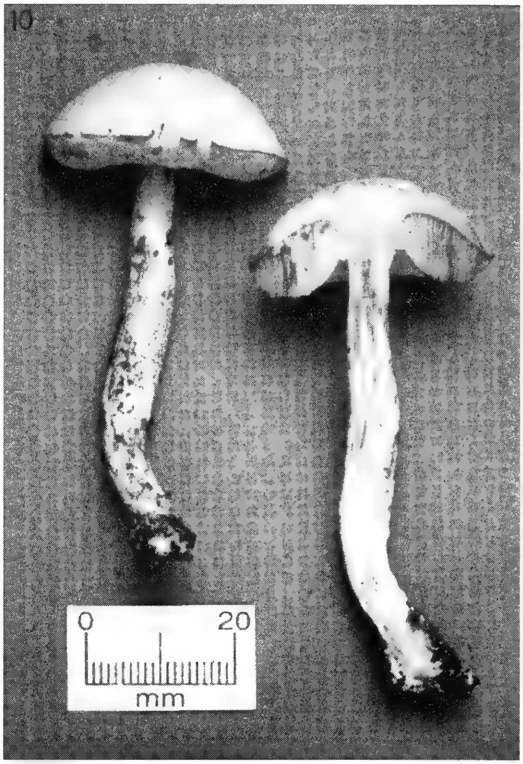

FIGURE 10. *Leccinum luteum* (*Lamoureux 1422*).

Basidiospores 14-19 x 5-6,5 µm, fusiformes, lisses, jaune brunâtre dans le KOH. *Basides* 27-32 x 12-16 µm. *Pleurocystides* atteignant 60 x 11 µm, fusiformes. *Pileipellis* formé d'éléments celluleux de 12-28 µm de largeur.

Réaction macrochimique: KOH, rouille vif sur le pileus.

Collections étudiées: Saraguay (45°31′12″N., 73°44′37″O.), 88-08-29, sous *Acer saccharum*, *Fagus grandifolia*, *Fraxinus* sp. et autres feuillus, *Lamoureux 267* (CMMTL), (DAOM 213251). L'Assomption (45°48′35″N., 73°28′10″O.), 90-07-12, sous *Betula alleghaniensis*, *Tilia americana*, *Fraxinus* sp. et *Acer saccharum*, *Lamoureux 1003* (CMMTL), et 91-08-20, sous *Tilia americana*, *Betula alleghaniensis* et *Fraxinus* sp., *Lamoureux 1422* (CMMTL).

L. luteum est facilement reconnaissable par son pileus jaune, devenant rouille au KOH, sa chair violacée à la coupe et son pileipellis celluleux. Il peut être confondu avec *L. rugosiceps* (Peck) Singer, une espèce semblable à chair rougissant à la coupe et au stipe jaune brunâtre. *L. luteum* semble rare au Québec où nous l'avons observé à quelques reprises sous divers feuillus, en terrain humide. Smith et Thiers (1971) mentionnent qu'il croît sous le Charme de Caroline dans le sud-est du Michigan.

Remerciements

Nous remercions sincèrement S. A. Redhead pour la confirmation de l'identité des spécimens d'herbier. Nous remercions également Raymond Archambault, Carlo Farnesi, Louise Rocheleau et Matthieu Sicard, ainsi que les membres du Cercle des mycologues de Montréal, pour nous avoir fourni de nombreux spécimens. La récolte de plusieurs spécimens a été facilitée par l'aide financière du Jardin botanique de Montréal et du Cercle des mycologues de Montréal.

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Reçu 4 March 1993
Accepé 17 January 1994

Distribution and Seasonal Movements of Grey Seals, *Halichoerus grypus*, Born in the Gulf of St. Lawrence and Eastern Nova Scotia Shore

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Lavigueur, Lucie, and Mike O. Hammill. 1993. Distribution and seasonal movements of Grey Seals, *Halichoerus grypus*, born in the Gulf of St. Lawrence and eastern Nova Scotia shore. Canadian Field-Naturalist 107(3): 329–340.

The distribution and seasonal movements of Grey Seals in the Gulf of St. Lawrence were analysed using data from tagging and bounty programs and telephone interviews of fishermen throughout the Gulf. Grey Seals are widely distributed throughout the Gulf of St. Lawrence and St. Lawrence Estuary with the highest concentrations observed around Anticosti Island, the Magdalen Islands, the Estuary and the southern Gulf. After pupping in January-February, animals disperse from the southern Gulf to the north and to the east. They likely remaining in offshore areas until moulting in May-June. Animals continue to disperse during July-September before returning to the southern Gulf in late fall for breeding.

Key Words: Grey Seal, *Halichoerus grypus*, bounty recoveries, tag recoveries, distribution, seasonal movements, Gulf of St. Lawrence.

The Grey Seal (*Halichoerus grypus* Fabricius, 1791) is a large phocid, found in temperate and subarctic waters on both sides of the Atlantic and in the Baltic Sea (Cameron 1967; Bonner 1985). In the western Atlantic, Grey Seal whelping occurs primarily on Sable Island and on the pack ice in the Gulf of St. Lawrence from late December until late January (Mansfield and Beck 1977). Other small whelping concentrations are found on Amet Island and Deadman Island in the Gulf of St. Lawrence and on Bowen Ledge and White Island along the Nova Scotia eastern shore (Figure 1).

Grey Seals were at one time very abundant and widely distributed along the Canadian east coast and in the Gulf of St. Lawrence where they were hunted by Amerindians such as the Micmacs on the Magdalen Islands and the Beothuks in Newfoundland (Chantraine 1980). During early European exploration of the Gulf of St. Lawrence large numbers of Grey Seals were seen by Cartier on the Moisie and Pentecôte Rivers near Sept-Iles on the lower north shore in 1535 (Barbeau 1959; Cartier 1986) although the possibility that these were walrus (*Odobenus rosmarus*) cannot be discounted (Lescarbot 1609; Lescarbot 1907-1914). Throughout the 1600s, Grey Seals were hunted in the St. Lawrence Estuary near Tadoussac (Roy 1889; Laverdière and Casgrain 1973), and several references are made to "sea-wolves", which could refer to Grey Seals, in the Gulf of St. Lawrence at Anticosti Island, the Rochers aux Oiseaux near the Magdalen Islands and Percé, in the Gaspé area (Législature de Québec 1883). Outside of the Gulf, large pupping colonies of Grey Seals were found on the southwest Nova Scotian coast, on the Tusket Islands and at Cape Sable, where as many as 800 pups were killed on a single day (Denys 1672). In the early 1700s, Charlevoix (1744), likely referring to Grey Seals, described a "sea wolf" that was hunted everywhere in the Gulf and reports the case of a sailor killing 900 seals after herding them with a pole to his house. By the 1800s, after the walrus on the Magdalen Islands had been hunted to extinction (Vigneau 1968), Grey Seal hunting increased as alternative sources of oil were sought (Chantraine 1980), resulting in a severe reduction in their numbers by the mid to late 1800s throughout much of the Gulf and on Sable Island (Martin 1837; Gilpin 1874). Grey Seals remained abundant around Anticosti Island (Mackay 1885) but were only occasionally seen along the southeast coast of Newfoundland, on the Labrador coast, along the upper north shore between Mingan Islands and Blanc Sablon, and in the St. Lawrence Estuary from Baie Comeau to St.-Jean-Port-Joli (Allen 1880; Saint-Cyr 1886; Stearns 1888; Puyjalon 1894; Grenfell 1910; Comeau 1945; Moussette 1979; Vigneau 1984). Several reports on seal species in the Gulf at this time fail to mention Grey Seals at all (Le Moine 1863; Anonymous 1868; Ferland 1877; Huard 1897) providing an indication of how scarce they had become. During the early 1900s Grey Seals were still considered to be widely distributed but there was no particular hunt for this species due to their small numbers (Comeau 1945). In the mid-1900s the Grey Seal in eastern Canada was considered to be uncommon or rare (Fisher 1950; Davies 1957).

In 1966, Mansfield (1966) conservatively estimated the total population to number 5600 animals. Since then the population has grown. Recent estimates suggest that the Grey Seal population has increased to 84 000–110 000 by 1987 and that the Sable Island component of the population was increasing by 12.6% per annum (Zwanenburg and

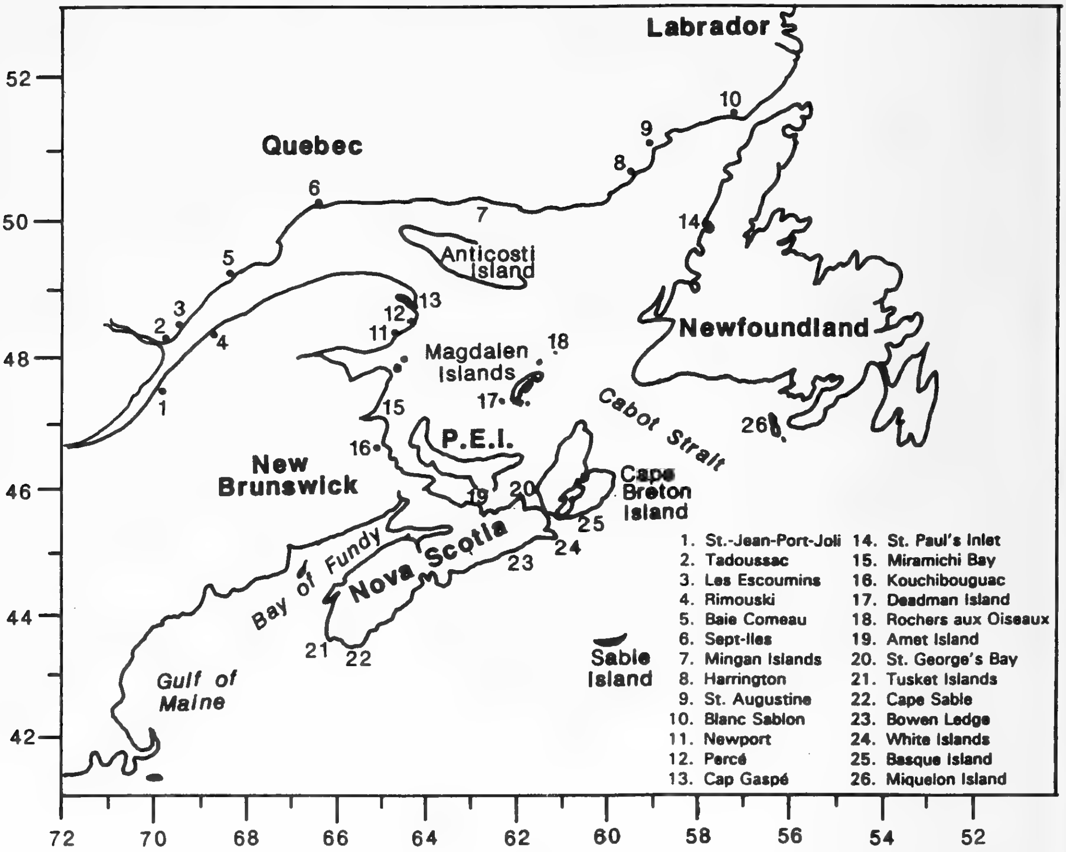

Figure 1. Study area and location of places mentioned in the text.

Bowen 1990). This rapid population growth has been accompanied by concerns that Grey Seals are having a negative impact on the commercial fishing industry (Malouf 1986).

Understanding Grey Seals and the interactions between Grey Seals and commercial fisheries requires information on the distribution and seasonal movements of Grey Seals. On Sable Island all pups born between 1977 and 1990 have been marked with uniquely numbered flipper tags (N=61 637; Stobo et al. 1990). Recently, Stobo et al. (1990), using information from tag and bounty recoveries summarized the distribution and seasonal movements of Sable Island Grey Seals and included some information on Grey Seals from the Gulf of St. Lawrence. Grey Seal pups have also been tagged in the Gulf of St. Lawrence and along the Nova Scotia eastern shore. Here, we provide more information from bounty and tag recoveries and include results from telephone and fishermen questionnaires to describe the distribution and movements of Grey Seals born and tagged in the Gulf of St. Lawrence and along the Nova Scotia eastern shore.

Methods

Pups were marked with hot iron brands (1971-1972; N=484) or individually numbered tags stamped with an address for return of the tag (1979-1990; N=10272) during the breeding season in the Gulf of St. Lawrence. Another 455 pups were marked along the Nova Scotia eastern shore on Camp Island (White Islands), Basque Island, and Bowen Ledge (Table 1; Figure 1). A reward was paid to individuals returning tags or brands along with information on date and location of capture (Stobo et al. 1990). In 1989, 2551 tags were applied to Grey Seal pups in the southern Gulf of St. Lawrence. An unusually late ice breakup during that spring provided access to large numbers of mostly young seals for shore-based hunters, resulting in a high return of tags (N=911). These tags have been excluded from the analysis. Tags returned after 1990 also have not been included in the analysis.

From 1978 to 1990 a bounty was paid in the Gulf of St. Lawrence to licenced fishermen who submitted lower jaws and information on date and location of capture. However, the bounty program was not

TABLE 1. Number of Grey Seal tags applied in each year in the Gulf and on the Nova Scotia Eastern Shore.

Location	71	72	79	80	82	83	84	85	86	89	90	Totals
Gulf	360	124	460	160	653	69	1409	2118	1537	1640	2226	10 756
Eastern Shore	–	–	–	–	–	–	14	125	144	172	–	455

well publicized in all areas, particularly in Newfoundland prior to 1985. From the submitted jaws a canine tooth was extracted, sectioned and examined to determine age (Mansfield 1991).

In 1983, 36 fisheries officers in the Gulf completed a questionnaire on the abundance and seasonal occurrence of Harbour Seals (*Phoca vitulina*) and Grey Seals in their patrolled area. They were asked during what months they saw seals and how many seals (0–50, 50–100, 100–500, etc.) were present in each of these areas. In 1989 and 1990, a questionnaire dealing primarily with incidental catches of porpoise (Fontaine et al. in press) was sent directly to fixed gear fishermen in the northern Gulf of St. Lawrence. Fishermen were also asked if they ever captured seals. Fishermen who responded positively, were contacted by telephone in 1991. They were asked for information on the number, the date and species of seal caught or seen in their fishing zone. Fishermen were also asked to describe the seals, which permitted us to evaluate their ability to identify seals to species.

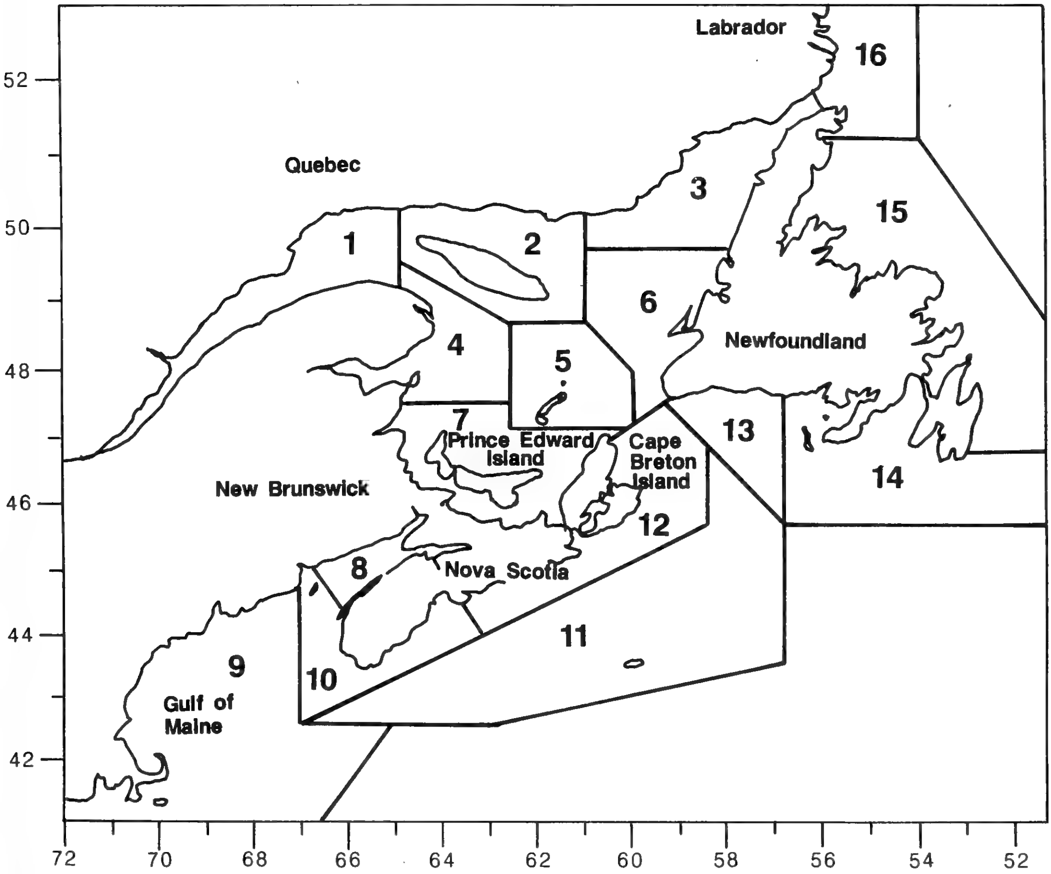

Figure 2. Areas of bounty and tag recoveries mentioned in the text. 1= Estuary; 2= Anticosti Island; 3= northern Gulf; 4= western Gulf; 5= Magdalen Islands; 6= western Newfoundland; 7= southern Gulf; 8= Bay of Fundy; 9= Gulf of Maine; 10= southwestern Nova Scotia; 11= Sable Island; 12= Nova Scotia eastern Shore; 13= southwestern Newfoundland; 14= southeastern Newfoundland; 15= eastern Newfoundland; 16= Labrador coast.

For the analysis of Grey Seal distribution, the bounty and tag recovery data have been grouped into distinct geographical areas (Figure 2) similar to those in Stobo et al. (1990). A supplementary division was added in the Gulf for the Magdalen Islands. Animals were grouped as pups (age < 1 year), juveniles (age 1–3 years) and adults (> 3 years of age) in four periods: January-April, May-June, July-September, and October-December (Stobo et al. 1990). Analysis of distribution using the bounty data is restricted to the Gulf of St. Lawrence (areas 1–7; Figure 2).

Results

Overall Recoveries by Year

Between 1978 and 1990, 4379 individuals have been recovered in the Gulf of St. Lawrence, including 4225 bounty kill returns and 594 tags or brands. Numbers of bounty returns were high the first year following the introduction of the bounty program in the Gulf, but decreased steadily until 1986 (Table 2). Recoveries increased to a maximum in 1987, but returned to low levels in 1988 and continued to decline until the program was cancelled in 1990.

Tag recoveries in the Gulf were primarily from pups tagged in the Gulf (57.9%; N=344), followed by animals from Sable Island (40.6%; N=241), pups tagged on the Nova Scotia eastern shore (0.5%; N=3) and animals of unknown origin (1%; N=6). The proportion of Gulf tags in the total recovery varied between years from 1.4% to 27.7% (3.6% to 35.5% using tags of all origins; Table 2) and was related to the number of Gulf tags applied in each year (Spearman correlation r= 0.761, N=12, P<0.05). Tags were obtained from seals that had been shot (70%), drowned in fishing gear (7%), found dead (3%), killed on the highway (1%), or were of unknown recovery (19%).

Another 185 Gulf tags and 24 Nova Scotia eastern shore tags were recovered outside the Gulf (Table 3). Overall, Gulf and Nova Scotia eastern shore recoveries equalled 4.9% (N=529) and 5.9% (N=27), respectively, of all tags applied in these regions.

Distribution of Recoveries in the Gulf

The greatest number of bounty recoveries were from the Anticosti Island area (47%), followed by the southern Gulf (23%), the Magdalen Islands (16%), the Estuary (8%) and the northeastern Gulf (5%). Recoveries from the western Gulf and western Newfoundland together provided only 0.2% of the bounty returns (Table 4). A similar distribution was observed in the pattern of tag recoveries. The largest number of tags were returned from the Anticosti Island area (37%), followed by the southern Gulf (32%), the Magdalen Islands (12%), the Estuary (10%), the northeastern Gulf (7%), western Newfoundland (1%) and the western Gulf (1%). The majority of bounty returns were from September-October in the Estuary, March in the southern Gulf and during July-August for all other regions.

The ratio of tag returns to bounty kills differed between areas (G=66.5, df=6, p<0.05; Table 4). No differences in the proportions of tags in the total recoveries were observed for returns from the Estuary, the northeastern Gulf and the southern Gulf (G=0.3, df=6, p>0.05). Smaller proportions of tags than expected were recovered from the Anticosti Island area (G=32.7, d=6, p<0.05) and the Magdalen Islands (G=20.3, d=6, p<0.05), while tag returns accounted for most of the recoveries from the western Gulf and western Newfoundland.

Seasonal Distribution of Recoveries of Gulf Origin by Age-group

For the analysis of seasonal distribution of seals born in the Gulf, individuals marked from Sable

TABLE 2. Number of bounty and tag recoveries in the Gulf areas by year of recovery.

Year	78	79	80	81	82	83	84	85	86	87	88	89	90	Totals
Bounty	11	669	575	440	136	406	264	256	222	753	293	121	79	4225
Total tags[a]	11	78	46	16	43	52	33	56	93	50	45	52	19	594
Gulf tags	0	45	25	6	25	10	9	47	72	30	16	41	18	344
Individuals	11	684	583	443	153	410	267	273	262	756	302	148	87	4379
% Gulf tags	0	6.6	4.3	1.4	16.3	2.4	3.4	17.2	27.5	4.0	5.3	27.7	20.7	

[a] Includes tags of Gulf, Sable Island and Nova Scotia Eastern Shore origin.

TABLE 3. Number of tag recoveries of Gulf and Nova Scotia Eastern Shore origin, between 1978 and 1990.

Area[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Totals
Gulf	18	98	19	4	38	5	162	3	1	6	6	94	7	40	16	12	529
Eastern Shore	–	2	–	–	1	–	–	–	–	2	3	18	–	1	–	–	27

[a]Cf. Figure 2.

TABLE 4. Number of bounty and tag recoveries for each area in the Gulf from 1978 to 1990.

Area[a]	1	2	3	4	5	6	7	Totals
Bounty	350	1992	201	5	684	4	989	4225
Total tags[b]	62	219	39	7	71	6	190	594
Gulf	18	98	19	4	38	5	162	344
Sable Island	43	119	20	3	27	1	28	241
Eastern shore	0	2	0	0	1	0	0	3
Individuals	357	2021	215	10	700	7	1069	4379
% Total tags	17.4	10.8	18.1	70.0	10.1	85.7	17.8	13.6

[a] Cf. Figure 2.

[b] Includes tags of Gulf, Sable Island, Nova Scotia Eastern Shore origin, and six tags of unknown origin in area 1 (N=1) and 5 (N=5).

Island (N=241) and data with missing information on date, location of recovery or age of the animal (N=549) have been eliminated. We assumed that all recoveries of untagged animals born after the start of the complete cohort tagging program on Sable Island came from the Gulf or the Nova Scotia eastern shore. Untagged individuals born before 1977 were eliminated from the bounty data set since their origin was uncertain (N=671, 662 adults and 9 juveniles), leaving 3252 individuals of Gulf or Nova Scotia eastern shore origin of which 2787 are bounty and 548 are tag returns (521 Gulf; 27 eastern shore tags).

Pups

After weaning, the pups disperse slowly from the whelping area in the southern Gulf towards the north and to the east. During January to April, most recoveries were from animals killed on the ice in the southern Gulf, with recoveries also occurring from the Magdalen Islands, where a small pupping colony is located on Deadman Island, Anticosti Island and western Newfoundland. Outside of the Gulf, most animals were recovered from the Nova Scotia eastern shore, on Sable Island, in eastern, southeastern and southwestern Newfoundland and in the Bay of Fundy (Figure 3a). The dispersal of animals from the southern Gulf, towards Anticosti Island, and also to the Newfoundland coasts and the Nova Scotia eastern shore, continues during May-June and by July-September the proportions of bounty and tag recoveries from the southern Gulf reach a minimum. By this time pups are widely distributed as shown by an increasing number of pups found in the Estuary, the Anticosti Island area, the northeastern Gulf and along the Labrador coast (Figure 3b, 3c). Only a few pups were recovered from the western Gulf. During October to December, there is a shift in the distribution of bounty and tag recoveries. Bounty and tag returns from the Estuary, and the Labrador coast reach a maximum, while recoveries from the Anticosti Island area, Newfoundland (west, southwest and southeastern coast) and the Nova Scotia eastern shore decline compared to previous periods. At the same time bounty recoveries from the Magdalen Islands and southern Gulf increase, suggesting a return movement by pups to the southern Gulf during their first fall (Figure 3d).

Of the Nova Scotia eastern shore tag recoveries, one pup was recovered in the Magdalen Islands in May-June and another in the Anticosti Island area during the July-September period. Seventeen pups were recovered from the Nova Scotia eastern shore (N=13; January-September), from the Sable Island area (N=3; May-September) and from the southwestern Nova Scotia area (N=1; May-June). Resighting of pups tagged from the Nova Scotia eastern shore is also frequently reported on Sable Island during the May-June period (nine resighting observations from this area).

Juveniles

There are very few bounty and tag returns from juvenile animals during the winter months (January-April; Figure 4a). During our tagging operations on the pack ice in the southern Gulf (January-February), no juveniles have been sighted. The few tags and bounty returns available from the winter (January-April) indicate that juveniles are likely dispersed in offshore areas such as the Magdalen Islands, with some animals present in the Estuary, along southwestern Nova Scotia and in the Gulf of Maine. During May-June, the number of bounty and tag recoveries increases sharply, as animals move into coastal areas to moult. In the Gulf, the majority of bounty returns are from the Anticosti Island area, followed by the Magdalen Islands and the southern Gulf. Movements out of the Gulf may also occur since half of the tags recovered during this period came from outside the Gulf, mostly from the Nova Scotia eastern shore and the southeastern Newfoundland coast (Figure 4b). During July-September, juveniles are more dispersed during the summer months, with an increase in returns from the Estuary, the northeastern Gulf and the Labrador coast (Figure 4c). During October-December, bounty returns were evenly distributed between the southern Gulf, the Magdalen Islands, the Estuary, the Anticosti Island and the northeastern Gulf areas.

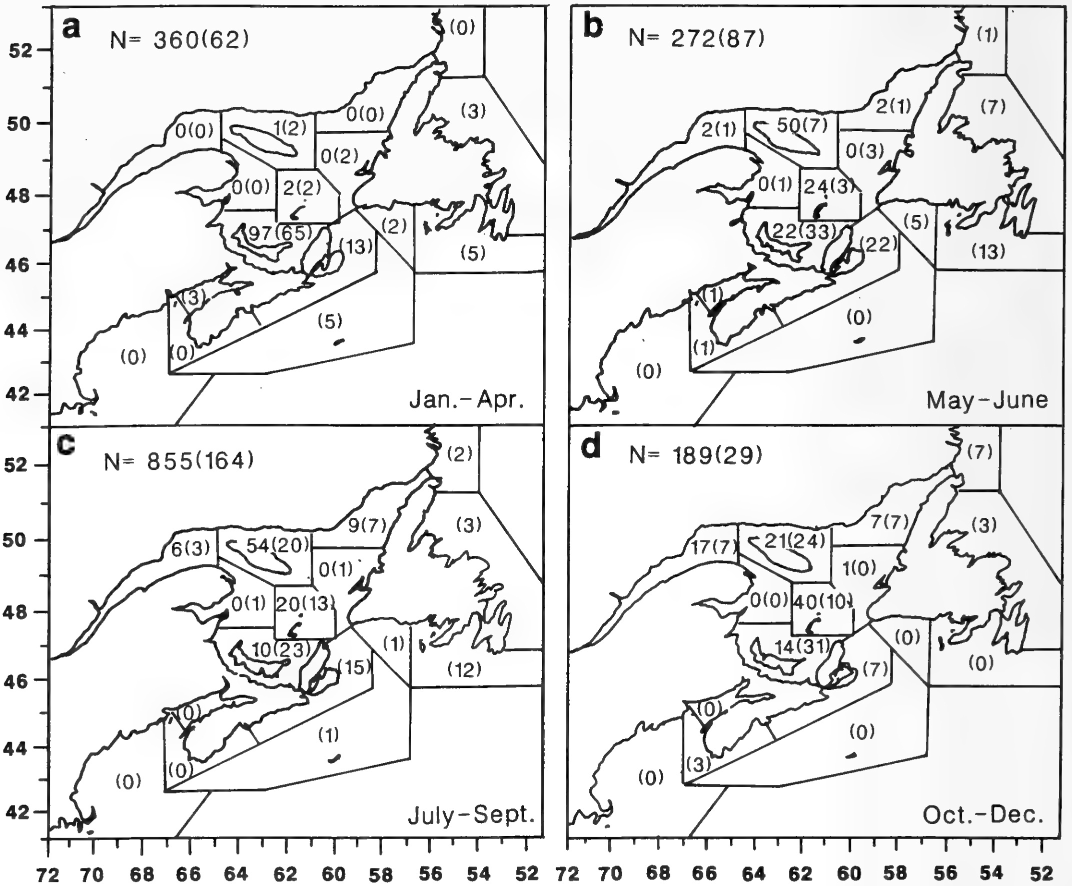

FIGURE 3. Proportions of bounty kills in the Gulf of St. Lawrence and Gulf tag recoveries (data in brackets) of Grey Seal pups in each season. Overall totals (N) are given for each season.

Small numbers of animals were also recovered from the western Gulf, the eastern, southwestern and southeastern coasts of Newfoundland, and the Nova Scotia eastern shore (Figure 4d).

For animals tagged on the Nova Scotia eastern shore and recovered as juveniles, an individual was recovered in the Anticosti Island area during July-September, three tags came from the Nova Scotia eastern shore between May and September, one from the southwestern Nova Scotia in May-June and one from the southeastern Newfoundland during July-September.

Adults

The highest number of bounty returns were from the July-September period, while the lowest number of returns were from January-April. During this period seven jaws were submitted from the southern Gulf for the bounty (Figure 5a). During tagging operations in the southern Gulf, 11 adults with Sable Island tags have been resighted on the whelping patch. After breeding, the adults disperse from the southern Gulf to the central and northern Gulf regions, primarily around Anticosti Island. However, it should be noted that substantial numbers of adults remain in the southern Gulf throughout the year. Tag recoveries also indicate the presence of Gulf animals on the Nova Scotia eastern shore between May and September (Figure 5b, 5c). During July-September, the movement of animals away from the southern Gulf continues and adults are distributed more widely as indicated by the increase in bounty returns from the Estuary, the Magdalen Islands and the northeastern Gulf, while the proportion of recoveries remained constant in the Anticosti Island area. Tag recoveries indicate that some animals may also be found in the western Gulf, the southeastern Newfoundland, the Labrador and the Sable Island areas (Figure 5c). During October to December, animals return to the southern Gulf but this movement occurs late in the season or occurs slowly as adults

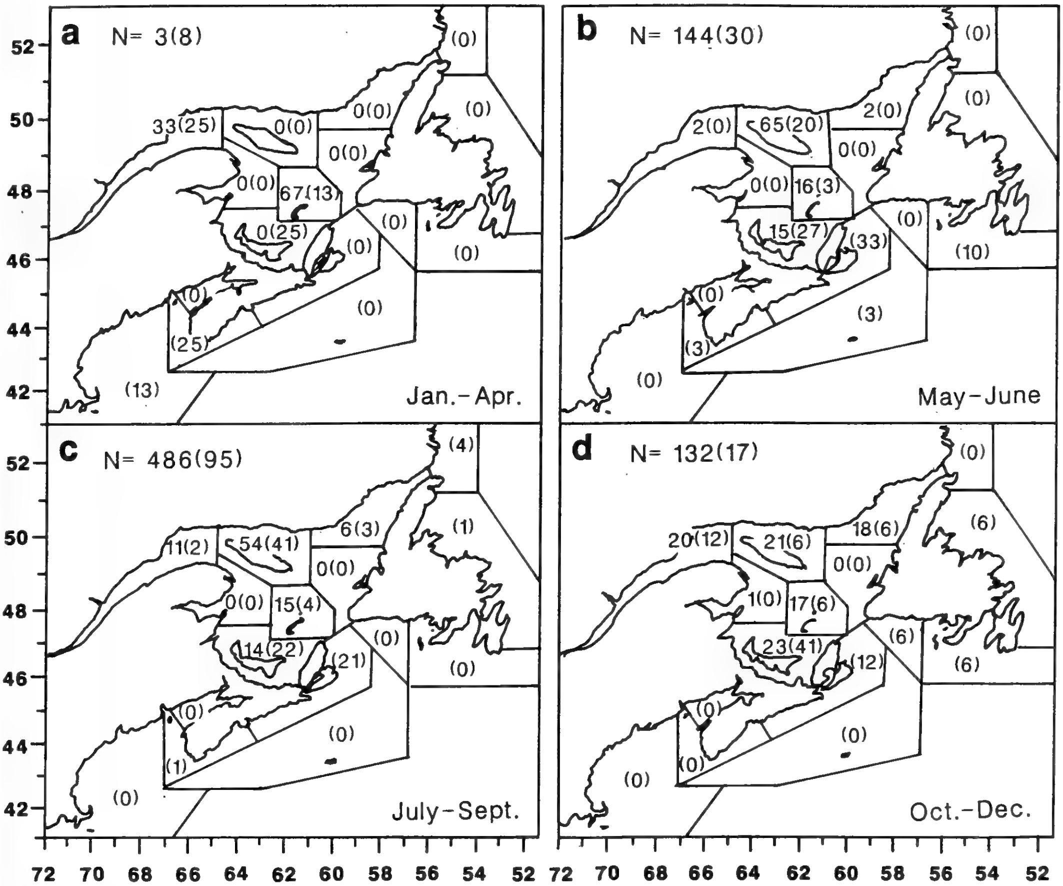

FIGURE 4. Proportions of bounty kills in the Gulf of St. Lawrence and Gulf tag recoveries (data in brackets) of Grey Seal juveniles in each season. Overall totals (N) are given for each season.

are still widely distributed throughout the northern part of the Gulf and the Estuary (Figure 5d).

Two adults tagged on the Nova Scotia eastern shore were recovered from this same region during the July-September period.

Age Structure

Total recoveries in the Gulf of known age individuals (N=4308), including tags of all origins, were composed of 47.6% pups, 29.6% adults and 22.8% juveniles. Due to insufficient sample sizes, differences in age structure could only be examined between July-September and October-December and between the Estuary, Anticosti Island, the northeastern Gulf, Magdalen Islands and southern Gulf areas. Population age structure in the bounty returns (N=3658) was not independent of region (Table 5) during summer (July-September; x^2=45.6, df=8, $p<0.05$) or autumn (October-December; x^2=47.3, df=8, $p<0.05$). During the summer, pups were under-represented, and juveniles were over-represented in bounty returns from the Estuary, pups were over-represented and adults were under-represented in returns from the northeastern Gulf, while relatively few pups were recovered from the southern Gulf. In the fall recoveries, more juveniles and fewer adults then expected were recovered in the northeastern Gulf, more pups and fewer juveniles then expected were recovered from the Magdalen Islands, while pups were under-represented and adults were over-represented in the returns from the southern Gulf. Comparing between seasons, significant differences between summer and fall periods were found for bounty returns from the northeastern Gulf (x^2=17.0, df=2, $p<0.05$), and the southern Gulf (x^2=10.0, df=2, $p<0.05$). Between July-September and October-December, bounty returns were characterized by a decline in the number of pups in both areas and an increase in the number of adults in the southern Gulf and of juveniles and adults, in the northeastern Gulf.

TABLE 5. Seasonal distribution of bounty recoveries[a] in the Gulf areas for each age-group.

Area[b]	Pups				Juveniles				Adults				Totals
	1	2	3	4	1	2	3	4	1	2	3	4[c]	
1	0	5	72	37	1	3	60	30	0	6	63	45	322
2	3	137	513	42	0	98	284	31	0	95	363	48	1614
3	1	5	84	14	0	4	37	25	0	2	11	9	192
5	8	66	182	80	2	23	84	23	0	20	123	46	657
7	348	60	96	31	0	21	75	33	29	38	82	60	873
	360	273	947	204	3	149	540	142	29	161	642	208	
Totals	1784				834				1040				3658

[a] Includes tags of Gulf, Sable Island and Nova Scotia Eastern Shore origin.
[b] Cf. Figure 2. Areas 4 and 6 have been excluded because of insufficient data.
[c] 1=January-April; 2=May-June; 3=July-September; 4=October-December.

Questionnaires

The questionnaires completed by fisheries officers in 1983, were returned from the southern Gulf (N=21), western Gulf (N=7), northeastern Gulf (N=3), Estuary (N=2), western Newfoundland (N=2) and Magdalen Islands (N=1). Grey Seals were reported present in all regions. In the southern Gulf, 11 questionnaires reported the presence of Grey Seals, six of unidentified species of seals, while four did not report that any seals were present. During winter, Grey Seals were reported to be very abundant from Kouchibouguac in New Brunswick to the Canso causeway, which links Cape Breton Island to Nova Scotia, and on the southeastern coasts of Prince Edward Island (Figure 1). Small numbers were also observed on the northeastern and southwestern coasts of Prince Edward Island through the year. Only one of six questionnaires sent from the Miramichi Bay, reported the presence of Grey Seals, between May and December (unidentified species in two questionnaires).

In the western Gulf, only two out of seven questionnaires reported the presence of small numbers of Grey Seals between April and October (unidentified seals in two additional questionnaires). In the northeastern Gulf, two out of three questionnaires mentioned that Grey Seals are abundant along the lower north shore from Harrington Harbour, to St. Augustine, between June and September (unidentified species of seals in the third questionnaire). The two questionnaires received from the Estuary reported considerable numbers of Grey Seals in the region of Rimouski, Baie-Comeau and Rivière-du-Loup, between March and November. In Newfoundland, one questionnaire reported small numbers of Grey Seals at St. Paul's Inlet, on the northwest coast of Newfoundland, between April and June. The only questionnaire received from the Magdalen Islands, reported considerable number of Grey Seals on Deadman Island, between January and March.

From the questionnaires sent out in 1989 (N=968) and 1990 (N=731) to obtain information on the incidental catches of porpoises (Fontaine et al. in press), 156 fishermen mentioned that they had also caught seals. Fishermen (N=126) were contacted by telephone in the Estuary (N=36), Anticosti Island (N=14), the northeastern Gulf (N=32), the western Gulf (N=41) and the Magdalen Islands (N=3) areas. The remaining fishermen could not be reached. The ability of fishermen to identify seals to species varied considerably between regions. Ninety one percent of the fishermen called in the northeastern Gulf (of N=32) had relatively good knowledge of the species, 69% in the Estuary (of N=36), 67% in the Magdalen Islands (of N=3), 54% in the western Gulf (of N=41) and only 21% in the Anticosti Island area (of N=14). The dataset was reduced to 106 fishermen after eliminating 20 unreliable respondents from Anticosti Island (N=11), western Gulf (N=7) and Estuary (N=2) areas.

Between 1988 and 1991, 29% of the fishermen contacted reported catching Grey Seals in their gill nets (N=31), including all of the fishermen from the Magdalen Islands (N=3), 44% (N=15) from the western Gulf, 29% (N=10) from the Estuary and 9% (N=3) from the northeastern Gulf. Of the fishermen who captured Grey Seals, 81% (N=25) caught fewer than five Grey Seals for the whole fishing year, 6% (N=2) between 10 and 20, 10% (N=3) between 30 and 50 and 3% (N=1) between 100 and 300. However, 58% of the fishermen (N=62) reported presence of Grey Seals in their fishing zone, including all the fishermen contacted in the Magdalen Islands (N=3), 74% in the Estuary (N=25), 67% in the Anticosti Island area (N=2), 62% in the western Gulf (N=21) and 34% in the northeastern Gulf (N=11). In all regions, most of the estimated number of Grey Seals seen in the fishing zone were between one and five seals. The highest numbers of Grey Seals observed or captured came from the Estuary (Les Escoumins) in July and August, the western

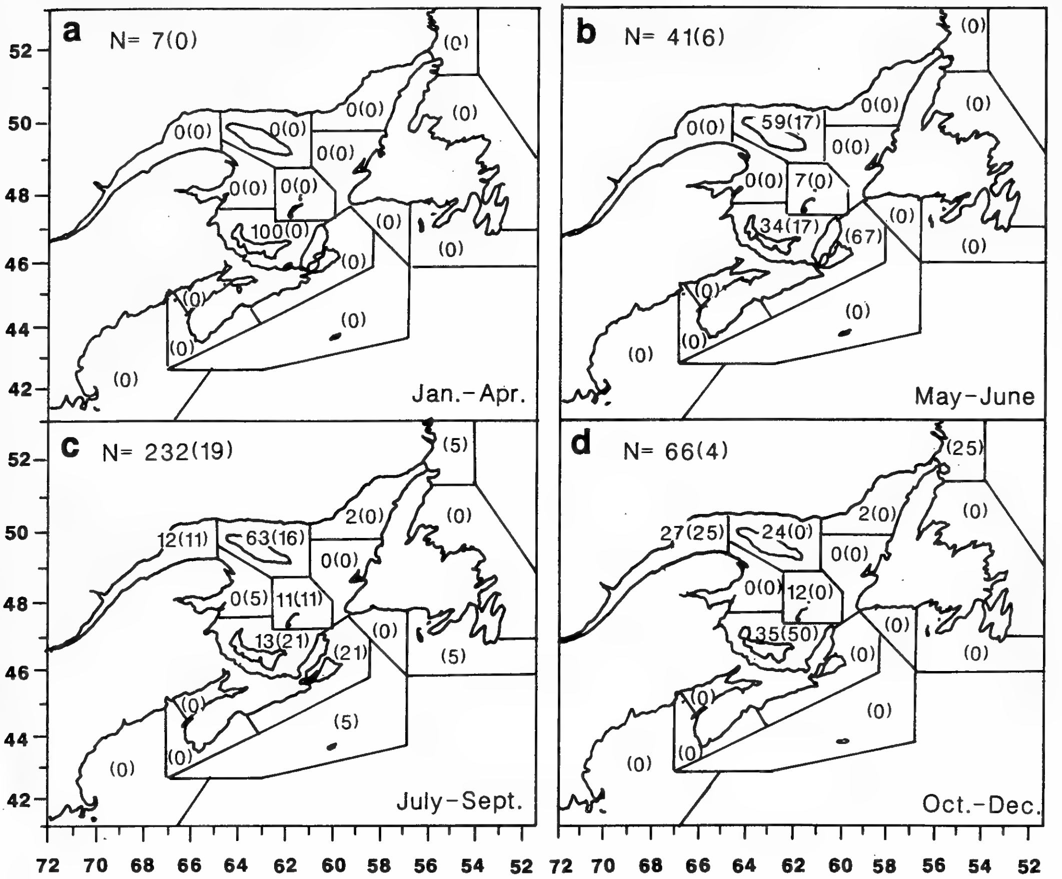

FIGURE 5. Proportions of bounty kills in the Gulf of St. lawrence and tag recoveries (data in brackets) of Grey Seal adults in each season. Overall totals (N) are given for each season.

Gulf (Newport; Cap Gaspé) in May and the Anticosti Island area in May.

Discussion

The use of questionnaires, bounty and tag returns to describe Grey Seal distribution are subject to several biases. One difficulty is that fishermen are often unable to identify seals to species, particularly in the Anticosti Island area (Newson 1937). The paucity of Grey Seal sightings in winter likely reflects minimal fishing activity due to the presence of ice rather than the absence of Grey Seals. Information gained from bounty and tag returns are also affected by changes in hunting activity, public knowledge of the bounty program and legal restrictions on hunting marine mammals, particularly in the United States (Stobo et al. 1990). Within the Gulf of St. Lawrence, hunting of Grey Seals is not permitted between May and September in the upper Estuary and in the southern Gulf between December and the end of March.

The high proportion of individuals tagged on Sable Island in the recoveries from the Gulf reflects the greater number of tags applied on Sable Island during the same period. The decline in the number of bounty returns with the exception of 1987, likely reflects decreased interest in the bounty program as hunter's costs increased between 1979 and 1990, but the size of the reward remained unchanged. In 1987, 40% (N=319) of the jaws submitted under the bounty program came from a March hunt primarily for pups (N=297) in the southern Gulf. We suggest that ice breakup in that spring was delayed, permitting hunters to have greater access to seals than normally possible, similar to the conditions that arose during the spring of 1989 (cf. Methods).

In spite of differences in bias between the questionnaires, bounty and tag returns, our data indicate that Grey Seals are distributed throughout the Gulf of St. Lawrence, St. Lawrence Estuary and around the coasts of Newfoundland with the most important areas being Anticosti Island, southern Gulf, Magdalen Islands and Estuary, while relatively few Grey Seals are observed in the northeastern Gulf. Both questionnaires and observations from aerial surveys (Clay and Nielsen 1985) indicate that Grey Seals are not as rare as suggested by tag and bounty returns in the western Gulf. Aerial survey data also indicate a larger number of animals on southwestern Newfoundland, and the French island of Miquelon than indicated by the bounty and tag return data (Fisher unpublished 1955, The Grey Seal, *Halichoerus grypus*, in the West Atlantic, Fisheries Research Board of Canada, 17 pages; Ling et al. 1974; Clay and Nielsen 1985).

Our information on Grey Seal movements indicates that after weaning the pups disperse slowly from the southern Gulf. Although dispersal occurs in all directions, the majority of pups disperse to the north and to the east, with substantial numbers of Gulf tagged pups being found on the Nova Scotia eastern shore and Sable Island during the January-April period. It appears that the rate and direction of dispersal is tied very closely to ice formation, breakup and drift out of the southern Gulf. Since construction of the Cape Breton causeway, linking mainland Nova Scotia to Cape Breton island, ice is retained in St. George's Bay instead of exiting through the Canso Straits into the ice free waters of the Atlantic Ocean. Dispersal from the Gulf has altered from historical patterns because ice must drift northwards along the west coast of Cape Breton Island, before exiting the Gulf via Cabot Strait (Markham 1981). The effects of the proposed fixed link on the distribution of whelping Grey Seals and subsequent dispersal are not known, but should be minimal given the proposed open span configuration.

The dispersal of pups from the southern Gulf continues throughout the spring with animals moving as far north as the Labrador coast, northwest into the St. Lawrence Estuary and to a lesser extent the western Gulf. Large numbers of Grey Seals, possibly including some pups, have been seen in the Barachois on Miquelon Island in March (Fisher unpublished 1955) but it is unknown if these are resident seals or animals that have been exported from the Gulf. Although pups do not moult during their first year (Stobo and Zwanenburg 1990), they tend to follow the moulting adults and juveniles as shown by the high proportion of pups found in the Anticosti Island area between May and September. However, large numbers of pups remain in the southern Gulf, on the Nova Scotia eastern shore and the southeastern coast of Newfoundland during the summer months. Groups of Grey Seals are known to haul-out on Miquelon Island in summer (Ling et al. 1974) although only one Gulf tag has been recovered from this region between 1971 and 1990, suggesting that these are largely Sable Island animals. During the fall some animals appear to move back to the southern Gulf, but this migration is not well defined. Instead many animals may remain in offshore areas during the winter months (Stobo et al. 1990). This pattern of dispersal differs from that occurring in the population of Sable Island, from which pups leave primarily in a southwesterly movement during January-April followed by a northeastern movement in May-June.

The paucity of adult and juvenile returns from the period January-April suggests that these animals remain largely pelagic during this period (Stobo et al. 1990). During May-June both adults and juveniles return to coastal areas to moult (Mansfield and Beck 1977). Some animals remain in the southern Gulf throughout the year, but most appear to move into the northern Gulf, around Anticosti Island and along the north shore (Clay and Nielsen 1985; Desaulniers 1989). After the moult, both adults and juveniles tend to disperse, but our data indicate that large numbers of Grey Seals remain around Anticosti island during the summer months. Most of the recoveries of pups, juveniles and adults from Anticosti Island were made during the months of July and August while fewer were recovered in May-June. This may reflect an increase in fishing and hunting effort during the summer months or alternatively an increase in the number of animals around the island. The large number of individuals of Sable Island origin present in the Gulf are also found around Anticosti Island during the July-September period (Stobo et al. 1990). Grey Seals are observed in the Mingan Islands (Anticosti Island area) between July and October with the maximum number of observations in September (Desaulniers 1989).

During the fall Grey Seals return to the southern Gulf for the breeding season, but this movement occurs slowly and late in the year. There are also some indications of a southward movement by juvenile Grey Seals, but this movement is less well defined than the adult migration and reports of Grey Seals present in the northern Gulf during winter (Desaulniers 1989) suggest that juveniles remain pelagic in winter (Stobo et al. 1990). Unlike Sable Island, juveniles are not seen in the breeding area suggesting a more offshore distribution.

Movement of seals of all ages between the Gulf of St. Lawrence and Sable Island occur frequently (Mansfield and Beck 1977; Stobo and Zwanenburg 1990; Stobo et al. 1990). However, tag recoveries suggests that some differences in distribution patterns do occur between Gulf of St. Lawrence and Sable Island Grey Seals. Within the Gulf of St. Lawrence, the southern Gulf, Magdalen Island and Anticosti Island are the most important areas for Gulf animals of all age classes. Recoveries of Gulf tags outside of the Gulf are limited primarily to the

Nova Scotia eastern shore and the southern Newfoundland coast, consisting primarily of pups and juvenile animals. For Sable Island animals, recoveries from outside of the Gulf occur primarily from the Nova Scotia eastern and southwestern shore for all age groups, Newfoundland and Gulf of Maine for pups and juveniles. Tags from Sable Island animals entering the Gulf of St. Lawrence have been recovered throughout the Gulf, but the greatest number of recoveries are from Anticosti area, northeastern Gulf and southern Gulf.

Most adult seals tend to return to the same breeding area each year. Resighting data show that less then 5% of the seals tagged in the Gulf breed on Sable Island, which is similar to rates of exchange reported for seals moving from Sable Island to the Gulf (Zwanenburg and Bowen 1990).

Acknowledgments

We thank W. Hoek, D. Hope, S. Leech, P. Marcott, W. Penney and G. Sleno for their help in the tagging program throughout the years. P. M. Fontaine collected the information on seal bicatch as part of another project and kindly allowed us to use the information from his questionnaires. We also thank D. Guay for his help with the historical research. G. Stenson commented on the manuscript. This project was supported by the Seal and Sealworm Ecology project and by PFDPQ, Department of Fisheries and Oceans Canada.

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Received 27 March 1993
Accepted 13 November 1993

Marsh Sow-thistle, *Sonchus palustris* L. (Asteraceae) in Ontario: An Addition to the Introduced Flora of North America

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Brunton, Daniel F., and Clifford W. Crompton. 1993. Marsh Sow-thistle, *Sonchus palustris* L. (Asteraceae) in Ontario: An addition to the introduced flora of North America. Canadian Field-Naturalist 107(3): 341–344.

Three small populations totally less than 100 plants of *Sonchus palustris*, a perennial native to western Eurasia, were discovered along the disturbed edge of a wet fen complex in Gloucester, Regional Municipality of Ottawa-Carleton, Ontario. This constitutes the first report of *S. palustris* in Canada and North America. Plants from this population were diploid (2n = 18) and had the characteristic diagnostic features of *Sonchus palustris* including exceptional height (>1.5 m), densely corymbose inflorescence of pale yellow flowers and long-pointed stem leaf bases. These, as well as ecological characteristics, were used in the separation of this from the smaller tetraploid (2n =44) *S. arvensis*. It is speculated that the distinctive and particular habitat requirement of *S. palustris* likely precludes it from becoming a widespread invasive or troublesome weed in Canada.

Key Words: Marsh Sow-thistle, *Sonchus palustris*, Asteraceae, Ontario, distribution, cytology.

The genus *Sonchus* (Asteraceae) in Canada consists of several non-native species which frequently become troublesome agricultural weeds (Frankton and Mulligan 1970; Hutchison et al. 1984). Accordingly, the discovery of an established population of an additional species of this genus in Canada is of phytogeographic and potential economic significance.

A small population of ± 68 plants of a very large *Sonchus* was discovered in Gloucester, Ontario in September 1992 (Figure 1). Investigations of the population indicated that it represented *Sonchus palustris* L., a species not previously recorded from Canada.

Methods

Chromosome preparations were made using the alchoholic HCl acid-carmine technique of Snow (1963). Plants were collected from the Albion Wetland along a 0.6 km stretch of Albion Road south from Delzotto Road in Gloucester, Regional Municipality of Ottawa-Carleton, Ontario (45°18.5'N 75° 37'W) (*D. F. Brunton & K. L. McIntosh 11,340*, September 13, 1992, DAO (CC No. 204). Additional replicates of this collection were distributed to several herbaria (TRT, D. F. Brunton Herbarium, MICH).

A roadside survey of similar habitat in the surrounding area of Gloucester and adjacent Ottawa was undertaken in September and October 1992 and September 1993 for additional populations. North American and European *Sonchus* voucher collections at DAO and CAN herbaria (herbarium acronyms according to Holmgren et al. 1990) as well as European and North American literature were also examined for distribution and identification purposes.

Results and Discussion

A comparison of dried material with literature and with voucher specimens preserved in the CAN and DAO herbaria confirmed that this population matched European *Sonchus palustris*. Its immense size of between 1.5 and 3.1 m tall in the Gloucester population (Figure 1) and unusual flooded roadside ditch habitat in peaty sand by a fen forest in Cat-tail (*Typha latifolia*), Reed Canary-grass (*Phalaris arundinacea*) and Purple Loosestrife (*Lythrum salicaria*) marsh vegetation, contrast markedly with the much smaller Perennial Sow-thistle (*S. arvensis* L.) of neighbouring dry, disturbed uplands. In addition, a large, corymbose inflorescence and long-pointed leaf bases extending beyond the width of the stem were conspicuous in the Gloucester, Ontario material (Figures 1, 2 and 3). These characteristics are noted in European literature to be distinctive of *S. palustris* (Hutchison 1955; Fitter and Fitter 1974; Clapham et al. 1987).

A chromosome count of n= 9II (metaphase 1) was determined. Pairing was regular and the count is in accordance with the European ones in the literature (Vachova 1976, 1978; Skaliniska et al. 1976; Morton 1977).

Clapham et al. (1987) also report *S. palustris* to be diploid ($2n$=18) and provide counts of $2n$=36 or $2n$=54 for *S. arvensis*. Scoggan (1979), however, reports a $2n$=27 chromosome count for greenhouse-grown *S. arvensis* (var. *shumovichii* Boivin). This likely represents the triploid hybrid between $2n$=36 *S. arvensis* and $2n$=18 *S. asper* (L.) Hill (n=18 + n=9, respectively = $2n$=27).

No North American specimens of *S. palustris* were detected in searches of CAN, DAO and MICH, nor

FIGURE 1. Population of fruiting, ca. 3 m high Marsh Sow-thistle (*Sonchus palustris*) in cat-tail (*Typha* spp.) dominated ditch by fen forest (Albion Wetland, Gloucester, September 1993); note 12 cm high drink can at base of tallest plant (centre right) for scale.

were any references noted in a survey of appropriate regional, national and continental floristic sources (e.g., Morton and Venn 1990; Scoggan 1979; Kartesz and Kartesz 1980; Fernald 1950). That leads us to conclude that this Ontario record represents the first report of *S. palustris* for North America.

As *S. palustris* is not described in North American literature a summary of important differences between it and *S. arvensis* is provided below (Table 1).

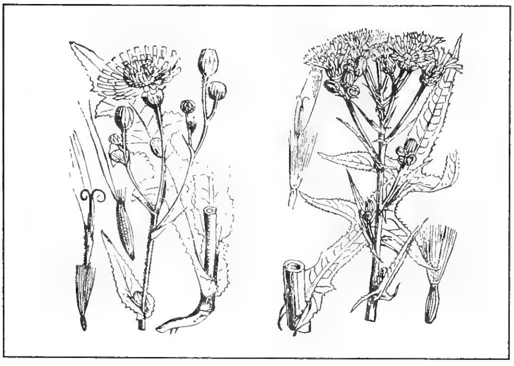

FIGURE 2. Illustration of key features of Marsh Sow-thistle (*Sonchus palustris*), right, and Prickly Sow-thistle (*Sonchus arvensis*), left (from Fitch and Smith 1946).

Although the Gloucester, Ontario site contains a number of locally and regionally rare or uncommon introductions (Dugal 1990, 1992) a pattern of occurrence which might help to explain the presence of *S. palustris* is not evident. *Sonchus palustris* is reported to be rare and declining in Great Britain (Hutchison 1955; Fitter and Fitter 1974). While this implies that the Gloucester, Ontario population more likely has its origin elsewhere in its western Eurasian range (central Europe to Armenia) (Clapham et al. 1987), its origin remains unknown.

A survey of the surrounding area east and south of Ottawa in 1992 failed to discover additional populations of *S. palustris*. Two small additional stands were discovered elsewhere along the edge of the Albion Fen in September 1993; 24 mature plants were observed along the east side of Albion Road 50 m north of Delzotto Road and two immature plants were noted 300 m west of Albion Road along Leitrim Road.

The disturbed, peaty fen habitat in which all plants were found is rare here and throughout southern Ontario (Dugal 1990; Riley 1989). As the Ontario plants are found only in this uncommon habitat despite an abundance of similar-looking wetland habitat, *S. palustris* is unlikely to constitute a significant competitor to native wetland vegetation, as has

FIGURE 3. Diagnostic long-pointed bases of stems leaves extending beyond width of the stem (Albion Wetland, Gloucester, September 1993)

TABLE 1. Comparison of *Sonchus palustris* and *S. arvensis* (based on Hutchison 1955; Frankton and Mulligan 1970; Clapham et al. 1978; personal observations).

Characteristic/Feature	*S. palustris*	*S. arvensis*
Roots	erect, tuberous rootstalk.	creeping rootstalk.
Stem	to >3 cm diameter; 1 to 3.1 m tall.	to ca. 1 cm diameter; 1 m or less tall.
Basal leaves	broadly oblong outline, with a few long and narrow lateral segments projecting at right angles.	oblong with short, triangular-oblong lateral segments or shallowly pinnately divided.
Stem leaves	linear-lanceolate with long-pointed bases projecting beyond the stem.	lanceolate-oblong with rounded, appressed auricles ± not projecting beyond stem.
Inflorescence	densely corymbose; glandular pubescence blackish.	paniculate to loosely corymbose; glandular pubescence yellowish.
Flowers	pale yellow; mature earlier than *S. arvensis*.	golden yellow; mature later than *S. palustris*.
Achene	straw-coloured, boldly marked with smooth longitudinal ridges; ca. 4 mm long.	dark brown, moderately marked with conspicuously warty longitudinal ridges; ca. 3.5 mm. long.
Pappus	smooth-bristled, dingy-white.	rough-bristled, snow-white.
Cytology	$2n$=18	$2n$=36
Habitat	wet, calcareous meadows and subacidic fens.	dry, disturbed upland sites.

been the case in Ontario with other Eurasian wetland species like *Lythrum salicaria* and Flowering-rush (*Butomus umbellatus*) (Neave et al. 1991).

Acknowledgments

Our thanks to A. A. Reznicek, University of Michigan Herbarium, for examining the MICH collection on our behalf and for his helpful comments on an earlier draft of the manuscript. Our appreciation is also extended to Clarence Frankton for his review of the manuscript and to K. L. McIntosh for her assistance in the field.

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Received 20 May 1993
Accepted 17 December 1993

Nouvelles stations du Saule d'Alaska, *Salix alaxensis,* au Nunavik, Québec

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Cayouette, Jacques, Linda Dion, et Marcel Blondeau. 1993. Novelles stations du Saule d'Alaska, *Salix alaxensis,* au Nunavik, Québec. Canadian Field-Naturalist 107(3): 345–348.

Jusqu'à maintenant, le Saule d'Alaska, *Salix alaxensis*, n'était connu que d'une seule station au Nunavik (Nouveau-Québec). Des récoltes récentes, des observations visuelles et une mention de la littérature, ignorée jusqu'à maintenant, ont permis d'étendre la connaissance de sa répartition à d'autres secteurs de la vallée fluviale comprise entre le lac Watts et la baie Déception et à des régions nouvelles comme au sud de Salluit, à Kangiqsujuaq ainsi qu'au lac Lanyan, ce dernier étant situé dans la portion ouest du Nunavik. Un hybride présumé entre *S. alaxensis* et *S. lanata* subsp. *calcicola* est mentionné pour Kangiqsujuaq.

Up to now, the Alaskan Willow, *Salix alaxensis*, was known from only one station in Nunavik, northern Quebec. Recent collections, sight records, and one overlooked literature report allowed the authors to add some localities along the fluvial axis Watts Lake-Deception Bay, and to add new areas such as the Salluit region, Kangiqsujuaq and Lanyan Lake, the last one in western Nunavik. A suspected hybrid between *S. alaxensis* and *S. lanata* subsp. *calcicola* is reported from Kangiqsujuaq.

Key Words: Alaskan Willow, le Saule d'Alaska, *Salix alaxensis,* Nunavik, Quebec, distribution, new records, hybrids.

Le Saule d'Alaska, *Salix alaxensis* (Anderss.) Cov., est une espèce amphi-béringienne (Hultén 1968) qui n'était connue au Nunavik (Nouveau-Québec) que de la station du lac Watts, "*Willow valley*", (61°31′ N.-74°05′ O.). Il avait été découvert en 1962 par Matthews lors d'une étude écologique (Maycock et Matthews 1966) et était considéré alors comme une addition à la flore du Québec (Maycock 1963). Depuis lors cette localité est demeurée la seule connue au Québec pour cette espèce (Porsild 1964; Rousseau 1974; Porsild et Cody 1980; Bouchard et al. 1983). Dans leurs études, Maycock (1963) et Maycock et Matthews (1966) ont indiqué que le *Salix alaxensis* pourrait se retrouver ailleurs au Nunavik dans des habitats similaires et ils signalaient comme possible la région située au sud de l'anse Sugluk. Ces hypothèses n'avaient pas été vérifiées jusqu'à maintenant.

Dans le cadre de travaux de géobotanique utilisant la télédétection (Seuthé et al. 1986), une équipe du Centre de foresterie des Laurentides, Québec, a localisé diverses populations arbustives dans la fosse du Nunavik au nord du 61°N. En télédétection, particulièrement dans la toundra arctique, les arbustes ont une valeur indicatrice de premier plan. L'étude de leur croissance peut servir également à mesurer les changements climatiques récents. Le *Salix alaxensis,* pouvant atteindre une taille élevée (Maycock et Matthews 1966), est un candidat de choix pour de telles études et la connaissance de sa répartition s'avère de toute première importance.

Des récoltes de *S. alaxensis* ont été effectuées dans le cadre d'une étude sur la flore de cette portion du Nunavik (Dion, Cayouette, et Deshaye en préparation). La même équipe a également réalisé des observations visuelles de populations de ce saule arctique. Finalement, d'autres récoltes récentes provenant des explorations floristiques de Marcel Blondeau dans les régions de Salluit (1989) et de Kangiqsujuaq (1990), ainsi que des mentions précédemment ignorées complètent cette mise à jour et font l'objet du présent article.

Résultats et discussion

Les nouvelles colonies de *S. alaxensis* proviennent de quatre régions différentes et sont localisées sur la Figure 1. Les récoltes et mentions commentées sont les suivantes:

NOUVEAU-QUÉBEC:

1) Région du lac Watts:

À la tête du lac Watts, 61°46'30" N.- 74°09'00" O., saulaie arborescente (entre 1 et 3 m) sur alluvions (galets), alt. 45 m, 10.VII.1985, L. Dion 4.5-11 (QFB-E). — Lac Françoys-Malherbe, secteur nord, 62°05'N.- 75°25'O., 5.VIII.1981, J. Cayouette, observation visuelle. — Baie Déception, 62°06' N.- 74°37' O., camp site, 2 feet high, near sea shore, 13.VIII.1970, G. Gardner 1233 (QFA); aussi Gardner 1230, cité dans Gardner (1973).

Ces données indiquent que le *Salix alaxensis* est toujours présent au lac Watts (Dion), qu'il se rencontre aussi en marge du lac Françoys-Malherbe (Cayouette) situé dans la décharge du précédent et qu'il s'étend même jusqu'à l'extrémité nord de la vallée fluviale soit à la baie Déception, au niveau de la mer (Gardner). D'autres mentions sont également à signaler pour cette région. Matthews (1983) est retourné au "*Willow valley*" du lac Watts au début du printemps 1982 pour y noter les conditions d'enneigement et il a pu observer que les buissons de *S. alaxensis* avaient pris de l'expansion depuis 1962.

2) Région de Salluit:
Rivière Gatin, au sud de la confluence avec la rivière Foucault, 61°58' N.- 75°25' O., arbustaie haute dans la vallée encaissée d'un ruisseau, près de son embouchure avec la rivière Gatin, alt. 200 m, 10.VII.1985, L. Dion, observation visuelle. — Environs de Salluit, 62°07′ N.- 75°45′ O., UTM: 18VVD603870, terrasse sablonneuse au bord d'un ruisseau se déversant dans la rivière Foucault, à moins de 100 m d'altitude, 15.VIII.1989, M. Blondeau SW89258 (DAO, QFA, Herb. Blondeau). — "Kovik Gorge", southeast of Sugluk Inlet, 6.VIII.1946, D. Coates and B. Carr (Polunin 1949).

Les deux premières mentions, et peut-être aussi la troisième, proviennent d'un système fluvial situé à l'ouest de celui du lac Watts-baie Déception. Il est formé des rivières Gatin et Foucault et de l'anse Sugluk. L'observation de populations à la rivière Gatin (Dion) s'est faite en hélicoptère et des photographies en couleur ont été prises dont certaines à une altitude d'environ 15 mètres. L'examen de ces photos a permis de différencier clairement les individus de taille élevée et de coloration pâle du *S. alaxensis*, des autres arbustes de taille inférieure et de coloration foncée, composés de *Salix planifolia* et de *Betula glandulosa.*

La présence du *S. alaxensis* dans cette région est authentifiée par une récolte récente à l'embouchure de la rivière Foucault (Blondeau).

La mention de "*Kovik Gorge*" provient d'un ouvrage de Polunin (1949) dans lequel il relate le journal d'une vaste expédition multidisciplinaire faite au Nouveau-Québec en 1946. Polunin reçoit des plantes que deux membres de l'expédition, Donald Coates et Bill Carr, lui rapportent d'un endroit situé au nord-ouest du lac McGill (ca 60° 13°′N) et qu'ils appellent Kovik Gorge. Ce lieu est décrit comme un lac fortement encaissé entre des collines hautes de plusieurs centaines de pieds, avec des rives protégées où croissent des saules dont certains dépassent la taille d'un homme. Polunin (1949, pages 178–179) commente ainsi les quelques spécimens provenant de cet endroit:

> *"Moreover, two or three of the plants which they [Coates and Carr] brought back were 'indicators' of some significance — most notably the Alaskan Willow (Salix alaxensis), which they affirmed grew to a goodly height...Bill's [Carr] reward, as I assured him...would be to become 'immortalized in botanical literature', for example as the co-discoverer of this Alaskan Willow in the Province of Quebec".*

Cette mention n'a pas été répertoriée par Maycock (1963) ui dans la littérature récente sur ce saule au Québec. Le spécimen authentifiant cette mention n'a pas été retracé parmi les récoltes de Polunin faites en 1946 qui se retrouvent à l'Herbier du Musée des Sciences Naturelles, Ottawa (CAN), le plus souvent sans information autre que le numéro de récolte (A. Dugal *verbatim*). Comme les carnets de notes de Polunin pour cette période ont été détruits, il est possible qu'on ne puisse jamais retracer correctement le spécimen de Kovik Gorge (M. J. Shchepanek *verbatim*).

La localisation exacte de Kovik Gorge cause un problème. En appendice au livre de Polunin, Drake (1949, page 277) situe ainsi Kovik Gorge: "*...which lies to the south-east of Sugluk Inlet not far from the south shore of Hudson Strait and hence in the extreme north of Ungava Peninsula*". D'un autre côté, Manning (1949, page 164), un autre membre de cette expédition, localise les observations oruithologiques de Coates pour Kovik Gorge comme suit: "*This station was on the shore of a lake about 10 miles long by half a mile wide. The surrounding hills with steep, rocky walls rose 1,000 feet above the lake. In the valley, the vegetation consisted of grasses, mosses, dwarf birch, and willow up to 15 feet tall*".

L'examen des cartes actuelles n'a pas permis de localiser avec certitude un lac réunissant à la fois les caractéristiques (dimension, topographie) décrites par Polunin (1949) et Manning (1949) et les précisions quant à sa localisation: vers la tête de la rivière Kovik, selon la carte de Manning (1949, page 154), et au sud-est de Sugluk, selon Drake (1949). Les lacs Nuvilik (ca 61°31′N.- 75°00′O.), situés au sud-est de Sugluk mais non dans la vallée de la Kovik, auraient les dimensions requises, mais leur topographie est peu escarpée et la végétation alpine qui les borde est trop basse (L. Dion *verbatim*). Par contre, il y aurait dans la vallée de la rivière Kovik, à la hauteur de la colline Talluq (61°41′N. - 76°30′O.) située en plus basse altitude, des élargissements de la rivière formant des lacs à rives escarpées et abritant une végétation plus diversifiée (L. Dion *verbatim*) qui pourrait comprendre le *S. alaxensis*; il s'agit peut-être de Kovik Gorge, mais cette région n'est pas située au sud-est de Sugluk, mais au sud-ouest.

3) Région de Kangiqsujuaq:
Salix alaxensis: Rivière Allaagiaq, 6 km au sud-ouest de Kangiqsujuaq, 61°33′30″ N.- 72°01′ O.: UTM: 18VDX584286, plateau herbeux longeant la rivière, avec *Salix glauca* et *S. lanata* subsp. *calcicola,* 23.VII.1990, M. Blondeau WB90140 (CAN, QFA, Herb. Blondeau), WB90141 (QFA, Herb. Blondeau); 24.VII.1990, M. Blondeau WB90170 (QFA, Herb. Blondeau), WB90171 (QFA, Herb. Blondeau); UTM: 18VDX585286, dans les cailloux de la partie inondable de la rivière Allaagiaq, avec *Salix arctophila, Epilobium latifolium* et des mousses,

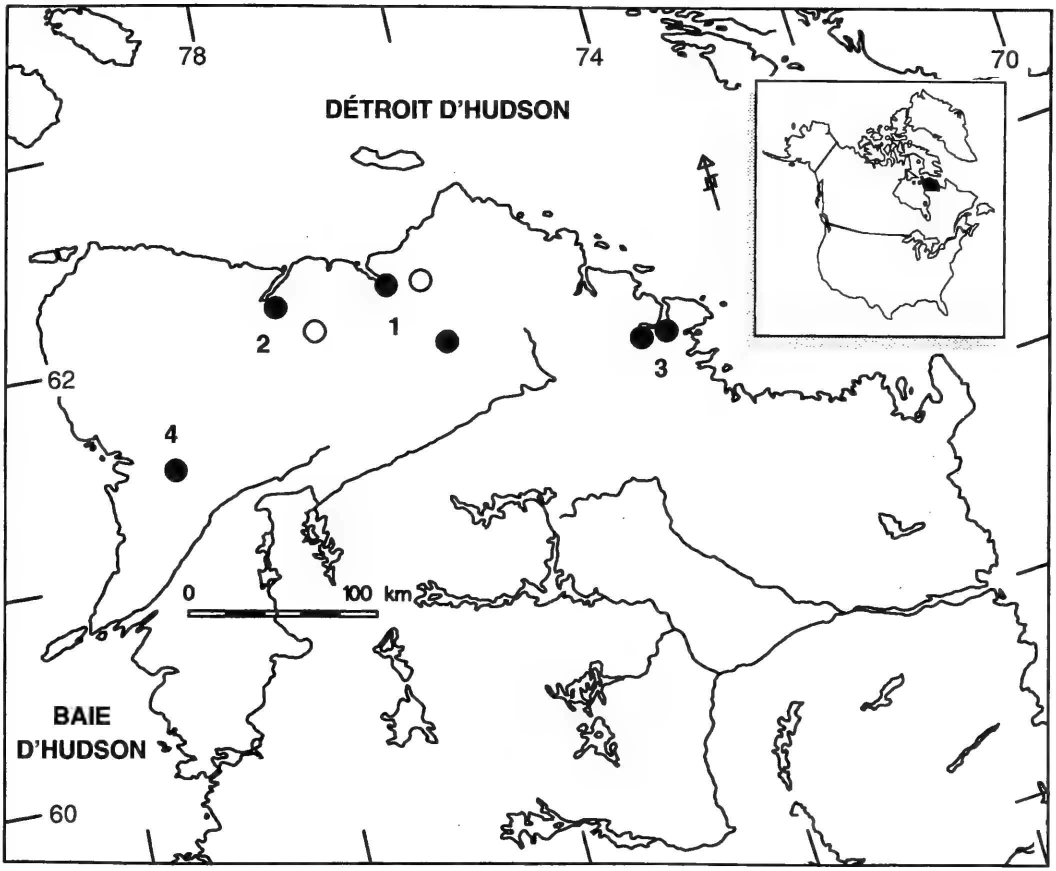

FIGURE 1: Répartition du *Salix alaxensis* au Nunavik (Nouveau-Québec). 1. Région du lac Watts; 2. Région de Salluit; 3. Région de Kangiqsujuak; 4. Lac Lanyan. Les cercles pleins désignent les localités authentifiées par des spécimens d'herbier; les cercles vides, les mentions visuelles. La mention pour "*Kovik Gorge*", qui n'a pas été localisée avec précision, n'est pas indiquée.

23.VII.1990, M. Blondeau WB90143 (DAO, QFA, Herb. Blondeau). — Au fond de la baie Wakeham, une quinzaine de kilomètres au sud-ouest du village, 61°33'30" N.- 72°16' O., UTM: 18VDX452278, terrasse de sable et de gravier, avec *Salix glauca*, au confluent d'un ruisseau et de la rivière Wakeham, 3.VIII.1990, M. Blondeau WB90318 (QFA, Herb. Blondeau), WB90320 (QFA).

Salix alaxensis x *S. lanata* L. subsp. *calcicola* (Fern. and Wieg.) Hult.: Rivière Allaagiaq, 6 km au sud-ouest de Kangiqsujuak, 61°33'30"N.- 72°01'O., UTM: 18VDX585286, dans les cailloux de la partie inondable de la rivière, entre *S. alaxensis* et *S. lanata* subsp. *calcicola,* 23.VII.1990, M. Blondeau WB90142 (CAN, QFA, Herb. Blondeau); 24.VII.1990, M. Blondeau WB90169 (CAN, QFA, Herb. Blondeau).

Six récoltes proviennent de la même station, soit les rives d'un bras de la rivière Allaagiaq, qui coule en direction nord. Une quinzaine d'individus d'environ un mètre (0.9 - 1.4 m) de hauteur étaient étalés sur une distance d'une cinquantaine de mètres, la plupart sur la berge ou sur le plateau herbeux plus ou moins élevé longeant la rivière.

C'est sur la platière de cette rivière que fut observé un individu pistillé, probablement hybride, d'environ 50 cm de hauteur, d'apparence intermédiaire entre les deux parents qui croissaient de chaque côté: *S. lanata* subsp. *calcicola*, à fleurs pistillées, et *S. alaxensis*, à fleurs staminées. Les capsules des chatons de l'hybride présumé sont parfois glabres comme chez le *S. lanata* et plusieurs feuilles se terminent par un angle obtus, à la manière du *S. lanata.* Les autres caractères l'associent au *S. alaxensis.* Son apparence intermédiaire était surtout visible sur le terrain, mais des études plus détaillées seraient nécessaires pour vérifier plus à fond cette hypothèse. Un commentaire de G. W. Argus (CAN) qui a examiné ces récoltes (*in litt.* à M. Blondeau 1990), laisse entrevoir la possibilité de l'hybridation: "*It is possible that your plant is a slightly atypical specimen of S. alaxensis. I am inclined, however, to trust* *your field impression and to accept your determination. Hybrids are often quite distinctive when growing in the same areas as the parents. As far as I know, this is the first report of this cross.*" Aucun autre individu ayant cette apparence ne fut observé ailleurs dans la région de Kangiqsujuaq.

Les deux autres récoltes de *S. alaxensis* proviennent du fond de la baie Wakeham, à l'embouchure de la rivière du même nom. Une cinquantaine d'arbustes d'environ un mètre de haut y furent observés sur une terrasse sablonneuse encaissée au confluent d'un ruisseau et de la rivière Wakeham. Cette terrasse semble partiellement inondée lors des crues printanières.

D'autres sites présentant des conditions similaires propices à la croissance du *S. alaxensis* existent ailleurs dans la région de la baie Wakeham, mais ces milieurx n'ont pu être visités.

4) Région du Lac Lanyan: lac Lanyan, 61°28' N.- 77°04' O., prairie à mousses avec des arbustes bas (*Betula, Salix*) et des plantes éricacées, milieu humide avec de nombreuses buttes gazonnées, alt. 90 m, 18.VII.1985, L. Dion 2.10a-10 (QFB-E).

Cette récolte marque une extension au sud et à l'ouest du *S. alaxensis* au Nunavik. L'habitat du saule est différent à cet endroit; il s'agit d'une prairie humide avec des arbustes bas comme *Salix planifolia*, *S. arctophila*, *Betula glandulosa* et *Ledum decumbens*, contrairement à des rives de ruisseaux, de rivières ou de lacs pour les mentions précédentes.

Les présentes mentions de *S. alaxensis* indiquent qu'il est plus répandu que prévu au Nunavik, comme le laissent entendre Maycock et Matthews (1966) pour la région de Salluit. D'autres populations pourraient sans doute être découvertes en explorant des habitats propices. Ces habitats semblent être principalement des milieux protégés (rives de ruisseaux ou de lacs, alluvions inondables des rivières) et situés en assez basse altitude (inférieure à 200 m). Cependant, la récolte du lac Lanyan (prairie à mousses) laisse entendre que l'habitat du *S. alaxensis* pourrait être plus diversifié que prévu.

Les populations de *S. alaxensis* au Nunavik représentent la limite est de sa répartition mondiale. Sa distribution géographique ressemble à celle d'*Oxytropis maydelliana* et l'on peut vraisemblablement reconstituer leur recolonisation postglaciaire au Québec arctique par des voies de migration empruntant le nord-ouest de la péninsule (Cayouette 1986).

Remerciements

Les auteurs remercient Robert Gauthier (QFA) pour le prêt de spécimens, Albert Dugal et Mike J. Shchepanek (CAN) pour les informations sur les récoltes de Polunin, George W. Argus (CAN) pour l'examen des récoltes de Kangiqsujuaq, Stephen J. Darbyshire et M. Jomphe (DAO) pour la confection de la Figure 1, Ernie Small et William J. Cody pour leurs commentaires judicieux sur le manuscrit.

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Reçu 6 July 1993
Accepté 17 September 1993

Notes

Early Nesting by the American Goldfinch, *Carduelis tristis*, and Subsequent Parasitism by the Brown-headed Cowbird, *Molothrus ater,* in Ontario

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Mariani, Christopher L., Christopher G. Earley, and Christopher McKinnon. 1993. Early nesting by the American Goldfinch, *Carduelis tristis*, and subsequent parasitism by the Brown-headed Cowbird, *Molothrus ater,* in Ontario. Canadian Field-Naturalist 107(3): 349–350.

An American Goldfinch, *Carduelis tristis*, nest was found on 27 May 1991 at Guelph, Ontario. The nest was lined with pappus from the Bull Thistle, *Cirsium vulgare*, probably obtained from last year's seed heads that survived over the winter, as well as a variety of other plant downs. Early completion of the prealternate moult of the female may have been a factor in stimulating early nesting and egg laying. Although the nest was parasitized by a Brown-headed Cowbird, *Molothrus ater*, the cowbird chick failed to survive. This was probably a result of the highly granivorous diet normally fed to American Goldfinch nestlings.

Key Words: American Goldfinch, *Carduelis tristis*, Brown-headed Cowbird, *Molothrus ater*, nesting behaviour, brood parasitism, moulting, Ontario.

The American Goldfinch, *Carduelis tristis*, does not normally begin nesting until July or August (Tyler 1968; Middleton 1978). Nevertheless, several publications reported egg-laying in June (Trautman 1940; Berger 1968; Tyler 1968) along with one instance in May (Roberts 1932). The earliest recorded egg date in Ontario was 13 June (Peck and James 1987). Thus, our discovery of an American Goldfinch nest at Guelph, Ontario on 27 May 1991 was unusual.

On 27 May 1991, a female American Goldfinch was seen flying into a Japanese Yew, *Taxus cuspidata*, in the Arboretum, University of Guelph. A nest was discovered that appeared to be complete. The first egg was laid on 28 May. Daily checks of the nest showed that four American Goldfinch eggs and one Brown-headed Cowbird, *Molothrus ater*, egg were laid, and incubation began around 1 June. On 10 June, the female goldfinch was mist-netted and colour-banded, and the eggs were examined by "candling" them against the sunlight. We saw no evidence of any development in the goldfinch eggs. The cowbird egg hatched on 11 June. Although it weighed 13.5 g on 19 June, the young cowbird's development was retarded, and it died in the nest between 20 and 21 June. The adult goldfinches were not seen thereafter and we were unable to locate any subsequent nests built by this female.

The question of why American Goldfinches delay nesting until July or August has long been of interest (Lynch 1970; Mundinger 1972). Breeding is timed to coincide with the flowering of composite plants (family Compositae), particularly thistles (Tyler 1968; Middleton 1978). Most composites begin flowering in the northern United States and Canada in late spring and early summer. The list of plants producing seeds that are consumed by the American Goldfinch is long and varied (Nickell 1951; Tyler 1968), but the strong preference for thistles, both for nesting material and food, is well documented (Nickell 1951; Miller 1978). Some authors believe that the dependency of goldfinches on thistles has been overstated (Batts 1948; Stokes 1950; Watt and Dimerbio 1990), and Nickell (1951) claimed that a wide variety of plant materials was used in nest building. The early nest at Guelph was built with large amounts of fluff from both Common Catttail, *Typha latifolia*, and Narrow-leaved Catttail, *T. angustifolia*, as well as an abundance of Common Dandelion, *Taraxacum officinale*, pappuses. Large amounts of synthetic material were also incorporated. Surprisingly, the majority of the downy material found in the nest was pappus of the Bull Thistle, *Cirsium vulgare*, which did not flower in the Guelph area until mid-June of 1991. Presence of thistledown in the nest may be explained by the fact that the plant's seed heads often remain intact throughout the winter and into the later months of spring (J. F. Alex and C.A. Lacroix, personal communications), facilitating early use by the goldfinch.

Our evidence supports the view that nesting is not dependent upon the actual flowering of thistles, and that the American Goldfinch can build and adequately line its nest from a variety of plant downs. What stimulated nesting by this female, however, remains unclear. Her eggs were infertile which was probably a reflection of male infertility at this time of the year (Mundinger 1972; Middleton 1978). By contrast, her own ability to produce eggs, though outside the norm for the population, fell within the extreme range of fertility recorded at Guelph (Middleton 1978). Photoperiod appears to be the proximate factor that regulates the annual cycle of the American Goldfinch, but the presence of the prealternate moult in spring has an effect in delaying all phases of the reproductive cycle (Mundinger 1972; Middleton 1978). If the female in question completed her prealternate moult early, she could have become responsive to a stimulatory photoperiod at an earlier date than normal, which in turn could have accelerated the onset of nesting. Such an explanation appears plausible and would also explain the early nesting records in the literature (Roberts 1932; Stokes 1950; Tyler 1968).

The presence of the cowbird chick was also of interest. As discussed by Middleton (1991), the likelihood of cowbirds being successfully raised by goldfinches is not high (Berger 1961; Friedmann and Kiff 1985). Friedmann (1963) suggested that this phenomenon has occurred, citing the following passage: "On my return I found the young cowbird occupying nearly the whole nest, and the foster mother as attentive to it as she would have been to her own" (Wilson 1810). Although this may fit Friedmann's (1963) requirements for a successful fosterer, proof of fledging is still very much in doubt. The cause of this failure is probably related to the highly granivorous diet fed to goldfinch nestlings, rather than to food shortage (Stokes 1950; Berger 1961; Middleton 1991). In our study, the cowbird survived for 10 days, but though its body size was large, its feather development was retarded, and the chick was clearly unprepared for fledging, a situation similar to that reported by Middleton (1991). The cowbird chick was not in competition for food, and so its failure to survive adds support for the view that the American Goldfinch is a poor fosterer of Brown-headed Cowbirds, and that the cause is a nutritional deficiency (Middleton 1991).

Acknowledgments

This report was supported by the Natural Sciences and Engineering Research Council of Canada, through grant #A6495 to A. L. A. Middleton. Additional funding was also provided through the Summer Undergraduate Research Scholarship, College of Biological Science, University of Guelph. The authors thank J. F. Alex and C. A. Lacroix at the Herbarium, University of Guelph, for assistance in plant identification and analysis of the nest contents, and A. L. A. Middleton for comments and help with the manuscript.

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Received 8 August 1992
Accepted 23 November 1993

Black Redhorse, *Moxostoma duquesnei* Rediscovered in Wisconsin

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Until recently, the Black Redhorse (*Moxostoma duquesnei*) was thought to be extirpated from the state of Wisconsin with the last documented record from Black Earth Creek in Dane County on 7 August 1928. On 22 April 1992, one specimen was caught in Lake Wausau, a reservoir on the Wisconsin River, in Marathon County. This site is 298 km upstream from the confluence of Blue Mounds Creek (Black Earth Creek is one of its tributaries) with the Wisconsin River. In July 1992, five additional specimens were collected in the Wisconsin River below the Wausau Hydroelectric Dam and three more specimens were collected in the Eau Claire River near its confluence with the Wisconsin River in Wausau. Wisconsin is in the process of adding this redhorse to its endangered species list.

Key Words: Black Redhorse, *Moxostoma duquesnei*, distribution, endangered, Wisconsin.

The last time that a Black Redhorse (*Moxostoma duquesnei*) was collected in Wisconsin was on 7 August 1928 in Black Earth Creek. This Dane County location (longitude 89°46′35.09″ latitude 43°9′24.06″) is 15 km above its confluence with the Blue Mounds Creek, which flows into the Wisconsin River 10 km downstream (Greene 1935). This specimen is cataloged at the University of Michigan (Michigan Zoology catalog number 47641). Black Earth Creek was sampled numerous times in the 1960s and 1970s without a Black Redhorse being identified (Fago 1992). The construction of an impoundment downstream of this location may have helped eliminate this species from Black Earth Creek (Becker 1983). The only other record is for a specimen (U.S. National Museum 20272) collected by S. F. Baird in 1853 from the Root River, Wisconsin (Jordan 1878; Becker 1983). There are two Root Rivers in Wisconsin based upon U. S. Geological 7.5″ topographic maps South Racine and Pleasant Prairie. The larger one flows into Lake Michigan at Racine in Racine Co., Wisconsin, and the smaller one is a tributary of the Des Plaines River (a tributary of the Illinois River, flowing into the Mississippi River) a few miles west of Kenosha in Kenosha County, Wisconsin. Since the only locational information for this record is Root River, Wisconsin, there is some concern as to which river is correct. Due to the Kenosha County Root River's smaller size and question as to possibility it was not called the Root River in the 1850s, we assume that the Root River at Racine is probably correct. Starting in the early 1920s and again in the 1970s, this Root River was sampled at numerous locations without a Black Redhorse being identified (Fago 1992). The changing land uses and resulting changes in water quality and habitat in the last 120 years could easily account for the extirpation of any population that was previously there. Therefore, the Root River at Racine was the only known location for this species on the western side of the Lake Michigan basin.

During spring fyke netting on 22 April 1992, a single specimen tentatively identified as a Black Redhorse was collected from Lake Wausau (a mainstem impoundment of the Wisconsin River) in Marathon County, Wisconsin (longitude 89°38′5.49″ latitude 44°55′12.17″). This site is 298 km upstream from Blue Mounds Creek's confluence with the Wisconsin River. The specimen's standard length was 320 mm and its identification was confirmed by Robert E. Jenkins at Roanoke College in Salem, Virginia. On 5 July 1992, we electrofished the Eau Claire River above the Schofield Dam in Wausau and collected three specimens. The location (longitude 89°35′57.22″ latitude 44°55′44.88″) was 1.6 km upstream from the river's confluence with the Wisconsin River. Five additional specimens were collected on 6 July 1992 during night electrofishing in Wisconsin River below the Wausau Hydroelectric Dam in Wausau (longitude 89°38′6.41″ latitude 44°57′20.97″). Total length of these specimens ranged from 281 to 400 mm. Scale analysis showed these fish to be 3 to 5 years old.

One specimen from the Wisconsin River at Wausau was frozen and given to D. G. Buth at the University of California - Los Angeles for electrophoretic analysis. He will compare this specimen with others collected throughout its range in the U.S. All other specimens are cataloged (numbers 18072-18079) and stored at the Wisconsin Department of Natural Resources' (WDNR) Southern District Headquarters in Fitchburg, Wisconsin.

Clearly, the Black Redhorse is extremely rare in Wisconsin. Formal procedures for adding the Black Redhorse to Wisconsin's endangered list have begun but are not expected to be completed until late 1994 or early 1995 (Robert Hay, Wisconsin Department of Natural Resources, personal communication 1993).

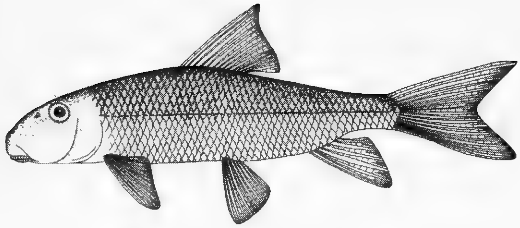

FIGURE 1. Black Redhorse (*Moxostoma duquesnei*), from *Fishes of Illinois* by Philip W. Smith (1979), by permission of the University of Illinois Press, Urbana.

The Wisconsin River watershed above the confluence of Blue Mounds Creek with the Wisconsin River has not been adequately sampled for the Black Redhorse. If anyone collects a redhorse in these waters or any other location in Wisconsin with a slate colored caudal fin, 44 to 47 scales along the lateral line, and a swollen snout that may overhang its mouth (see Figure 1), please preserve one specimen and call Don Fago collect at (608) 221-6366 as soon as possible. The Golden Redhorse (*Moxostoma erythrurum*) is the most easily confused redhorse with the Black Redhorse. The Golden Redhorse has 40 to 42 lateral line scales and a snout that is bluntly pointed to rounded but not swollen or overhanging its mouth.

Acknowledgments

We thank Robert E. Jenkins, Department of Biology, Roanoke College, Salem, Virginia, for confirming the identification of the Black Redhorse specimen collected on 22 April 1992. This article was critically reviewed by Tom Pellett and Wendy McCown. Permission to use the line drawing of the Black Redhorse from *Fishes of Illinois* (1979), by Philip Smith, was granted by University of Illinois Press.

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Received 16 September 1992
Accepted 18 January 1994

Skipjack Herring, *Alosa chrysochloris,* Expanding Its Range into the Great Lakes

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Fago, Don. 1993. Skipjack Herring, *Alosa chrysochloris*, expanding its range into the Great Lakes. Canadian Field-Naturalist 107(3): 352–353.

The first reported catch of a Skipjack Herring (*Alosa chrysochloris*) in the Great Lakes occurred in Green Bay north of Dyckesville, Kewaunee County, Wisconsin, on 2 August 1989 . The specimen, which was caught in 8 m of water, weighed 283 g and measured 31 cm in total length (Fago, 1990). In January of 1991, a second specimen was caught in Lake Michigan in 116 m of water east of Kenosha, Kenosha County, Wisconsin. A third specimen was caught on 12 October 1992 in Lake Michigan east of Bailey's Harbor, Door County, Wisconsin, near the outlet of Moonlight Bay in 9 m of water. This 43-cm specimen weighed 1.1 kg. All were caught by commercial fishermen.

Key Words: Skipjack Herring, *Alosa chrysochloris*, distribution, endangered, Wisconsin, Great Lakes.

On 2 August 1989, the first reported catch of a Skipjack Herring (*Alosa chrysochloris*) in the Great Lakes occurred in 8 m of water in Green Bay north of Dyckesville, Kewaunee County, Wisconsin (longitude 87°46′47.40″, latitude 44°38′16.69″). The fish weighed 283 g and measured 31 cm in total length (Fago 1990). The specimen was deposited at the University of Wisconsin Zoology Museum (catalog number 9962). In January 1991, a second specimen was taken in 116 m of water from Lake Michigan east of Kenosha, Kenosha County, Wisconsin (longitude 87°47′57.15″ latitude 42°34′44.50″). The fish weighed

235 g and measured 277 mm in total length. Almost two years later, on 12 October 1992, a third Skipjack Herring was caught in 9 m of water from Lake Michigan east of Bailey's Harbor, Wisconsin, near the outlet of Moonlight Bay (longitude 87°4′0.81″, latitude 45°4′30.04″). This 43 cm specimen weighed 1.1 kg. These last two specimens are stored at the Wisconsin Department of Natural Resources's (WDNR) Research Center in Monona, WI (catalog numbers 18070 and 18071). All specimens were caught by commercial fishermen. A thorough review of the literature turned up no other reference to the Skipjack Herring from the Great Lakes (Becker 1983; Greene 1935; Hubbs and Lagler 1964; Scott and Crossman 1973). This species' native range includes the larger rivers of the Mississippi River basin and tributaries along the Gulf of Mexico from northwestern Florida to Texas (Lee et al. 1980).

One plausible explanation for their occurrence in Green Bay and Lake Michigan would be they moved up from the Illinois River and into the Chicago Sanitary and Ship Canal and from there into Lake Michigan. This route was created in 1900 but recent improvements in water quality may have allowed this species to migrate into Lake Michigan (Commonwealth Edison Company 1977; Metropolitan Water Reclamation District of Greater Chicago 1990).

Little is known about the spawning habits of this species (Becker 1983). It is important to keep track of the expansion of any non native species into a basin or the reappearance of an extirpated species to determine if a viable population has been established. In 1989, the Skipjack Herring was put on Wisconsin's Endangered List based upon its recent return to the Wisconsin portion of the Mississippi River. If anyone thinks that they have collected this herring with its distinctive protruding lower jaw with prominent teeth, and teeth on its tongue (see figure 1), please preserve one specimen and call Don Fago collect at (608) 221-6366. The Alewife, *Alosa pseudoharengus,* which is the most easily confused species with the Skipjack Herring, lacks the above characteristics and also has 41-44 gill rakers on lower limb of first gill arch and 42-50 lateral line scales instead of the 20-30 and 53-60 respectively for the Skipjack Herring.

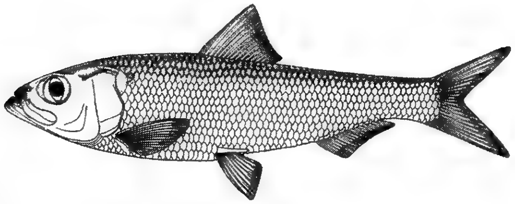

FIGURE 1. Skipjack Herring, *Alosa chrysochloris,* from *Fishes of Illinois* (1979) by Philip W. Smith, by permission of the University of Illinois Press, Urbana.

Acknowledgments

This article was critically reviewed by Tom Pellett. Permission to use the line drawing of the Skipjack Herring from *Fishes of Illinois* (1979) by Philip W. Smith was granted by University of Illinois Press.

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Received 22 December 1992
Accepted 18 January 1994

Population Status and Reproductive Biology of the Mute Swan, *Cygnus olor*, at Long Point, Lake Erie, Ontario

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Knapton, Richard W. 1993. Population status and reproductive biology of the Mute Swan, *Cygnus olor*, at Long Point, Lake Erie, Ontario. Canadian Field-Naturalist 107(3): 354–356.

During 1991 - 1992, a study of the population status and breeding biology of the Mute Swan, *Cygnus olor*, was carried out at Long Point, Lake Erie. Thirty-one pairs with broods were located, 9 in 1991, 22 in 1992. Brood size ranged from 2 to 10, with 4 and 5 being the most frequent. Brood size averaged 4.9 at hatching and 3.1 at fledging, a value which compares with that of rapidly expanding populations in Europe. Aerial surveys in fall at Long Point revealed a peak total of 148 in 1991 and 172 in 1992, an increase of 14 %. A high proportion of "Polish" morph juveniles were detected.

Key Words: Mute Swan, *Cygnus olor*, status, reproductive biology, Long Point, "Polish" morph.

Mute Swans, *Cygnus olor*, were first reported breeding in the wild in Ontario in 1958 (Peck 1966), and in the Long Point area in the early 1970s (McCracken et al. 1981). The species was classed as a locally rare and irregular breeder at Long Point up to 1980 (McCracken et al. 1981). The population of Mute Swans at Long Point has increased considerably in the last decade; the species appears at present to be a common, widespread, conspicuous and regular breeder in marshes and wetlands around the Inner Bay at Long Point and in Turkey Point Marsh. In this paper, I report on the results of censuses of breeding pairs and non-breeding adults in 1991 and 1992 at Long Point, on the degree of reproductive success, and on evidence of a rapidly increasing and expanding population.

Methods

A census route was set up at Long Point (42° 35' N, 80° 24' W), using road accessible locations for viewing the marshes and wetlands around the Inner Bay. The route ran from the Long Point Provincial Park on the southeast corner around the perimeter of the bay to Turkey Point at the northeast corner of the bay. Numbers and locations of adults and young were recorded during each census. Counts were carried out in the morning every five to six days from 16 May to 25 August in 1991 (N = 14) and from 5 May to 20 August in 1992 (N = 16). Breeding pairs of swans showed high fidelity to given areas, hence a pair once found was relocated regularly in subsequent censuses. Pairs with broods, especially very young cygnets, were particularly easy to relocate. The ground censuses in 1992 were supplemented by boat trips to check the status of pairs that had taken their young into areas which were not visible from shore.

As part of a larger monitoring program of populations of waterfowl gathering at Long Point during spring and fall, aerial censuses were flown in September and October of each year, before the arrival of fall migrant Tundra Swans, *Olor columbianus*. Mute Swans are easily located from the air; during each survey, the locations and numbers of Mute Swans seen were recorded and mapped.

Results

In total, 31 pairs with broods were located, 9 in 1991 and 22 in 1992. Brood size ranged from 2 to 10 young (Table 1), with brood sizes 4 and 5 being the most frequent. Average brood size at hatching was 4.3 in 1991 and 5.1 in 1992, with a mean and standard deviation for the two years of 4.9 ± 1.9.

Eleven of 31 broods were raised without loss, and two pairs did not raise any young. Causes of cygnet mortality were not known in most cases. Snapping Turtles, *Chelydra serpentina*, were thought to be major predators on cygnets up to one month old elsewhere in North America (Palmer 1976), and loss of young to Snapping Turtles at Long Point was suspected in some instances. Rearing success tended to increase with brood size, although sample sizes for larger brood sizes were too small for statistical analysis. Conversely, all broods over six cygnets lost at least one young (Table 1), probably through the inability of the parents to supply all cygnets equally with food or to protect them from predators such as Snapping Turtles. Rearing success varied considerably among localities. Some areas had consistently low success rates; in one marsh complex, for example, four broods (two in 1991, two in 1992) resulted in only two young fledging out of 21 hatched.

In 1991, nine pairs with young were located. These pairs initially had 39 cygnets; 25 young were raised to at least 60 days of age, giving a fledging success rate of 64% and an average of 2.8 young per pair. In 1992, a more comprehensive search revealed larger breeding numbers than in 1991; 22 nesting

TABLE 1. Analysis of rearing success within brood sizes of Mute Swans, 1991-1992.

Brood size	N	Total number of young raised	Number rearing complete broods	Number losing at least one cygnet	Number losing complete broods
2	4	5	2	1	1
3	2	5	1	1	0
4	7	21	3	4	0
5	10	29	4	5	1
6	2	10	1	1	0
7	2	6	0	2	0
8	3	13	0	3	0
10	1	7	0	1	0

pairs were found. These pairs produced 112 cygnets and raised 71 young to at least 60 days of age, giving a fledging success rate of 63%, and an average of 3.3 young per pair.

Aerial censuses gave a fairly accurate reflection of size of the Mute Swan population at the end of the breeding season. The largest total in 1991 was 148 on 13 October, and in 1992 172 on 11 September. This represents an increase of 14% in the total number of Mute Swans between years.

A non-breeding flock of Mute Swans occurred in the marshes of Turkey Point during both summers. In 1991, numbers peaked at 31 (along with a Black Swan, *Chenopsis atrata*, presumably a local escape) in early July, and in 1992, they peaked at 35 in mid-June.

Discussion

The Mute Swan population in the Long Point area is rapidly increasing. The 14 % increase recorded for maximum counts between 1991 and 1992 is similar to the annual increase (12%) calculated over a 12-year period (1969 - 1981) for a population of Mute Swans which showed rapid increase in British Columbia (Campbell et al. 1990). Mute Swans, especially females, show high site-fidelity to their natal areas (Coleman and Minton 1979); therefore the increase in swans at Long Point is probably not due to recruitment from other areas, but from nesting success at Long Point and subsequent survivorship of young birds to their first breeding.

Brood size at hatching was 4.9 for the two years combined, slightly higher than found in Europe (for example, 4.5 for 13 years in Staffordshire, England; Coleman and Minton 1980). The number of cygnets fledged per breeding pair for the two seasons combined at Long Point was 3.1, comparable to rapidly expanding populations reported in Europe; values of 3.1 were determined in an increasing population in Denmark and 3.2 for a population in Latvia (in Eltringham 1966). In Britain, where the bulk of Mute Swan research has been undertaken and where long-established populations are mostly stable, the number of cygnets per breeding pair in long-term studies was considerably lower, ranging from 1.4 in the Outer Hebrides to 2.2 in Oxford (Perrins and Reynolds 1967; Jenkins et al. 1976; Bacon 1980a; Perrins and Ogilvie 1981).

In an expanding population, the age structure of the nesting population could be skewed towards younger birds. There are no data on the age of the nesting birds at Long Point, nor is there a clear relationship between clutch size and age of breeding female in Mute Swans (Perrins and Reynolds 1967). Clutch size is correlated with season, larger clutches being laid earlier. First-time nesting females tend to lay later than older nesters, and thus have smaller clutches; otherwise there are no age-related correlations. One positive correlation seems to be between mass of breeding female and clutch size (Reynolds 1972). However, one intriguing aspect of the growing population of Mute Swans at Long Point is the proportion of the "Polish" morph among the cygnets. Cygnets of the Mute Swan show plumage polymorphism; in juvenile plumage, the "normal" morph is gray-brown, whereas the "Polish" morph is white. Bacon (1980b) advanced the hypothesis that there is an advantage to the heterogametic female to be white, because it enables her to establish a pair-bond and begin breeding earlier in low density and expanding populations. Some of the highest frequencies recorded for the Polish gene are in such populations (e.g., Munro et al. 1968). In 1992, the majority of cygnets at Long Point were white, at a ratio of about 7:1 white:gray-brown, and Long Point's Mute Swan population is expanding, hence lending support to Bacon's hypothesis.

Acknowledgments

I thank the assistants who helped in collecting and tabulating data on Mute Swan pairs and their broods, and for helping count swans during aerial surveys: Dave Agro, Kerrie Pauls, Chris Drummond, Keiko Kimura, Garth Herring and Peter Burke. I thank Michael Bradstreet for helpful comments on an earlier draft of the manuscript. Funding was supplied by the Long Point Waterfowl and Wetlands Research Fund, through support from the Bluff's Hunting Club, Ontario Ministry of Natural Resources, Canadian Wildlife Service, Nature Conservancy of Canada, Long Point Bird Observatory, Ontario Environmental Youth Corps and Federal Section 25 and Challenge programs. Logistical support was provided by Long Point Bird Observatory. This is publication 93-03 of the Long Point Waterfowl and Wetlands Research Fund.

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Received 2 February 1993
Accepted 8 October 1993

Supernumerary Clutches of Common Loons, *Gavia immer,* in Ontario

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McNicholl, Martin K. 1993. Supernumerary clutches of Common Loons, *Gavia immer,* in Ontario. Canadian Field-Naturalist 107(3): 356–358.

Evidence for three or four-egg clutches of Common Loons reported by contributors to the Canadian/Ontario Lakes Loon Survey, along with previously published records, suggested renesting is at least sometimes responsible, but laying by two females is sometimes likely. Genuine three or four-egg clutches cannot be entirely ruled out.

Key Words: Common Loon, *Gavia immer*, Ontario, supernumerary clutches.

The Common Loon *Gavia immer* usually lays two-egg clutches (Bent 1919; Palmer 1962; H. H. Harrison 1975; Cramp et al. 1977; C. Harrison 1978; Johnsgard 1987; McIntyre 1988). Although J. J. Audubon believed three eggs to be the usual clutch size (Bent 1919), Bent's assertion that three-egg clutches must be very rare is borne out by McIntyre's (1988: Table 2-5) summary of eight quantitative studies. Of 622 clutches considered, only five (0.8%) consisted of three eggs. Similarly, of 125 nests in the Ontario Nest Records Scheme, only one (0.8%) contained more than two eggs (Peck and James 1983), and only one of 192 nests (0.5%) reported to the British Columbia Nest Records Scheme contained three eggs (Campbell et al. 1990). No supernumerary clutches were found in 193 nests studied by Croskery (1991) in western Ontario. Three-egg clutches have been reported in Alberta (three records: Henderson 1924; Vermeer 1973), British Columbia (one record: Bennie 1979; Campbell et al. 1990), Minnesota (two records: Hollis La Tourelle *in* Olson and Marshall 1952; McIntyre 1988), New Brunswick (one record: Boyer 1961), and Saskatchewan (one record: K. Yonge *fide* McIntyre 1988). McIntyre (1988) also reported seeing "two broods of three partially grown young that I could verify had come from the same nest," and there is a report of 14 three-chick broods among 333 broods (4.2%) recorded in Minnesota (K. V. Hirsch and C. L. Henderson. 1980. Results of an observer card program for Common Loons in Minnesota - 1980. Unpublished report, Minnesota Department of Natural Resources). Three four-egg clutches have been reported, one each in Minnesota (Zicus et al. 1983), New Hampshire (Nelson 1983) and Ontario (Peck and James 1983).

Nelson (1983) summarized three possible explanations for supernumerary clutches in Common Loons. The first was that two females laid in the same nest, as also suggested by Peck and James (1983) for a four-egg clutch in Ontario and by Johnsgard (1987) for supernumerary clutches generally. Several observers reported, however, that only one pair was seen in the vicinity of the nest (Boyer 1961; Nelson 1983; Zicus et al. 1983; Campbell et al. 1990 regarding Bennie 1979). Nevertheless, all these clutches were complete by the time they were discovered except that of Boyer (1961), so a second pair (or at least a second female) could have been present earlier. McIntyre's (1988) observation of two three-chick broods that she could attribute to specific nests is the only published report of supernumerary clutches known to have hatched, and the fertility of most such clutches is unknown; female-female pairs (as known in some larids - see Hunt 1980) may have been responsible in some instances. Nelson's (1983) second explanation was that one female laid all eggs in one breeding cycle. Evidence for this would require knowledge of the laying history at the nest, lacking from all published records, as the only nest found before laying was completed contained two eggs when discovered (Boyer 1961). The third explanation given by Nelson (1983) was that an initial clutch had been abandoned, after which a second clutch was laid in the same nest. Hatching of one or two eggs only would support this explanation, although it would not preclude the other explanations. Observations of three-chick broods need not involve a three-egg clutch at all, as one or two chick(s) could have been "adopted" (J. McIntyre *in* Hirsch and Henderson, unpublished report cited above). Young chicks are known to become separated from adults by weather or other factors (Strong and Bissonette 1989) and adults will sometimes accept chicks under 14 days old (Belant and Olson 1991).

The Long Point Bird Observatory has conducted a volunteer loon survey since 1981 (Ashenden 1988), initially restricted to Ontario, and more recently Canada-wide. Although contributors are discouraged from disturbing nests, they are asked to report any details of nest contents that they observe. Of 34 clutches reported during 1984 through 1986, 26 consisted of two eggs, six of one egg and two of three eggs (M. K. McNicholl. 1987. Ontario Lakes Loon Survey Progress Report Number 4: 1984-1986. Long Point Bird Observatory, Port Rowan, Ontario). Three cases of three or four young during that period also suggested supernumerary clutches (McNicholl *op. cit.*). This note puts details of these reports on record, along with several records reported to the Canadian or Ontario Lakes Loon Survey in subsequent years.

The two three-egg clutches noted in the progress report were reported by Josephine Leadbetter two years in a row from an island in Allen Lake, Haliburton County. The nest was abandoned prior to hatching in 1984, and no young were seen in 1985. The fact that three eggs were laid for two years in a row suggests that the same female with a propensity for laying larger than normal clutches was involved, but other scenarios are possible. No three-egg clutches were reported in 1986, 1987 or 1988. In 1989, a nest watched by Gordon Bellerby on Redstone Lake, Haliburton County, contained two eggs that were incubated, and an additional egg was floating in the water nearby. Bellerby believed that a first nesting attempt had been disturbed, possibly by Beavers, *Castor canadensis*. In 1990, William Elliott reported a third egg laid in a nest at Wauqimakogon Lake (also known as Wilson Lake), Parry Sound District, after a period of low water levels had prevented the loons from gaining access to their nest. These 1989 and 1990 reports apparently represent re-laying. In 1991, three eggs were observed by Karrio Dennison in a nest at Deerhound Lake, Sudbury District. The downy young were seen with the pair of adults from this nest on 5 and 14 July. One young subsequently disappeared from that brood, when a young of the same size appeared with a previously chickless pair on the same lake. This is only the third record of three chicks seen in the same area as a three-egg clutch, and chick adoption is also unusual.

Dennison's observation of changing brood size at Deerhound Lake provided circumstantial evidence for chick adoption. Several cases of larger than normal broods were also reported. Donna Mackinnon observed four young with a pair of adults on Shepherd Lake, Grey County, from mid-June through mid-August 1984, and she commented that another resident had reported a pair with four young there in 1983. On 15 August 1988, she saw a pair with three young on the same lake. Three-chick broods were also reported by Miriam Oudejans at Last Channel Lake, Parry Sound District, in 1987; by Karen Brown at Cheer Lake, Chapman Township, in 1987; by C. J. Salber at Little Crosby Lake, Leeds County, in 1988; and by Tom and Joan Forbes at Kawagama Lake, Haliburton County, in 1988. Larger-than-normal clutches presumably involve cases of genuine supernumerary clutches, laying of two fertile females in one nest and/or adoption. These would be unrelated to re-laying.

The observations collectively add several cases of supernumerary clutches and broods to the record. While two cases plausibly represent re-laying, others appear to suggest other explanations.

Acknowledgments

Participants in the Ontario/Canadian Lakes Loon Survey provided the data on which this note is based. Those whose observations were used are acknowledged in the text, but all reporters to the survey contributed by supplying background data. Former Canadian Lakes Loon Survey Coordinator Chris McCall extracted relevant post-1986 records and supplied me with copies. Peter Croskery, Anthony J. Erskine, Judith W. McIntyre and Paul I. V. Strong kindly reviewed earlier drafts. This note is a contribution of the Long Point Bird Observatory.

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Received 24 February 1993
Accepted 6 December 1993

Variation in Denning and Parturition Dates of a Wild Gray Wolf, *Canis lupus*, in the Rocky Mountains

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Boyd, Diane K., Robert R. Ream, Daniel H. Pletscher, and Michael W. Fairchild. 1993. Variation in denning and parturition dates of a wild Gray Wolf, *Canis lupus*, in the Rocky Mountains. Canadian Field-Naturalist 107(3): 359–360.

A radio-collared wild Wolf (*Canis lupus*) which had lost her alpha status and left her pack in 1987 denned one month later than she had in 1985 and 1986. We calculated that she bred approximately 15–20 March in 1987 in contrast to dates of 24 and 15 February in 1985 and 1986 respectively, when she was still with the pack.

Key Words: Gray Wolf, *Canis lupus*, estrus, denning, parturition, Rocky Mountains.

The reproductive physiology of Gray Wolves (*Canis lupus*) has been studied in captive and wild wolves (Packard et al. 1983; Packard and Mech 1983; Mech and Seal 1987; Packard et al. 1985; Seal et al. 1979), but, except for Fuller (1989), variation in denning or parturition dates has not been documented for wolves. One record of multiple or extended estrus was reported in a captive coyote (Harrington 1987).

Gray Wolves we studied in northwestern Montana and southeastern British Columbia generally have had consistent denning times. Denning dates were defined as the date a radio-collared wolf was first found at the den and subsequently remained there for at least two weeks. Six females denned a total of 16 times from 1985-1991; other than the exception reported in this paper, the average denning date was 18 April (range 5-28 April), similar to denning dates at this latitude (Mech 1970; Fritts and Mech 1981; Fuller 1989). One typical wolf, W8653, denned five times from 1987-1991; her average denning date was 18 April (range 12-22 April).

However, this note reports on a wolf whose denning dates varied by about one month. Lactating female wolf W8550 was captured and radio-collared in southeastern British Columbia on 18 May 1985 (Ream et al. 1991). She was estimated to be three years old based on tooth wear and history of an intensively studied, low-density, recolonizing wolf population (Ream et al. 1991). She was the alpha female and the only breeding female in the pack in 1985. On 26 May 1885, W8550 was aerially observed nursing seven black pups and playing with them. The pups were estimated to be one month old, based on size and physical coordination (Mech 1970): their heads were over-sized and legs short; they romped with each other, walked well, and ran after W8550 when she walked away from them. The approximate date of conception was estimated to be 24 February, calculated from a 62-day gestation period (Mech 1970).

In 1986, W8550 maintained her alpha status and denned in Glacier National Park, Montana, between 14 and 17 April, 28 km south of her 1985 den (Ream et al. 1989). She moved throughout her home range until mid-April and was 6 km southeast of her den on 13 April. She was located at her den on 17 April and was there for 96% of telemetry locations ($N = 52$) from 17 April – 17 May. Assuming she gave birth shortly after denning, her date of conception was estimated to be approximately 15 February.

On 28 May 1986, a young-adult female, W8653, was captured and radio-collared. She was probably W8550's daughter from the 1985 litter, and had a strong fidelity to W8550 and the 1986 den. W8550 was observed with five gray pups near the den on 31 July 1986. On 9 October 1986, a female pup of W8550's, W8654, was captured and radio-collared. By fall, the pack consisted of ten wolves, three of which were radio-collared.

All ten pack members travelled together through 24 January 1987. On 25 and 26 January 1987, W8653 and W8654 were located together, but W8550 could not be located. On 27 January, nine wolves, including W8653 and W8654, were aerially observed together, while W8550 was located 25 km northwest of the pack. W8653 was first located at her den in Glacier National Park 30 km south of the Canadian border on 23 April 1987, after being located 10 km northwest on 21 April. She was located at the den on 98% ($N = 44$) of locations from 23 April – 22 May.

W8550 remained alone for most of the winter after she separated from the pack, except for 6 February 1987 when she was located with the pack. She was heard howling with another Wolf on 27 February 1987.

W8550 roamed throughout the northern portion of the pack's home range April 2 through 17 May (16 locations). On 5 May, W8550 was observed with two Wolves 1 km north of her den. She was located at her den in British Columbia on 22 May, 44 km southeast of her 17 May location and was located at the den on 75% ($N = 20$) of locations from 22 May – 22 June. This 1987 den was less than 1 km from her 1985 den and 40 km north of W8653's 1987 den.

Assuming she whelped with a few days of denning, her date of conception was estimated to be approximately 15–20 March. This is one month later than her previous conception times and than conception times reported for all other wolves at about this latitude (Mech 1970; Fritts and Mech 1981; Fuller 1989). In May and June, she was joined by two more wolves, including W8654, and five pups were successfully raised.

W8550 did not leave her den site for approximately one month after initially denning during each of the three years she was monitored. In 1985 and 1986 when W8550 was the alpha female of the pack, her denning dates varied by only nine days. After being displaced as alpha and becoming a loner prior to the breeding season in 1987, she denned one month later than the previous two years. Assuming den selection and subsequent time of parturition to be consistent within a given female's behavior, it appears that W8550 bred one month later than usual after she left the pack. Wolves generally are in estrus about 7-15 days (Zimen 1976) and the mechanisms for the variation in W8550's denning, parturition, or estrus are unknown. Although social and physiological influences on reproduction in Wolves have been intensively investigated (Packard et al. 1983; Packard and Mech 1983; Mech and Seal 1987; Packard et al. 1985; Seal et al. 1979), none of the literature (or L. D. Mech, personal communication) reported this kind of variation in dates of reproduction.

Acknowledgments

Portions of this study were funded by the Montana Department of Fish, Wildlife, and Parks, U.S. Fish and Wildlife Service, U.S. National Park Service, and the U.S. Forest Service, the School of Forestry and Montana Co-operative Wildlife Research Unit, University of Montana. The dedication of numerous volunteers contributed greatly to the data collection. We thank L. D. Mech, P. C. Paquet, and two anonymous reviewers for their valuable comments on the manuscript.

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Received 11 March 1993
Accepted 15 November 1993

Swimming and Aquatic Play by Timber Wolf, *Canis lupus,* Pups

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Coscia, Elizabeth M. 1993. Swimming and aquatic play by Timber Wolf, *Canis lupus,* pups. Canadian Field-Naturalist 107(3): 361–362.

Timber Wolf (*Canis lupus*) pup activities in water were observed in the wild, at Banff National Park, Alberta, and in captivity, in central Nova Scotia. This report describes sightings of young Wolves swimming and engaging in aquatic play.

Key Words: Timber Wolf, *Canis lupus,* wolf pups, swimming, aquatic play.

Timber Wolves (*Canis lupus*) encounter bodies of water during movements throughout their territory and when in pursuit of prey. Vast water bodies serve as geographical travel barriers (Peterson 1977; Mech 1987), however, smaller waterways provide an opportunity for wolves to extend their range (Mech 1970). Observations have been reported of wolves entering water; e.g., to pursue prey which has retreated to water for safety (Mech 1970). Other descriptive accounts of wolves' movements in water have recounted single sightings of rare hunting/scavenging events. For example, Bromley (1973) published an observation of an individual female wolf lunging to capture fish (*Coregonus* sp.) in a river in the Northwest Territories. While the wolf's forelegs were in the water, the hind-legs never left the shore. Johnson (1921) observed a wolf treading water in a river while scavenging a floating Moose (*Alces alces*) carcass. Nelson and Mech (1984) described several wolves swimming around a retreating White-tailed Deer (*Odocoileus virginianus*) while one wolf attacked and killed the animal. This account revealed the ability of wolves to hunt in water using similar strategies to those used on land.

In addition to purposes of travelling and hunting, it is common for wolves to approach a lake or river and drink or wade in shallow places. Also of relevance, Murie (1944) postulated that wolves utilize waterways as escape routes. On one occasion, Murie (1944, page 40) observed an adult and pup crossing a river to retreat from human intrusion and harassment. He noted that the pup (of unknown age) "was carried down-stream some distance and treated roughly by the fast water."

The present account chronicles observations of wolf pups swimming and playing in the Spray River within Banff National Park, in southwestern Alberta. Additional observations of captive wolves using water in central Nova Scotia are described. These collective observations represent the first documentation of aquatic play and swimming by wild and captive young wolves.

Spray Pack Observations

The Spray River Valley extends within Banff National Park. Within this study area the breadth of the Spray River ranges from 10 to 20+ m depending on recent precipitation and snow-melt in the higher watershed. At the time of the study heavy precipitation resulted in elevated water levels creating a strong current and small rapids in the river. The depth of the river ranged up to 6 m.

I observed seven adult and yearling wolves and six pups in the Spray River Valley. Several of the adults had been observed with other packs, and may not have been permanent members of the Spray Pack (P. Paquet, personal communication). The Spray Pack pups were born around the third or fourth week of April 1990, in a den < 50 m east of the Spray River. On 8 June, I saw adult and pup tracks at an Elk (*Cervus elaphus*) carcass west of the Spray River. These tracks indicated that young were capable of crossing the river at seven to eight weeks of age, or had been carried across by an adult pack member. Around that time the pack relocated to a den site 150 m east of the river. Later they relocated to a rendezvous site beside the river. I also saw pup tracks several km south of the rendezvous site, west of the Spray River (17 June). Adult tracks were adjacent to those of the pups, and all tracks indicated travel across the river.

I made all observations of wolf pups in water at the Spray Pack rendezvous site. On 11 July, when the pups were 12-13 weeks old, I observed four pups playing in the river. The pups were accompanied by a radio-collared female (Diane) and were travelling slowly, south along the riverbank. The pups remained in close proximity to each other, and pounced in the shallow waters of the river. They chased each other, running in and out of the water and swimming in areas that were too deep for them to stand in. When pups bounded into the river, they used exaggerated forelimb movements to splash and spray water. Later that day, I watched two pups playing on the opposite shore. I saw both pups swim across the river unaccompanied by an adult pack member. They swam back across the river to the rendezvous site and resumed playing on the opposite shore and in the water.

On the morning of 17 July, I saw the largest of the Spray Pack pups swimming unaccompanied upstream in the middle of the river. This observation was noteworthy because the water was high, yet the pup did not appear to be struggling. Later that day, I saw five pups on a trail 20 m from the river, again unaccompanied by an adult/yearling pack member. The pups swam across the river and continued with episodes of play both in the water and along the opposite shore. Their aquatic play was similar to that observed on 11 July when the pups were accompanied by an adult, but their grouping was less cohesive. Interspersed between play episodes the pups would rest, or sit and stare at me.

My last sighting of young wolves in water was on 22 July when I saw the largest pup swimming upstream by itself. The observation season ended on 26 July.

Nova Scotia Pack Observations

I have made similar yet more extensive observations of wolf pup activity in water with a captive pack of Timber Wolves maintained at the Canadian Centre for Wolf Research in Nova Scotia. The sectioned compound (3.8 ha) includes an enclosure (3.2 ha) which houses a group of pack-reared wolves. Within this heavily wooded enclosure there are two small ponds. One of the ponds, with a winter surface area of approximately 30 m^2, is easily visible from an observation station. Research conducted since 1974, during which time pup development and behaviour have been documented by video records and personal observations, has included documentation of pup and adult activity in water. Although the pond characteristics are different from those of a fast-flowing river, during certain seasons the pond depth necessitates swimming in order to cross.

By six to seven weeks of age the captive pups approach the pond, and they enter the water as early as eight weeks of age. Aquatic behaviour entails unprovoked solitary swimming and play chases in which the pups run into the water, splash in shallow areas, and/or wade/swim across the pond. Aquatic play chases are often incorporated into terrestrial play activities.

Wolf pups and adults occasionally execute extended leaps into the pond but also jump into the pond landing in a form similar to a belly-flop. Once in the pond, wolves have been observed splashing water with their forefeet. In addition, wolves have been observed to run through the entire length of the pond when the water is low enough to do so, even when the pond can be easily avoided. Often during play chases of two or more individuals, one wolf bounds through the water, while another or several individuals run to the bank to intercept as it emerges from the pond. Other cooperative aquatic activities include non-agonistic body or jaw wrestling.

Discussion

Numerous functions for play behaviour in young animals have been reported in the literature including exercise, physical training and development of coordinated activities (*see* Fagen 1981, for review; Bekoff 1983). Rigorous swimming and aquatic play may serve to increase strength and coordination in a manner not acquired by engaging in terrestrial activities alone. In addition, I suggest that play may also serve as a form of recreational activity in which wolves investigate and manipulate aspects of their environment. These observations from wild and captive animals add another dimension to the rich and varied play repertoire of wolves.

Acknowledgments

I thank J. Fentress for funding this project and P. Paquet, the Banff Wolf Project, and the Warden Office at Banff National Park for their generous support. I graciously thank J. Ryon for her valued knowledge and suggestions, and B. Freedman, S. Friet, W. Danilchuk, and two anonymous reviewers for their insightful comments.

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Received 11 March 1993
Accepted 20 December 1993

Unusually High Number of Embryos in a Muskrat, *Ondatra zibethicus*, from Central Labrador

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Chubbs, Tony E., and Frank R. Phillips. 1993. Unusually high number of embryos in a Muskrat, *Ondatra zibethicus*, from Central Labrador. Canadian Field-Naturalist 107(3): 363.

A total of 14 embryos were found in an adult Muskrat (*Ondatra zibethicus*) trapped in May 1986, in central Labrador. This potential litter size exceeds the maximum reported in the literature.

Key Words: Muskrat, *Ondatra zibethicus*, litter, reproduction, embryo, Labrador.

In northern latitudes, Muskrats (*Ondatra zibethicus*) have, on average, two litters each reproductive season (Proulx and Gilbert 1983). The mean litter size varies with environmental conditions and season length (Stewart and Bider 1974; Proulx and Gilbert 1983), and range from five to eight young (Boutin and Birkenholz 1987; Beer 1950; Errington 1951; Olsen 1959).

Stewart and Bider (1974) reported a maximum litter size of 8 in a study of 16 gravid females taken in southern Quebec. Proulx and Gilbert (1983) reported a maximum 9 in a capture-recapture program in Ontario. Olsen (1959) reported a maximum litter size of 11 based upon 80 complete litters examined at Delta, Manitoba. To our knowledge, Olsen's (1959) maximum litter size is the highest reported in literature.

On 20 May 1986 we trapped an adult female Muskrat near Terrington Basin (53°20′30″N, 60°24′00″W) in central Labrador. The Muskrat's reproductive tract was collected and frozen for later study. Our examination revealed the presence of 14 implanted embryos: 6 in the left uterine horn and 8 in the right one (Figure 1). The embryos ranged in size from 20 mm x 15 mm to 26 mm x 18 mm and appeared normal.

First litter production in Muskrats has been reported in late April in Saskatchewan (Messier et al. 1990), early May in Manitoba (Olsen 1959), and late May in southern Quebec (Stewart and Bider 1974). We believe that this Labrador female must have been in the later stages of first litter production. This is the highest number of embryos reported for a Muskrat's first litter. The reproductive tract, with implanted embryos, was deposited in the Newfoundland Museum under Catalogue number NFM MA-75.

FIGURE 1. Reproductive tract of an adult female Muskrat trapped in May 1986, in central Labrador, showing 14 implanted embryos.

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Received 5 May 1993
Accepted 22 November 1993

Night Use by Ducklings of Active American Coot, *Fulica americana*, Nests

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Hurd, Peter L. 1993. Night use by ducklings of active American Coot, *Fulica americana*, nests. Canadian Field-Naturalist 107(3): 364.

Two active American Coot nests visited during the night were found to contain ducklings. The coot clutches subsequently hatched normally.

Key Words: American Coot, *Fulica americana*, inter-specific nest use.

As part of a study of territorial aggression in the American Coot (*Fulica americana*) I trapped coots on nests using potter traps (Crawford 1977) at the Creston Valley Wildlife Management Area in Creston, British Columbia (49°05'N,116°35'W). Trapping was done at night between 22:00 and 03:00 hours to maximize the proportion of males caught (Gullion 1954; Crawford 1977). I placed 35 traps on 25 nests between 5 May 1991 and 18 July 1991. Throughout this time there were eight additional instances in which trapping was planned but was cancelled upon arriving at the nest due to predation, pipping eggs, and other unforeseen events.

One of the cancelled trappings occurred on the night of 11 July. Sometime between 22:00 and 24:00, I arrived at nest P2N14b to place a trap on a nest which contained five coot eggs, four days from hatching. I did not see either resident coot at the nest. Instead, eight to 12 young ducklings began to empty out of the nest cup. They were dabbling ducks, either Mallard (*Anas platyrhynchos*), Wood Duck (*Aix sponsa*), Blue-winged Teal (*Anas discors*) or Green-winged Teal (*A. crecca*) (more accurate identification was not possible in the dark, but Wood Duck broods were most often seen in this area during the day). I saw no sign of adult ducks or coots during my approach to or departure from the nest.

A similar event occurred on the night of 16 July. I visited nest P3N25 between 22:00 and 23:00 to place a trap over six eggs. No adults were present when I arrived, but the eggs were warm. When I arrived to remove the trap, between 2:30 and 3:00, I found three large ducklings inside. The ducklings were about five to six weeks old, two-thirds adult size, and were dabblers of some sort. As in the first incident, the nest and eggs were undamaged. Coots at both nests subsequently hatched and fledged chicks from their nests. No indication of incompetence was seen in their subsequent parental behaviour.

Although the motivation for the ducklings to roost on a dry platform in the middle of a marsh is understandable, the coots' behaviour was peculiar. At night a coot is much more visible off its nest than on it (personal observation) and would likely be exposed to a much greater risk of predation. The only evident predation of coots were night attacks by Great Horned Owls (*Bubo virginianus*). Both hunting owls and the remains of coots were seen regularly during my night wanderings in the marsh. If coots do have to leave the nest at night to feed, find their mate, or pursue extra-pair copulations, it may be beneficial to allow duckling broods on the eggs rather than let the eggs sit uncovered. In any case, I think it highly unlikely that ducklings force coots off the nest. American Coots are pugnacious birds and highly intolerant of interspecific intruders on their territories (Gullion 1952, 1953; Ryder 1959). Wood Ducks with broods seem to be subject to particularly intense attacks (personal observation). How often ducklings sit in coot nests and, how long they stay if undisturbed are interesting questions in light of the antagonistic behaviour coots display towards them during the day.

Acknowledgments

I thank W. Rendell, S. Wilson, A.J. Erskine and an anonymous reviewer for comments on the manuscript. These observations were made as part of a larger study on the behaviour of American Coots made possible by the Creston Valley Wildlife Management Area. This work was funded by an NSERC Post-Graduate Scholarship and an SFU Special Graduate Research Fellowship to me, and by an NSERC operating grant to R. C. Ydenberg. W. Rendell helped paddle the canoe.

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Received 16 March 1993
Accepted 4 October 1993

Cub Adoption by Brown Bears, *Ursus arctos middendorffi*, on Kodiak Island, Alaska

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We report three cases where female Brown Bears (*Ursus arctos middendorffi*) with new (<1 yr) cub litters adopted additional new cubs. Four cubs were adopted into three litters that originally totaled five cubs. Adopted offspring remained with their foster mothers through ≥1 winter season. The adoptions occurred in a sample of 104 litters produced by 89 different females on Kodiak Island, Alaska during 1982-1990. A maximum of six cubs were reared from litters that probably would have produced 3-4 subadults if the adoptions had not taken place.

Key Words: Brown Bear, *Ursus arctos middendorffi*, cub adoption.

Adult female Brown Bears (*Ursus arctos*) occasionally adopt cubs of other females. This behavior might explain large litters that are infrequently observed (Bunnell and Tait 1985; Wilk et al. 1988); it also could influence cub survival and subsequent recruitment of juveniles into a population (Erickson and Miller 1963; Glenn et al. 1976). We are aware of one study documenting permanent cub adoption (Craighead et al. 1969). In that case, a female Grizzly Bear (*U. a. horribilis*) with one new (<1 yr) cub adopted another new cub whose mother had died. The two cubs were weaned as 2-year-olds. Other records of known or possible adoption involved temporary exchange of cubs during one summer (Erickson and Miller 1963; Glenn et al. 1976) or were inconclusive because persistence of adoption in succeeding years could not be verified (Erickson 1964; Bledsoe 1987, p. 179; Wilk et al. 1988).

We report three cases of permanent cub adoption by Brown Bear (*U. a. middendorffi*) on Kodiak Island, Alaska (56°-58° N, 152°-155° W) during 1982-1990. Data were obtained by monitoring radio-collared females (Barnes 1990; Smith and Van Daele 1990); ages of females were estimated by counting cementum annuli of an extracted premolar (Goodwin and Ballard 1985).

Females were relocated primarily (>90%) by radio-tracking from fixed-wing aircraft, usually at 7-10 day intervals. Changes in litter size were considered tentative until confirmed by ≥2 subsequent observations, and sightings were censored if visibility of cubs was compromised by habitat conditions or behavior of the animals. These criteria were employed because females with cubs often occupied precipitous terrain in spring, were frequently located in shrub cover at other times, and new cubs typically hid behind or beneath their mother when alarmed by tracking aircraft. Cubs that disappeared from litters before other siblings separated from the female (weaning) were considered mortalities.

Case 1.— The first adoption involved a 10-year-old female that emerged from winter denning in 1984 with two new cubs. She was observed with two cubs on 10 separate occasions from 20 May to 10 July and was last seen with that litter complement at 1442 h on 10 July. She was recaptured by darting from a helicopter <1 h later and at that time was accompanied by three cubs; all were females and weighed 8.6, 9.9, and 10.9 kg. We were unable to determine which was the adopted cub. The adoption did not occur at a time or in an area where bears were concentrated at a food source. However, the study area supported a high bear density (Smith and Van Daele 1990) and we speculated that the adopted cub may have separated from a nearby but undetected family group that became disturbed by the capture activities.

One cub disappeared from the family group between 28 August and 05 September 1986. The remaining two cubs were last observed with the female on 20 November 1986 and approximately nine days prior to den entrance. We were unable to determine if the cubs were with the female after den emergence in 1987, but we assumed they were weaned during the mid-May to early July period when family separation usually occurred on that study area (Smith and Van Daele 1988).

Case 2.— The second adoption involved a 13-year-old female that emerged from her winter den in mid-May 1987 with two new cubs. She was observed with two cubs on four occasions from 28 May to 24 July. On 18 August and subsequent relocations in 1987 the observed litter size was three. One cub disappeared from the litter between 7 June and 12 July 1988 and the other two cubs were weaned at age 2 yr between 20 May and 11 June 1989.

This adoption occurred when the female was part of a large seasonal aggregation of bears feeding on Sockeye Salmon (*Oncorhynchus nerka*) in the Red Lake drainage (Barnes 1990). Other accounts of cub adoption have described similar circumstances

(Erickson and Miller 1963; Glenn et al. 1976; Wilk et al. 1988).

Case 3.— The third adoption, in 1989, involved a 24-year-old female that emerged from her winter den by 20 May 1989 but was not observed until 11 June, when she was observed with one new cub. She was accompanied by that cub on 24 June, when she was recaptured, and was observed again on 27 June with a single cub. The female was next observed on 18 July when she arrived at Dog Salmon Creek with a litter of three cubs. The family remained intact until one cub was lost from the litter in July 1990. The female and her two remaining yearlings (1.5 yr) were last observed on 31 August 1990. She died due to an unknown but apparently natural cause prior to 12 October 1990 and fate of the yearlings was unknown. We believe the orphaned cubs could have survived because we observed one case where a Brown Bear cub became self-sufficient at 1.5 yr and Johnson and LeRoux (1973) reported self-sufficiency in Brown Bears at <1 yr.

During the summers of 1989 and 1990, this family group frequented an artificial fishpass on Dog Salmon Creek where it was possible for State of Alaska and federal personnel to closely observe the group from the ground. The two adopted cubs could be distinguished from the natural cub because they were distinctly larger and had lighter-colored pelage. Moreover, the two adopted cubs were more socially bonded to each other than to the small cub. When the two adopted cubs engaged in play activity the small cub usually remained close to its mother. These physical and behavioral differences were most pronounced in 1989 but were still evident in 1990. In early June 1990 the small cub appeared to become increasingly lethargic and on one occasion would not follow its mother and two litter mates when they forded Dog Salmon Creek; instead it remained on the far bank and bawled. This cub disappeared from the family group on 10 July.

The three cases of cub adoption reported here occurred in a sample of 125 litters of new cubs produced by 89 different females. Twenty (16%) of the litters were entirely lost within the first year, and status of another litter was unknown because the female shed the radio-collar. If these 21 litters are censored from the sample, permanent cub adoption occurred in three (3%) of 104 litters in which such an event could have taken place and been detected. The four adopted cubs represented <2% of the cubs originally identified in those litters (n=254). Assuming that the two adopted cubs of the third female survived, six cubs were raised from litters that initially contained five new cubs. We expect that three or four cubs would have been raised if adoption had not occurred, based on mortality rates of Bunnell and Tait (1985) and the success of the three females in rearing cubs from previous litters (four of six). Thus, the adoptions probably resulted in recruitment of an additional two or three subadults into the population.

The adoptions we noted did not result in large (>4) litters. This could be one reason why Hensel et al. (1969) reported no evidence of adoption in 201 Brown Bear litters observed on Kodiak Island and the Alaska Peninsula. We recorded six litters of four first-year cubs in this study; two litters were with adult females when the females were initially captured and four litters were with females previously radio-collared. Data on the four females with best documentation indicated they each emerged from winter dens with four cubs.

Temporary (<1 yr) cub adoption has been reported elsewhere (Bledsoe 1987, pages 166-184; Glenn et al. 1976) and may have gone undetected in our study because of long (>10 days) time intervals between sightings of some family groups. Also, we do not know if permanent adoption of cubs affected ability of the females to raise their own cubs.

Accurate counts of Brown Bear litters from fixed-wing aircraft are difficult because the animals usually are in view only a few seconds at one time. This problem is compounded by factors such as vegetation, terrain, behavior of the adult female, and perhaps differences among litter mates in how they react to aircraft. We attempted to eliminate those sources of bias, but we cannot discount the possibility that one or more imprecise counts could have influenced our results. Nonetheless, our data indicate that permanent adoption by Brown Bears on Kodiak Island occurs infrequently and probably is of little importance to recruitment of subadult bears into the population.

Acknowledgments

We thank the many individuals of the U.S. Fish and Wildlife Service and Alaska Department of Fish and Game who assisted in capturing, marking, and radio-tracking bears. F. C. Dean, G. W. Garner, E. D. Rockwell, R. J. Wilk, and two anonymous reviewers provided helpful comments and editorial assistance on drafts of the manuscript. Funding was provided by the above two agencies, Alaska Power Authority and the Kodiak Brown Bear Research and Habitat Maintenance Trust.

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Received 20 May 1993
Accepted 31 December 1993

An Apparent Longevity Record for Canada Lynx, *Lynx canadensis*, in Labrador

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Chubbs, Tony E., and Frank R. Phillips. 1993. An apparent longevity record for Canada Lynx, *Lynx canadensis*, in Labrador. Canadian Field-Naturalist 107(3): 367–368.

Of 40 Canada Lynxes (*Lynx canadensis*) collected from trappers in Labrador during the winters of 1988-1989 and 1989-1990, one female was aged at 14 years 7 months. This exceeds the oldest record in the literature by nearly two years.

Key Words: Canada Lynx, *Lynx canadensis*, age, annuli, Labrador.

Many aspects of Canada Lynx (*Lynx canadensis*) ecology and population dynamics have been studied, but little information is available on maximum ages. Most studies have categorized lynxes trapped in the fall as either juveniles (0.5 yrs.), based upon an open root apical foramen (Brand and Keith 1979; Saunders 1963), yearlings (1.5 yrs.) having a closed root apical foramen and no cementum annulus, or adults (≥ 2.5 yrs.) depending upon the condition of nipples, external genitalia (Ward and Krebs 1985), and body weight and size (Koehler 1990). Studies implementing age determination techniques using cementum annuli counts (Bailey et al. 1986; Brand and Keith 1979; Parker et al. 1983; Quinn and Thompson 1987) report more specific ages.

Brand and Keith (1979) reported several lynxes aged ≥ 5 years during a study in Alberta, but failed to report specific ages for those older individuals. Parker et al. (1983) reported several lynxes attaining ages of 11 years during a study on Cape Breton Island. The maximum reported age in lynx appears to be 13 years for a female harvested in northeastern Ontario (Quinn and Thompson 1987).

During the winters of 1988-1989 and 1989-1990, 40 Lynxes trapped in Labrador were examined to determine population sex and age composition. Trappers were offered a $25 reward as an incentive to surrender carcasses. In some instances, only partial carcasses were submitted for examination.

In mid-January 1989 an adult female lynx, numbered F10, was captured along Upper Brook (53° 13'N, 60° 58'W) in south central Labrador. Only the skull and reproductive tract of this female was secured at the time of collection. A canine tooth was extracted and aged using a cementum annuli count (Matson's, Milltown, Montana). Her age, as of her last birthday, was reliably determined at 14 years

(Matson 1991) with an "A" rating (90% accuracy). This indicated an age of 14 years 7 months at death.

Subsequent to aging, the skull and reproductive tract of this lynx have been lost but the longitudinal tooth sections have been retained. The mounted slide, displaying two longitudinal canine tooth sections, has been deposited in the Newfoundland Museum, Catalogue Number NFM MA-76.

Acknowledgments

The work from which this record was obtained was funded by the Department of Indian and Northern Affairs and conducted by the Newfoundland and Labrador Trappers Association in conjunction with the Newfoundland-Labrador Wildlife Division. We give special thanks to the late R. Baikie for his help in carcass examination and to J. Maundor of the Newfoundland Museum, for his advice.

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Received 3 June 1993
Accepted 26 November 1993

Observations of Calf-hiding Behavior by Female Woodland Caribou, *Rangifer tarandus caribou*, in East-central Newfoundland

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Chubbs, Tony E. 1993. Observations of calf-hiding behavior by female Woodland Caribou, *Rangifer tarandus caribou*, in east-central Newfoundland. Canadian Field Naturalist 107(3): 368–369.

Three observations of calf-hiding behavior by adult female Woodland Caribou (*Rangifer tarandus caribou*) are described. Female caribou apparently hid their calf while feeding along roadsides near clear-cut areas.

Key Words: Woodland Caribou, *Rangifer tarnadus caribou*, calf, hiding, cutover, Newfoundland.

In many cervids, young calves do not actively follow their mothers but spend much time hidden in concealing vegetation and are visited at irregular intervals by their mother (Espmark 1971). This type of behavior is typically associated with cryptic coloration of the calf as is observed in Whitetail Deer (*Odocoileus virginianus*) and Red Deer (*Cervus elaphus*) (Clutton-Brock et al. 1982). Altman (1963 cited in Espmark 1971) has described this behavior occurring during the first few hours after birth in Moose (*Alces alces*). De Vos (1960) stated that Barren-ground Caribou cows do not cache their young calves for long periods of time as do other cervids. Lent (1966) is also of the opinion that Barren-ground Caribou cows do not leave their calves for long intervals while feeding, but a "freezing" response does occur in the first two days of life. Newborn Barren-ground Caribou normally follow their dams within hours after birth, but some calves exhibit the "freezing" behavior common to all North American cervid neonates (Miller and Broughton 1973). Although occasional separations and "freezing" responses have been observed, calf-caching behavior by female caribou has never been reported.

Changes in observed sex and age ratios have been widely used to estimate population abundance, productivity and survival probabilities (Seber 1973). Estimation of herd composition and calf survival in Woodland Caribou often depends on identification and numerical counts of three age-classes: calves, yearlings, and adults. Calf:cow ratios are frequently used for estimating survival rates for caribou calves.

This note is intended to alert caribou biologists to yet another difficulty associated with estimates of female productivity and calf survival based upon cow:calf ratios.

Methods

Observations of cow-calf behavior were recorded during a study conducted in east-central Newfoundland during the summers of 1989 and 1990 (Chubbs et al. 1993). Behavior of adult female caribou-calf pairs, and lone adult females thought to have had a calf, but which was not observed during capture, were noted. These adult females were later relocated, and further visual observations of cow-calf behavior recorded.

Observations

On 27 June 1989 at 1545 h, I darted animal number 50, an adult female, while she fed near a cutover. Although she was alone, close examination revealed that she was lactating, indicating that she was nursing a calf. Upon revival at 1610 h, she entered a stand of Black Spruce (*Picea mariana*) forest. At 2000 h, female number 50 was observed near her capture location accompanied by her calf. I can only assume that prior to capture, female number 50 had hidden her calf while she fed.

On 8 July 1989, female 50 was again observed alone and had a distended udder. It is uncertain whether she was again hiding her calf, or her calf had recently died.

On 28 June 1989 at 1040 h, I darted animal number 51, an adult female, accompanied by her calf. The calf remained by her immobilized mother until I approached within 3 m, then the calf retreated into the forest. At 1100 h, female number 51 was revived. She immediately walked to where her calf was concealed and emerged at 1105 h with her calf. The calf had apparently hid until its mother could retrieve it.

On 29 June 1989 at 1545 h, a lone adult female, number 54 was darted. When hit, she trotted about 100 m along the road, staggered up an embankment, and into a small stand of spruce trees. At 1552 h she returned to the road with her calf and continued another 50 m until she became immobilized at 1610 h. When I approached within 2 m, the calf retreated to the stand of trees where its mother had initially retrieved it. This incident suggests that the calf was not exhibiting exploratory behavior typical of young caribou calves, but was responding to a distressful situation by hiding.

Although much information of cow-calf behavior has been recorded in the literature (De Vos 1960; Lent 1966; Espmark 1971; Miller and Broughton 1973; Hirotani 1990; Fancy et al. 1990), specific incidences of calf-hiding behaviour have never been described. The absence of a calf, when a recently parturient female is observed, is usually attributed to either calf abandonment or recent calf mortality (Bergerud 1964; 1971). The incidents described here are not occasional separations but suggest deliberate calf-hiding behavior which may influence observed cow-calf ratios.

Since the peak calving period for Woodland Caribou in central Newfoundland occurred during the first week of June in 1989, these observations document hiding behavior by caribou calves nearly three to four weeks old.

Acknowledgments

The project from which these was observations were made was funded by the Government of Newfoundland and Labrador, Department of Environment and Lands (Wildlife Division), Wildlife Habitat Canada, Abitibi-Price Company Ltd., and the Department of Wildlife Ecology, College of Agricultural and Life Sciences, University of Wisconsin, Madison. I thank B. Hearn for helpful comments on the manuscript.

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Received 2 July 1993
Accepted 29 December 1993

Duration of Effectiveness of Fluorescent Pigment when Tracking Small Mammals

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Hallman, Troy M., Laura C. Adams, Debra J. Mullins, and John R. Tester. 1993. Duration of effectiveness of fluorescent pigment when tracking small mammals. Canadian Field-Naturalist 107(3): 370–372.

Tracking of animals marked with fluorescent pigment has been used primarily in studies of habitat use and home range, without considering time as a factor. We determined the length of time that fluorescent pigment remains effective in marking trails of Eastern Chipmunks (*Tamias striatus*) in Itasca State Park, Minnesota. Chipmunks were released and recaptured at specific times during the same day. We found that fluorescent pigments were effective in marking trails of chipmunks for a mean time of 6.61 hours with a maximum time of 7.75 hours. The amount of grooming the chipmunks performed was the most important factor influencing the duration the fluorescent pigment effectively leaves a trail.

Key Words: Eastern Chipmunk, *Tamias striatus,* fluorescent pigment, tracking, grooming.

Fluorescent pigments have been used to mark shrews (Quay 1948) and to monitor the movements of small mammals in analyses of microhabitat use (Lemen and Freeman 1985), home range size (Mullican 1988), and the location of nesting sites (Boonstra and Craine 1986; Getz and Hofmann 1986). However, we are not aware of research concerning the length of time that the fluorescent pigment is effective in marking the path traveled.

The length of time that fluorescent pigments remain effective was assumed to be at least several hours in a study done by Whittaker et al. (1991). Lemen and Freeman (1985) state that the pigment may still be detectable on an animal a second night, but that the animal no longer leaves a trail. Therefore, knowledge of the length of time that the pigment not only remains on the animal, but leaves a visible trail, is necessary to appropriately analyze temporal and spatial movement patterns and habitat use. Without this information, it would not be known whether a specific trail was made in only a few hours or throughout the animal's entire activity period.

Eastern Chipmunks (*Tamias striatus*), diurnal rodents, are abundant in Itasca State Park, Minnesota (Erlien and Tester 1984), and are easily captured and recaptured. Use of fluorescent pigments has not yet been reported for diurnal mammals. However, we believe that chipmunks can be used to test aspects of the effectiveness of this technique.

Methods

We captured chipmunks using 11.5 x 11.5 x 35.5 cm live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin) at the Lake Itasca Forestry and Biological Station, Clearwater County, Minnesota (T143N, R36W, Section 2). The Station is located in an area of mixed deciduous and coniferous forests (Hanson et al. 1974) interspersed with open fields, roads and buildings. Traps were arranged in two grids of seven and eight rows of four traps, with 15 m separating each trap in a row. Rows of traps were spaced 25 m apart. We baited these traps with peanut butter and oatmeal plus pieces of fresh apples, melons, or peaches. From 4 August to 19 August 1992, traps were opened at 0800 h, checked hourly, and closed at 2100 h.

Chipmunks were anesthetized with Metofane (Pitman-Moore, Inc., Washington Crossing, New Jersey) to minimize stress of handling, sexed, and marked with numbered ear tags. Some chipmunks were released after a one hour recovery period following anesthesia, after which they were mobile and alert. Immediately prior to release, chipmunks were coated with fluorescent pigment using the technique described by Lemen and Freeman (1985). To avoid overlapping of trails, the same color pigment was not applied to a chipmunk twice in the same row nor in each adjacent row. Since recaptured chipmunks were already ear-tagged, it was not necessary to anesthetize them to be powdered. The colors used were magenta (318), sunset orange (319), chartreuse (320), deep green (321), cerise (326) and a mixture of three parts deep green with two parts magenta (Radiant Color, 2800 Radiant Ave., Richmond, California 94804).

Release times were controlled to allow for a better understanding of the duration of effectiveness of the fluorescent pigment. Animals trapped late in the day were held overnight, given food and water ad lib., and released the following morning at 0700 hours. Trapping efforts were intensified to attempt to recapture individual chipmunks at specified time periods after their release. Five additional traps were set within a radius of 15 m around the previous release site. If an animal was recaptured on the same day of its release, and pigment visibly remained, it was released within a few minutes 100 meters away from its capture site. We could then determine whether or not the remaining pigment was still effective in depositing a second trail, which was measured if present.

All trails were examined at night after 2300 h. using an ultraviolet lamp (Lemen and Freeman 1985) and flagged at 2-3 m intervals until the fluorescent trail could no longer be detected. Grooming sites, indicated by an accumulation of pigment, were also counted. The following day the distances between the flags were measured and maps of trails were sketched on a grid, beginning with the release site and ending where the trail could no longer be detected.

Results

Twenty different chipmunks were captured and released, with 34 recaptures. Chipmunks were recaptured at times ranging from 2 to 143 hours after release. We used presence and length of the second trail to determine time of effectiveness. Three individuals recaptured after 2, 2.75 and 4 hours left second trails longer than 70 m. There were 23 recaptures that occurred after 9 hours, which was the longest period of time between release and recapture on the same day. None of these individuals, which had only minute traces of pigment, left second trails. Therefore, data from these chipmunks were not considered further.

Seven recaptures provided data on duration of effectiveness. Only a sparse amount of pigment remained on these chipmunks at the time of recapture. Upon release, they left either a very short (less than 10 m) or no second trail. One chipmunk was recaptured after 5.5 hours and left a visible second pigment trail upon release, whereas another, recaptured at 7.75 hours, left no trail upon release. The mean time of effectiveness for these seven recaptures was 6.61 hours with a standard error of ±0.26 hours.

Regression analysis revealed that the length of the first trail was significantly negatively related to the length of the second trail ($r = 0.93$, $P = 0.0204$). The number of grooming sites, which were 15-20 cm in diameter, on the path traveled by each chipmunk was significantly negatively related to the time of effectiveness (Figure 1, $r = 0.84$, $P = 0.0012$). We analyzed the number of grooming sites on all pigment trails and found a highly significant negative relation between the number of grooming sites and length of trail (Figure 2, $r = 0.93$, $P = 0.0001$). There was no significant relationship between the number of grooming sites and sex, nor between length of trail and time between release and recapture.

Discussion

Six of the 34 recaptured chipmunks carried barely visible amounts of fluorescent pigment on the day following release. We observed that this minimal amount of pigment did not result in the animal leaving a pigment trail when released, confirming the observations of Lemen and Freeman (1985). We determined 7.75 hours to be the upper time limit for effectiveness of fluorescent tracking of chipmunks because individuals recaptured at or after this time left no detectable pigment trails. When the recapture time was 9 hours, little pigment was visible on the chipmunk, except for traces on the ear tags.

Variables which may have influenced the results of the time of effectiveness of the pigments include vegetation differences, rain, or time in captivity. We did not observe differences related to pigment color. Although we powdered the chipmunks only minutes before release, an undetermined amount of pigment was removed by grooming and deposited in the

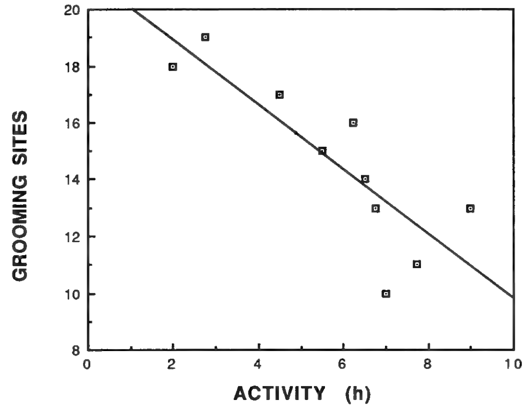

Figure 1. Relation between number of grooming sites and time between releases and subsequent recaptures of Eastern Chipmunks.

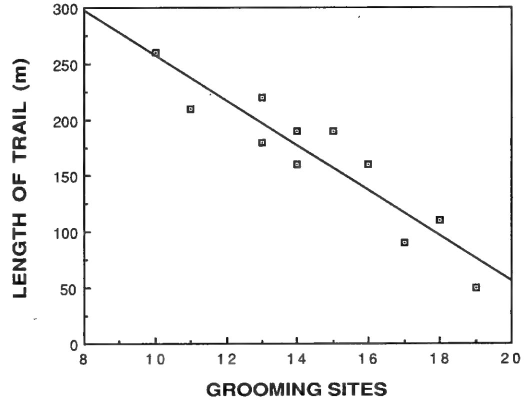

Figure 2. Relation between the length of first trails and the number of grooming sites for all Eastern Chipmunks recaptured on the same day of release.

cage. We speculate that in a trail that could measure up to 260 meters, this minimal amount of pigment removed by the animal before release would not have marked more than a few meters in length.

Upon release, chipmunks would usually run a few meters and then immediately stop to groom. It was observed that chipmunks groomed regularly throughout the entire trail. The number of grooming sites appeared to be the most important factor influencing effective time and length of trails. Since a relatively large amount of pigment was removed by the animal at each grooming site, it was difficult to ascertain the implications on time and distance that the discarded pigment might have had. We speculate that it could mean well over 100 m of extended length of trail, especially for those chipmunks with 17 to 19 grooming sites per trail. We observed that powdered chipmunks groomed more often than non-powdered chipmunks. Examination of recaptures between 5.5-6.5 hours indicated that the chipmunks had groomed the areas of their bodies which they could readily reach, including the face, tail, and lower back. The upper dorsal area retained pigment for the longest time.

Because the pigments are quite bright and the powdered animals are very conspicuous, it is possible that increased predation may occur. However, we believe that in our study area powdering did not lead to increased predation because of the high frequency of recaptures and the lack of observed predation.

Assuming that pigment retention and grooming in other species of small mammals may be somewhat similar to chipmunks, our findings provide a basis for future studies of movements of both diurnal and nocturnal small mammals. For example, if an animal is captured, powdered, and released at the beginning of its active period, it appears that the pigment trail which it leaves represents movements for about 6-7 hours. In some instances this interval may represent the entire active period, but in other species or seasons, the active period may be longer. Therefore, it is important to note that tracking animals with fluorescent pigment will indicate the path traveled within the time that the pigment remains effective. This path will not necessarily represent the home range, nor the path of movement throughout the entire activity period.

Acknowledgments

We thank the Lake Itasca Forestry and Biological Station, University of Minnesota, for facilities and equipment, Holly Rasmussen for assistance with trapping and marking, and Dr. Laurie Tompkins of Temple University for editorial advice.

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Received 20 July 1993
Accepted 20 September 1993

Adult Black Bear, *Ursus americanus*, Displaced from a Kill by a Wolf, *Canis lupus*, Pack

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Gehring, Thomas M. 1993. Adult Black Bear, *Ursus americanus*, displaced from a kill by a Wolf, *Canis lupus*, pack. Canadian Field-Naturalist 107(3): 373–374.

An observation was made of three Wolves (*Canis lupus*) attacking a lone adult Black Bear (*Ursus americanus*). Remains of a White-Tailed Deer fawn (*Odocoileus virginianus*) were found at the site after the incident.

Key Words: Wolf, *Canis lupus*, Black Bear, *Ursus americanus*, behavior, White-Tailed Deer, *Odocoileus virginianus*.

Several researchers have reported on interactions of Wolves (*Canis lupus*) and Black Bears (*Ursus americanus*) (Young and Goldman 1944; Joslin 1966; Rogers and Mech 1981; Horejsi et al. 1984; Paquet and Carbyn 1986). All of these reports have documented the death of Black Bears due to Wolf predation or the death of Wolves due to Black Bears. Wolf-bear interactions have mainly been noted to occur at Wolf or bear dens (e.g., Rogers and Mech 1981). Ballard (1982) and Hornbeck and Horejsi (1986) provided accounts of Wolf and Brown Bear (*U. arctos*) interactions in relation to kills. I report on an observation of a Wolf pack displacing an adult Black Bear from a White-Tailed Deer fawn (*Odocoileus virginianus*) in northeastern Minnesota.

Two members of the Five Corners Pack (n = 4-5) were radio-collared as part of a study of winter Wolf movements in St. Croix State Park, Pine Co., Minnesota. The following observation was made while collecting hourly, sequential locations on these two collared Wolves. Between 08:30 h and 09:00 h CST on 4 June 1993, Wolf #145 (*x*-female) and #188 (yearling male) left their den site and began moving. While scanning for the signals of these two animals I heard barking and growling within 50 m of the road. I approached the scene to within 40 m undetected and climbed 6 m up a Jack Pine (*Pinus banksiana*) tree.

I observed three Wolves (i.e., Wolf #145, #188, and an unmarked Wolf) attacking a lone adult Black Bear. The bear was located within a Hazelnut (*Corylus americana*) thicket with its back toward the base of a jack pine tree. A well-defined "game" trail was approximately 10 m from the bear's location. The three Wolves repeatedly lunged into the hazelnut thicket, nipping, barking and growling at the bear. The bear responded by swatting at the Wolves, bluff charging and vocalizing. The Wolves easily out-maneuvered the bear's defense. Two Wolves appeared to alternate attacks to the front of the bear while the other Wolf attempted to flank the bear.

After approximately 10 minutes of observation, the bear turned and ran. The Wolves continued to mill around the site. At this time, I observed the smallest Wolf involved in the attack run into the thicket where the bear had been and run out with something in its mouth. The Wolf quickly swallowed the unknown object. The Wolf pack slowly moved from the area over the next five minutes. I do not believe that I interfered in this incident since the Wolves continued to investigate and slowly moved out of the area over an extended period of time.

This incident was located 4-5 km from the Five Corners Pack's 1993 den site. For the remainder of the morning, Wolf #188 continued to hunt, presumably with the other members of the pack. Wolf #145 moved back to the den site within $^1/_2$ h after this observation. I later examined the scene and found White-tailed Deer fawn hair, rib fragments and blood in a depression where the bear had been. It appears that this pack was successful in gaining at least a portion of a suspected bear-killed fawn.

Acknowledgments

This research was supported by the Wisconsin Department of Natural Resources, Wisconsin Department of Transportation, University of Wisconsin-Stevens Point, and Minnesota Department of Natural Resources. E. M. Anderson provided helpful comments on various drafts of this manuscript.

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Received 8 July 1993
Accepted 6 December 1993

News and Comment

WANTED: Black Redhorse, *Moxostoma duquesnei*, from Wisconsin and Skipjack Herring, *Alosa chrysochloris*, from the Great Lakes

The first Black Redhorse to be identified from Wisconsin since 1928 was collected in April of 1992. The specimen was taken from an impoundment on the Wisconsin River in Wausau 298 km above the confluence of Blue Mounds Creek with the Wisconsin River. The site of the 1928 collection is from Black Earth Creek which flows into Blue Mounds Creek. See "Black Redhorse (*Moxostoma duquesnei*) Rediscovered in Wisconsin" by Don Fago and Alan Hauber, in this issue, pages 351–352, for more information.

In August of 1989, the first reported Skipjack Herring from the Great Lakes was taken in Green Bay in Kewaunee County Wisconsin. See "Skipjack Herring, *Alosa chrysochloris*, Expanding its Range into the Great Lakes", by Don Fago, in this issue pages 352–353, for more information.

Anyone who thinks they have collected a Black Redhorse from Wisconsin or a Skipjack Herring from the Great Lakes should preserve at least one specimen and call Don Fago collect at (608) 221-6366. Your assistance will be greatly appreciated.

DON FAGO

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Book Reviews

ZOOLOGY

Phylogeny and Classification of Birds: A Study in Molecular Evolution

By Charles G. Sibley and Jon E. Ahlquist. 1991. Yale University Press, New Haven, Connecticutt. xxiii, 976 pp., illus. U.S. $100.00.

In the 20th century avian systematics has remained very stable, at least until the late 1960s, if one were to compare its condition to that of other areas of animal systematics. It was in fact so stable that it had become virtually static and could generate only little interest or new research in spite of the efforts of a few daring ornithologists in North America and Europe. There are several reasons to explain such a situation but I think that ornithology as a science was ruled by a conservative ideology, under the strong influence of a few figures who dominated the field, and whose influence prevailed during that long period. Avian systematics in particular suffered greatly from such a situation. However, the publication of the first research results on comparisons of egg white proteins by Charles G. Sibley in 1970 [*A comparative study of the egg-white proteins of Passerine birds*. Peabody Museum of Natural History, Bulletin 32] and, in 1972, by Charles G. Sibley and Jon E. Ahlquist [*A comparative study of the egg white proteins of Non-Passerine birds*. Peabody Museum of Natural History, Bulletin 39], questioned the traditional and generally accepted classification of the birds of the world and generated the first serious challenges to an established system. The egg white protein analysis technique had serious limitations and the Sibley and Alhquist team soon oriented their research efforts in another direction. They started their work on DNA in 1973 and have produced ever since numerous papers on the phylogeny and classification of birds. Many of their results were controversial from the beginning and have been disputed by many but this work has generated much attention in the ornithological community and provoked a new world wide interest in avian systematics.

The present book presents a synthesis of their work since 1973 and exposes new hypotheses about the phylogeny and classification of the approximately 10,000 known species of birds. In addition to a brief introduction the book is divided into two main parts followed by an extensive series of figures (367) and a detailed list of references. In the first part, the authors describe their techniques, summarize known classifications of birds, discuss the principles and methods of classification, and present their own classification proposals based on DNA-DNA hybridization. In the second part, they provide detailed "accounts of the groups of birds" and explain their classification. The historical review of the classification of each group is particularly complete and done with great care. Even if one does not agree with the classification that follows it, this constitutes a very important part of the book and should be referred to by anyone interested in bird classification although it may be rather technical for the non-ornithologist. It is brief but complete and fully documents, chronologically, the classification changes that have taken place in each group since the first publications.

The technique, which is described in detail in the introduction and upon which their classification is based, is known as DNA-DNA hybridization. DNA (deoxyribonucleic acid) is the intricate molecule that composes the genetic material of living organisms. It consists of two long strands composed of series of nucleotides held together by chemical bonds. These strands are replicates of each other when obtained from the same species. The procedure consists of heating these strands to an appropriate temperature so that the bonds dissociate allowing the two strands to separate. If the temperature is lowered the two strands come together again in their exact original position. When this procedure is carried on with a mixture of DNA from two different species, some strands of one species can connect with strands of the other species and produce hybrid strands of DNA. When heated again, these hybrid strands will separate at a lower temperature because of their weaker bonds. The difference between the melting temperatures of the 'pure' strands and that of the 'hybrid' strands is then used to calculate the differences between the two species. This technique has been criticized but it provides a measure of genetic similarity between a large number of species in a Class of animals for the first time and supports a phylogeny based on a original and powerful methodology.

In spite of the methodological limitations described by the genuine critics as well as the detractors, the work of the authors is the first in this century to propose a reassessment of modern avian classification. Although many of their conclusions are shocking to those used and entrenched in classical and widely accepted bird classifications, the authors may be closer to a natural phylogeny than at any time in the past. Right or wrong in their proposals and conclusions, the authors have succeeded in giving a new life to avian systematics, and, this alone is an outstanding contribution to science. Many of their conclusions will remain as challenges until they are verified or 'tested' by other researchers using the same technique or more sophisticated analytical procedures.

This book figures among the most important works on avian taxonomy and phylogeny published in this century. Because it is very technical, it may not appeal to the majority of bird watchers and even to the ornithologists who are not interested in avian systematics. However, it should be part of the library of any ornithologist interested in avian phylogeny and classification, and it should be known and available to any student searching for a thesis topic in avian systematics. Overall, this book is carefully produced and will stand for a long time as an example of scholarship and as a source of inspiration and challenge, if not provocation, to many ornithologists.

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Distribution and Taxonomy of Birds of the World

By Charles G. Sibley and Burt L. Monroe, Jr. 1991. Yale University Press, New Haven, Connecticut. xxiv + 111 pp. + 24 maps. U.S. $125.00.

It was a monumental task for the authors to undertake and complete a work of this magnitude to deal with the distribution and taxonomy of the birds of the world. In all, they have treated 9,672 species, 3,960 non-Passeriformes and 5,712 Passeriformes, as recognized on the basis of the biological species concept and have given a synopsis of their entire distribution. In the first paragraph of the introduction, the five objectives upon which the work is structured are clearly defined and listed: "(1) to delineate the present distribution of the species of birds of the world in a moderate detail and up-to-date to the beginning of 1990; (2) to arrange species in a classification based primarily on evidence of phylogenetic relationships from the comparisons of their DNA; (3) to provide a numbering system for the species of living birds; (4) to include a gazetteer with maps indicating the positions of localities mentioned in the distributional accounts; and (5) to provide and index to scientific and English names of species." One may query whether the authors have attained such ambitious objectives? The answer is an unequivocal "Yes", although one may disagree with the treatment used in parts of the book and on the classification system they have adopted.

The "Introduction" (pages i-xxiv) addresses topics essential to the understanding of the work, such as classification, numbering system, species accounts, taxonomic approach for species, English names, abbreviations, symbols, place-names, gazetteer, index, and acknowledgments. The body of the book, which runs from page 1 to 784, deals with the species accounts. It is followed by a substantial section on "World Numbers" (pages 785 to 848) in which each species of birds is provided with a unique number. This system is flexible enough to allow new species, or species not recognized by the authors at printing time, to be given a number in the future without perturbing the entire numbering system. A series of 25 maps covering the world is given in the next section "Maps" (pages 849 to 874) and is followed by a extensive "Gazetteer" (pages 875 to 906). The 'References' section is very comprehensive (32 pages) and appears to comprise all the major references used by the authors in documenting their taxonomic decisions. The book closes with a detailed '"Index" (pages 940 to 1111) in which the Latin and English names of all taxonomic categories are listed.

The classification used is that proposed by C. G. Sibley and J. E. Ahlquist in another work *Phylogeny and Classification of Birds: a study in molecular evolution* (1991) where the conclusive results of their extensive work on DNA-DNA hybridization are presented, detailed, and explained, and where C. G. Sibley was the principal author. This biochemical technique seeks to directly compare the DNA of different species to unravel relationships. This revolutionary classification has been known for a few years, at least partially, to those who have followed recent developments in avian classification in the literature but has astounded many who were not familiar with the earlier proposals of the authors. The proposed changes are mainly restricted to the higher classification levels although they may sometimes modify the position of the lower categories. For example, the New World vultures are removed from the traditional Family Cathartidae (Order Falconiformes) and placed in the new and more encompassing Family Ciconiidae of the Order Ciconiiformes which includes shorebirds, gulls, alcids, hawks, falcons, tropicbirds, gannets, cormorants, penguins, loons, etc., to mention here only one of the more spectacular proposals.

Species accounts are brief but contain a great deal of information. The Latin name is usually binominal with a generic and a specific name. Species names may include the name of a superspecies when this option has been adopted by the authors. It is followed by the descriptor's name and the date of the description. An English name, indicating a serious effort at internationalization, comes next with the universal number as defined according to the system proposed by the authors. Each species account includes a concise habitat description where the altitude at which a species occurs is frequently given. The range of the species is outlined clearly in a brief but precise text, and, if one uses the maps of the book, it is easy to delineate the distribution of any species. The authors give English synonyms when their names are different from those used in other well known publications. As well, they provide information on the taxonomy of species, particularly in those cases where their taxonomy differs from that in current usage.

The numbering system is based on the American Ornithologists' Union numbers with modifications based on a scheme developed by P. W. Smith. It takes into consideration the numerous data bases using current A.O.U. numbers and can be used without disruption. The system serves a useful purpose and should be utilized by anyone who needs numbers for bird species to facilitate the exchange of data and increase compatibility between systems.

The maps assembled in the appendix cover the world. They are clear and contain sufficient information, particularly when used in conjunction with the gazetteer, to generate a mental representation of the distribution of a species without having to plot it on a base map. The gazetteer appears to be complete inasmuch as the localities mentioned in the text are concerned. It contains a brief geographical description of what the name relates to, its location in the world, very often its coordinates, and shows on what map it can be found. In cases where the entry is known by another name, this name appears in brackets with appropriate explanations. Using these features in combination with the maps, there is generally little need to refer to a more elaborate gazetteer to understand a species range as given in the text.

The principal merit of this book is to provide the ornithological community with a complete and up-to-date list of the known bird species of the world as of 1990, a brief outline of their habitats, and a succinct description of their range in a single book. This huge body of information is useful to ornithologists as well as to other biologists and bird watchers, because it is solidly documented. Although non-taxonomists may find the classification confusing, this work offers a new approach to avian classification and a multitude of taxonomic hypotheses which remain to be verified by other methods or through the replication of the techniques used by one of the authors. Graduate students interested in avian taxonomy and looking for a "thesis subject" will find a wealth of topics and hypotheses waiting to be "tested".

A work of this size contains a relatively small number of topographical errors, oversights, and other errors. Some of these have been corrected in a list of corrections but the others should be included with them in a second printing or second edition, because there is no doubt in my mind that this work will remain a fundamental reference for all those interested in bird distribution and classification anywhere in the world for many years to come.

In spite of my reservations about the classification used in the book — I cannot conceive how C. G. Sibley could have done otherwise to remain consistent with his previous work — I strongly recommend this important reference to anyone who needs a list of the birds of the world or information about their distribution and general habitat. The book is not inexpensive, but considering the amount of information it offers, it will become a worthwhile investment. This is without any doubt one of the most important ornithological publications of the 20th century. The authors deserve our thanks for such a comprehensive document and for the abundant challenges they are proposing to inquiring minds anywhere in the world.

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The Birdwatcher's Book of Lists (Eastern Region): Lists for Recreation and Recordkeeping

By Lester L. Short. 1987. Raincoast Books, Vancouver. 128 pp., illus. $8.95.

I am not an enthusiastic lister. I particularly do not see the point of listing within artificial political boundaries. For example, you can imagine my consternation with a good friend and ardent lister, who, when we saw a rarity flying across the Ottawa River said he could put the bird on five lists! (Life, Quebec, Ontario, year and day lists).

It was with some scepticism then that I opened Lester Short's book for listers. Surprisingly I found myself agreeing with some of the list titles. Of the 23 proposed, 16 had some appeal. These are the lists that emphasise ecosystems, like arctic and alpine birds. The author, however, misses a few key zones such as the boreal and temperate forests and the great plains. Other lists are interesting and valuable only to the individual, such as birdfeeder and nesting yard species lists.

The usefulness of the remainder are more questionable. For example what is the validity of a "Canadian Border and Mountain Birds" list? The border is arbitrarily chosen division between two countries, which mean nothing to a bird. And why couple it with mountains when they occupy very little of the border region? Now is a good time to consider the author's choice of species for this list. He includes Atlantic Puffin (it would be a real feat to see one at the Maine-New Brunswich border, although I have seen Tufted Puffin — not listed — close to the Washington-B.C. border) but leaves out birds like Mountain Bluebird or Clarke's Nutcracker.

I have similar problems with the species selected for all the suggested lists. There is a strong bias to the south eastern U.S., with pelicans, egrets, rails, and mocking birds generally being included. At last look my commonest yard bird was Iceland Gull. The most numerous species of owl I have seen in the last year was Snowy. The most consistent bird at my feeder is Red-breasted Nuthatch, and I have never had a Red-winged Blackbird. None of the lists really fit my current or previous locations, so how am I to use them?

This book also has range maps for the commoner species, many of which are inaccurate. Common Tern, Laughing Gull, Killdeer, and Dark-eyed Junco, for example, have much larger ranges than shown and the House Finch range is way out of date.

So who would use this book? Not the serious lister, as it is not sophisticated enough. The novice birder would have problems with the inconsistency of the species selection. A person who has been watching birds with increasing seriousness for a few years, and who has not begun keep notes (or is not yet an ardent lister!), might use this as a stepping stone. I still believe a birder should keep field notes, complete with drawings, diagrams, and comments of what they personally see. The amusement of rearranging these notes into a multitude of lists can be had at any time.

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Illustrated Key to Skulls of Genera of North American Land Mammals

By J. Knox Jones, Jr. and Richard W. Manning. 1992. Texas Tech University Press, Lubbock. iii + 75 pp., illus. Paper U.S. $9.95.

This spiral bound book is aimed at university courses covering North American mammalogy. Annotated and illustrated cranial keys identify mammals found north of Mexico to the level of genera. This laboratory manual is intended to supplement lecture and textbook material.

The contents include an introduction of the publication followed by identification keys arranged in systematic order, a glossary, and ending with a literature cited section. The keys are dichotomous with an either/or choice and there are usually two skull features to be compared in making this choice. Ample space along the margins is provided for jotting down any other traits deemed useful. Photographs, illustrations, and tables are included to help in visualizing diagnostic features. Each taxonomic order and family has a brief summary of distribution, description, species composition, or other pertinent biological information.

I found the glossary very helpful and the figures facilitated character identification in addition to the cross referencing of genera not directly compared. The taxonomic name Didelphimorphia is applied at the level of order with the more familiar Marsupialia evaluated to supraorder to reflect the most recent interpretation of metatherian classification. Other applications of current systematic revisions include the grouping of cricetid rodents within the family Muridae and zapodids within the family Dipodidae.

On the down side, the cut-and-paste presentation of some of the photographs (e.g. Figs. 23 and 24) detract from the professionalism of the remainder of the book. Limiting the coverage to only terrestrial mammals was an unnecessary bias. Marine mammals are some of the most high profile animals from the perspective of both the general public and biologists conducting research in marine biology. Two additions that would have enhanced the utility of the manual include listing the page number for orders and families in the key for ease of reference and citing all figures within the text.

Overall, this manual will be very instructive in a laboratory setting. The laminated covers and spiral binding will ensure long use with the handbook size and slimness encouraging use in museum collections as well as in the field. Students and professional mammalogists will find the keys and figures helpful in identifying specimens and as a reference source to be consulted regularly.

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Landscape With Reptile: Rattlesnakes in an Urban World

By Thomas Palmer. 1992. Ticknor & Fields, New York. 340 pp. U.S. $19.95.

Once in a great while a book comes along that manages to stimulate all the emotions that reading may evoke; annoyance, frustration and ambivalence, commisseration, fascination, and satisfaction. *Landscape With Reptile* is such a work. In the form of an oblique ode to nature lost, and an exploration of the natural history of a secretive, but embattled species, this carefully researched chapterfied essay on rattlesnakes in an urban world marches straight into the brain but ultimately lands in the gut.

Set in the Blue Hills Reservation, a miniscule parkland on the outskirts of Boston, Massachusetts, *Landscape With Reptile* offers us a tawdry vision of our urban selves, complete with the evolution of our needs, views, and prejudices. Aside from entreating and enticing the naturalist, this book would serve well as a text for a first year course in urban planning, or even American history! Indeed I learned more about the pilgrims and early New England than I did about rattlesnakes (but then again, I'm a herpetologist).

But while exposing colonizing humanity for the short-sighted and frequently ridiculous juggernaut that it is, the book cuts a swath through attitudes and ignorance without taking any prisoners; there is no axe to grind it seems, and all swords are double-edged. Everyone from snake to Senator is engaged in the business of survival, and it becomes clear that insightful evaluation of our involvement in the process is a recent and evolving phenomenon. This revelation, which permeates the narrative, surfacing in various guises (protecting the family, commercial quarrying, politics of development) serves the purpose of offering a subtextual eulogy for the Timber Rattlesnake, *Crotalus horridus*, in New England. To wit: no matter how egalitarian our environmental consciousness, and no matter how high the ground on which our floating benevolence has come to rest, with regard to *Crotalus*, it is likely too late. And it is here, in this simple statement, that the reality of an animal's biology plays clear to our minds; the ramifications of small populations, lack of gene flow, low birth rate, slow maturity, and high adult mortality in the form of an asphalt grave are prescient concerns even when conservation-minded statesmen have set aside acreage to preserve some semblance of wildness for future generations.

Even though the press releases for the book prove the point of human over-reaction by revolving around the issue of people bitten by rattlesnakes(an almost non-existent problem in the Blue Hills), the artful account of ambush/venom/death in the text is happily spun in a business-as-usual context. Palmer gets inside the brain of a hapless chipmunk that is bitten by a rattler and dies, and delves into the physiological horror and medical minefield of a serious human bite with a detailed account of a worst-case scenario (of which the actual probability of occurrence is almost nil) — but not until we have learned about the complete history of bite treatment and had a good glimpse of venom biochemistry. It all adds up to the lesson that rattlers are too easily avoided, and bites too easily prevented, to justify the longstanding war between man and serpent.

The remote danger to the gentry posed by rattlesnakes is further diminished when Palmer sweeps us into the hairy world and deadly legacy of commercial quarrying in the Blue Hills. This represents just one example of his clever juxtaposition of subject matter that makes it difficult to separate the existence and interactions of a natural world, Massachusetts Indians, settlers, farmers, highway-builders, real-estate developers, and ultimately, conservationists. After all, when the bounties offered on rattlesnakes in early New England rivalled those being paid for the scalps of Indian men, women, and children, its easy to see that we are really dealing with the attendant attitude problems of a frontier mentality.

The book is a tapestry, and though the reader's early impressions may be that of a scattered, hop-scotch smarm-a-rama (à la Stephen J. Gould), one quickly comes to realize that the focus evolves (also à la Gould) through the multiple views of natural history, ecology, evolution, history, medicine, and anthropology offered by a writer whose ability to turn a phrase ranks with the best of our contemporary chroniclers of natural history.

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Cougar — Ghost of the Rockies

By Karen McCall and Jim Dutcher. Douglas & McIntyre, Vancouver. 324 pp., illus. $35.00.

Any admirer of wild cats will be immediately drawn to the cover photograph and intriguing title of this book. Cougars, well-known for their elusiveness have long challenged researchers to observe their behaviour in a natural habitat. In this book, veteran wildlife cinematographer Jim Dutcher and author Karen McCall combine their expertise to study cougar behaviour using an unusual method. The authors were advised that to film a wild cougar over an extended period of time would be impossible. They decided that the best alternative would be to film a cougar that was born in the wild and raised in captivity. The selected cougar could then be released in a special study area. The authors carefully chose a five-acre site at the foot of the White Cloud Mountains in south central Idaho. This large area was completely fenced in and had terrain diverse enough to be a luxury home to any cat accustomed to more restricted surroundings. The star of the project was Catrina, a four-year old female from the Boise Zoo. The added appeal of this particular cat was the fact that Catrina was thought to be pregnant.

The result of the two-year efforts of McCall, Dutcher, and their team is this excellent book and a multiple award-winning film of the same name. Their study provided detailed documentation of cougar behaviour in the wild that contributes to a better understanding of the species and can aid in their protection. Catrina's familiarity with human contact allowed her to go about her daily business unpreturbed by the fact that she was being observed. After the birth of her three kittens Catrina provided the opportunity for close-up observation of family interaction, a very rare occurrence, and certainly one that generally eludes photographers and researchers alike.

There is a sound symbiotic relationship between the writing and the photography. The material is well-presented and balanced. Information is provided on such things as cougar body language, hunting techniques, parenting, and territorial marking. In addition to relating their observations, the text is supported with factual information previously obtained from research on cougars in the wild.

McCall and Dutcher have presented a visual celebration of the species accompanied by an informative and enjoyable text. The book cannot help but instill in readers a greater awareness, understanding, and appreciation of this beautiful animal.

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Life Histories of North American Woodpeckers

By Arthur Cleveland Bent with original paintings by William Zimmerman. 1992. Indiana University Press, Bloomington. xiv + 270 pp. + 25 color plates + 25 maps. U.S. $29.95

The original edition of Bent's *Life Histories of North American Woodpeckers* was published in 1939 as Bulletin Number 174 of the United States National Museum, Smithsonian Institution. It was a typical government publication of the time without colour illustrations. It was an extensive synopsis of the woodpecker natural history as known at that time and has served since as one of the basic and most important references on woodpeckers to several generations of ornithologists, naturalists, biologists, and foresters. Since the publication of this work, woodpeckers have attracted much attention and a copious volume of information on their distribution, taxonomy, ecology, and behaviour has appeared and continues to appear in the scientific literature. Obviously, the present edition would have had to be enlarged tremendously in order to incorporate this massive amount of new and modern knowledge on North American woodpeckers. This was not the option retained by the publisher as the original text was integrally reproduced in this volume.

Then how does the present edition differ from the original? Firstly, the format of the book has been enlarged (8″ × 10.5″), it has a cloth binding, it is printed on high quality paper, it contains color plates, there is a range map for each species, and it is a beautiful production. The 25 original color plates, the work of wildlife artist William Zimmerman, are very attractive and yet very accurate, while giving an impression of freshness and realism. Alone they warrant the purchase of the book. Their layout is extremely pleasing and they are superbly reproduced, which contributes to enhancing the quality of the artist's work. The captions are clear and make it easy to identify the individual birds of the illustrations. Current English and scientific names are used, as well as "historic names", given in smaller print, as they are used in the text. This will be useful to those not familiar with nomenclatural changes or older English and scientific names.

A range map based on the distribution summaries of *The A.O.U. Check-list of North American Birds* (1983) has been added to each species, along with the length of the bird (in inches), the modern English name and the number of the plate on which it is illustrated. These are basically the only departures from the original edition. However, the black-and-white photographs of habitats, nesting sites, nesting cavities, etc., characteristic of the first edition, which provided so much detail and information, have been left out. There is a serious shortcoming of the book and I hope that the publisher and editor will decide to include these original illustrations for the planned re-edition of the other volumes of the *Life Histories* series.

I recommend this modern version of a classic and basic reference on North American woodpeckers to all who are interested in beautiful books particularly at a very reasonable price, even to those who own the original edition.

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A Field Guide to Eastern Butterflies

By Paul A. Opler and Vichai Malikul. 1992. Peterson Field Guide Series, Houghton Mifflin, Boston. xvii + 396 pp., illus. + 48 colour plates. Cloth U.S.$24.95; paper U.S.$16.95.

North American field naturalists are intimately familiar with the Peterson Field Guide Series and most will also know *A Field Guide to the Butterflies of North America, East of the Great Plains* by Alexander B. Klots, number 4 in the series, originally issued in 1951 (also by Houghton Mifflin) and reissued with updated nomenclature only in the late 1980s. It's been a long time coming but the much-anticipated, thorough and complete revision of Klots' 1951 guide is finally here.

The typical Peterson Field Guide format is adhered to throughout. The end-papers provide schematic drawings illustrating the parts of the butterfly body, wing area, veins, and wing margins, and a frontispiece map shows that the guide is intended to cover all of North America east of the 100th meridian. A short "how to use this book" section is followed by brief chapters about butterfly structure and life history, ways and means to study butterflies (with a modern emphasis on watching, photographing, and rearing butterflies although sufficient information is presented to allow a novice to make a collection), butterfly gardening including short tables of common nectar and larval hostplants, butterfly conservation illustrated by specific habitats, and finally, the usual life zones and general habitat descriptions.

The bulk of the book is given over to the individual species descriptions, 524 of them (up from 422 in the 1951 guide), presented in six family groups. Each description gives size, colour, pattern, wing shape, and specific information regarding sexual dimorphism and seasonal polyphenism, a comparison to similar species, descriptions of larvae and pupae together with known foodplants and flight period information, overall range, and a short description of the habitat where the butterflies are usually found. Augmenting the range information of the text are 348 range maps — a very useful addition. Appendices include an extensive 29 page "life list", a 6 page glossary, general and specific regional references, a directory of organizations, supply houses, butterfly houses and insect zoos, collecting ethics and guide-lines, and a truly useful pair of indices to host and nectar plants and to the butterflies themselves (by genus, species and common name).

However, the more obvious (and most used) part of field guides are the plates. One of the recognized failings of Klots' 1951 guide was the many black-and-white plates. The authors here have addressed this failing with a profusion of colour. The 48 plates are placed together in the centre of the guide and cover butterfly flowers (1 photographic plate), larvae, eggs and pupae (three photo plates), nine glorious photographic plates of free-living butterflies showing characteristic resting postures, and 25 plates of reduced acrylic paintings of the conventional spread specimens, beautifully rendered by Vichai Malikul. The by-now expected Peterson "trademark" arrows point to unique field marks. Each facing page provides common and scientific names, sex, specimen origin, and a short general description. The plates and species descriptions are fully cross-referenced.

The original guide has long been an essential staple of both the amateur and the professional Lepidopterist and, as unfortunate as it may seem, comparison is inevitable. So how does the long awaited revision measure up? Improvements in the new guide include the grouping together of the all-colour plates, the plates of free-living butterflies, the new range maps, conservative naming conventions (eg., *Papilio* vs. *Pterourus*), and the overall scope of the very up-to-date coverage (for example, Opler includes both the Tiger Swallowtail (*Papilio glaucus*) and the Canadian Tiger Swallowtail (*Papilio canadensis*) as separate species, a recent delineation). However, other areas have suffered in the process of updating the work. The lack of any discussion of classification and naming conventions is not surprising considering that no identification keys are included at all. More plates of the larval stages, information that is not readily available anywhere else, would have been extremely useful but fewer are shown in the new work than the original (and far fewer pupae).

In general, more reliance is placed on the use of outside sources for information regarding butterfly structure, biology, ecology, classification, and nomenclature than was found in Klots' guide (not necessarily a bad thing, this is a field guide after all and almost 20% more species are treated, but Klots' guide was more than a field guide). The specimens on the painted plates appear smaller than they could have been given the amount of white space around them, the magnification given for plate 32 is obviously in error and a few text overprints (eg., plate 48) are all that mar an otherwise excellent presentation. Despite these few shortcomings it is a worthwhile and necessary successor to Klots' original field guide and deserves a place on every Canadian naturalist's bookshelf, for six months of the year.

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The Development and Evolution of Butterfly Wing Patterns

By H. Frederik Nijhout. 1991. Smithsonian Institution Press, Washington. xvi + 297 pp., illus. + 8 colour plates. Cloth U.S.$45.00; paper U.S.$20.00.

This is not a book for the average naturalist, Canadian or otherwise. Which is not to imply that it is not a good book, in fact it is very good, however, it is addressed to a very specific audience and is technically demanding because of this. If your interests include developmental biology and genetics, comparative morphology, the evolution of morphological diversity, or the Lepidoptera as a whole, then this volume belongs on your bookshelf. The scope of the subject which this volume covers is enormous. As Dr. Nijhout begins his preface "Most if not all of the 12,000 or so species of butterflies can be told from another on the basis of their colour pattern alone" (pp. xi) and he notes that sexual, geographic, and seasonal differences within butterfly species are common. A further increase in pattern diversity is evident in the independence of the patterns of the dorsal and ventral wing surfaces.

The author's stated purpose for the book is to summarize his 18 years of study on the developmental genetics and evolution of butterfly colour patterns, building, as he himself admits, on earlier observations of the homologous nature of the patterns, to provide a guide to "reading" the colour patterns of butterflies, to determine the evolutionary and developmental origins of patterns, and to suggest directions of future research in this field. In spite of the broad complexity of the subject, he succeeds rather well in these goals. The volume is a marvellous summary and extension of Nijhout's research, and if you get very involved with the conceptual basis for the homologus ground plan common to all butterflies, the instructions are here for interpreting and extrapolating the developmental and evolutionary origins of the patterns found on any butterflies wings.

The volume contains eight chapters, from a general introduction of the structure and development of butterfly wings, veins, scales and colour, escalating rapidly through the foundations for a comparative morphology of pattern elements, analysis and exploration of wing pattern, to the author's experimental studies on the mechanisms of colour pattern formation. A chapter on placing the preceding within the context of genetic control and its expression in mimetic and variable taxa is followed by one on modelling pattern development and the evolutionary mechanisms involved and finally culminates in the author's discussion of the process of evolution in butterfly colour patterns. Appendices provide a broad overview of the classification of butterflies and there is the surprising inclusion of a new systematic treatment of the Nymphalidae by Donald J. Harvey. While in many ways useful to the book (the Nymphalid ground plan forms the basis of the pattern homology discussed throughout), this "paper" feels out-of-place here.

The book is profusely illustrated with many schematic drawings and black and white photographs, in addition to the eight colour plates, to aid the reader in assimilating the written work. The language is, of necessity, technical, and a glossary would have been useful. I found myself, more than once, wishing for an easy to locate definition for a particular word. The subject, however, is a fascinating one and, as is usual in evolutionary problems, the answers may not come easy but perseverance is rewarding.

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Wisconsin Birdlife: Population and Distribution, Past and Present

By Samuel D. Robbins, Jr. 1991. University of Wisconsin Press, Madison. 702 pp. U.S. $75.

This book, a veritable tour de force, had a gestation period of just over 50 years, confirming in spades that "the generation period of a book is longer than that of an elephant." The impetus for it began in earnest in 1939 with Owen Gromme, who collected voluminous material and painted 105 full-colour plates to depict all Wisconsin birds. By 1959, Gromme realized the impossibility of completing the text to his satisfaction, so instead prepared the paintings and maps for publication separately in 1963, thus usurping the title, *Birds of Wisconsin.*

Sam Robbins took over the next phase of the project in 1969. Sam is a younger brother of Chan Robbins, co-author of the best-selling *Golden Field Guide to Field Identification of Birds of North America*. In the course of his various postings as a minister, Sam had resided in six Wisconsin counties, but he next undertook numerous trips to familiarize himself with other corners of the state. He reviewed all the information collected by Gromme and added much new material, so that the book is based on all extant specimens, study skins, and eggs, in various museums, and the results of 2500 Christmas Bird Counts, 1520 Breeding Bird Surveys, 5000 nest record cards, and 4000 banding recovery cards.

There is an excellent chapter on the history of Wisconsin ornithology, telling of the early observers who recorded changes in bird numbers over the years. For example, the Common Raven was replaced by the American Crow and the Upland Sandpiper, common in the 1850s, diminished drastically by the turn of the century, similar to the situation in southern Saskatchewan. A long chapter on "The landscape and the birds" by James Hall Zimmerman details the effects on birds of human changes to geographical features.

The well-written species accounts cover 394 species. For each there is a map and a summary of status, habitat, migration dates, breeding dates, and seasonal distribution, followed by about one page of general text. Brief accounts deal with another 13 hypothetical and six possibly escaped species. Interesting material abounds: near Green Bay, for example, 40% of kestrels use cavities in dead trees and an equal number use cavities in live trees, while 10% occupy boxes and 10% reside in buildings.

Other maps depict the research stations and sanctuaries; the five geographical provinces; the progress of spring across Wisconsin; average depth of soil frost in February; average air temperatures in January and July; limits of major tree species; landform relief; soil regions; glaciation; geology; avifaunal zones. A map inside the front and back covers shows the townships, main cities, and rivers. There are charts to show habitat preferences of breeding birds, wintering birds, and migrants. A 36-page bibliography and a 7-page list of observers round out the book.

Altogether, this is one of the finest state bird books yet published. It summarizes what is known about Wisconsin birds and can serve as a useful model for anyone beginning such a project elsewhere.

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Kingfishers, Bee-eaters, and Rollers

By C. Hilary Fry, Kathie Fry, and Alan Harris. 1992. Princeton University Press, Princeton, New Jersey. xi + 324 pp., illus. U.S.$49.50.

Some years ago I was taken, after giving a vow of secrecy, to an obscure location in Europe. We drove through narrow tree-shrouded lanes bordered by vineyards and gravel pits to a secluded spot. As it was early in the spring, nobody was sure if the birds had returned yet. We scoured the area on foot for over an hour before the sky suddenly filled with exuberant trilling calls. The Bee-eaters were indeed back. We watched these stunning, exotic birds perform their aerial courtship flights over the freshening green of the vines and the golden brown gravel pits and I became an instant fan of bee-eaters. Now there is a fine new book on them and their equally colourful allies, the kingfishers and rollers.

The book follows the style used by Harrison in his work on *Seabirds* (and subsequently followed for *Shorebirds, Waterfowl*, and *Swallows and Martins*). As the title suggests the book covers kingfishers, bee-eaters, and rollers, from five of the eight families in the Order Coraciiformes (not covered are the todies, Caribbean flycatchers, Madagascan groundrollers, and motmots). In all 123 species are included.

The introductory sections are more extensive than those in *Seabirds*, etc. and give basic information on the group's biology. General descriptions are given of feeding, nesting, courtship, and distribution. This is both appropriate and useful as these species' natural history is less well known than many other birds. This is, in part, because they are not hunted (all governments seem more willing to spend research money on the hunted species) and, in part, because most of them are far away from the western research centres. Indeed about 60 per cent of the species discussed live in the far east (Southeast Asia, Australia, the Phillipines, and nearby islands). Africa is home to over 30 per cent, leaving little for the rest of us. For kingfishers the numbers are more restrictive, for almost 20 percent of the world's species are exclusive or almost exclusive to New Guinea. Indeed the Far East holds close to 75 per cent of the kingfisher supply!

As with any book covering the entire globe the authors have difficulty reconciling some of the common names. They have made rational choices which would be useful to adopt for other publications. For example, they have used River Kingfisher for *Alcedo atthis*, the European or Eurasian kingfisher(even though the last one I saw a few weeks ago was fishing in a drainage ditch!). I like their suggestion to change European to Golden Bee-eater even better.

The text is well organised and clearly written. The coverage of geographical races is particularly well done. The amount of information varies somewhat from species to species, but generally runs to two pages of concise, useable information. The plates, done by Alan Harris, are the best I have seen for birds with light-reflective feathers. He has done a remarkable job in capturing the shininess of these glossy birds. Indeed if I have a criticism of the text, it is that it is too dogmatic about colours. The exact shade seen will depend on the light and the angle between the bird and the observer. Also, there are some slight variations in the distribution maps from other published data, but this is mainly in the remote regions (where the range is less well known).

This book is a fine addition to an excellent series of useful books. Even if we are not able to visit New Guinea and the like, we can still get a great deal of enjoyment from this book. I will use it to identify birds I see on the many first class nature programs I have on video tape. Often the announcer does not identify all species, especially the smaller birds. I remember one sequence about a fig tree that involved several species of colourful birds. I only identified about half of them. Books like this will help both the armchair and real world travellers.

I have just learned that the magazine *British Birds* has chosen this work as book of the year. They have made an excellent choice.

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The Migration of Knots

Edited by Theunis Piersma and Nick Davidson. 1992. Wader Study Group Bulletin 64. Joint Nature Conservation Committee, Peterborough, United Kingdom. 209pp., illus. £15.

This bulletin is a collection of 28 scientific papers exclusively devoted to examining the biology of the Red Knot, *Calidris canutus*. Most are written about research done in Europe or Iceland, although there are contributions to eight papers by Canadian authors and one paper is from South Africa. The first paper presents the arguments for five subspecies; *C.c. islandica, C.c. rufa, C.c. roselaari, C.c. rogersi*, and *C.c. canutus*.

About half of this work is on one of those subspecies, *C. c. islandica*, This Knot breeds on Ellesmere Island down through Greenland, and winters in western Europe. Indeed there is one section exclusively on the *C.c. islandica* subspecies. Three others sections cover migration, fall and winter in Africa and Europe, and a synthesis that includes the conservation needs. All the papers are written by prominent researchers in the field and are concerned with population, distribution, and migration. Almost 80 percent of them deal directly with migration. The remainder of the papers are on other, related, aspects of biology. About one third of the papers are quite short, being less than five pages.

Some different approaches are taken to achieve an understanding of migration. For example, one paper describes how elemental analysis of feathers is used to deduce where these birds congregate. Unfortunately this is one of the shorter papers and it is one the topics where I would like to have known more.

While this publication is aimed solely at Knots it has implications for other shorebirds and, in a sense, for coastal wetlands. The Knot is but one of many species impacted by human activity along the sea shore, but it is a good indicator species. The work represented by this bulletin is of value to scientists in a number of areas.

Although primarily aimed at scientists there is some useful and interesting material for the amateur. Any enthusiastic non-biologist, who has been birding for some time, will have learned enough of the technical terms to be able to follow the discussions without difficulty. The writing styles and illustrations (chart, maps, graphs) are easy to follow. Because of this, this bulletin would make a good text for the non-biologist birder as their introduction to scientific literature. For North Americans it will also give a more global perspective of shorebirds. One last point, my particular copy of this bulletin has a major printing error; pages 9 to 16 are repeated.

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Alberta Birds, 1971–80, Volume 1: Non-passerines

By Harold W. Pinel, Wayne W. Smith, and Cleve R. Wershler. 1991. Calgary Field Naturalists Society, 1017-19 Avenue N.W., Calgary T2M 0Z8. 243 pp. $15.50.

Birds attract a wide audience. The most causal watchers are those who look for the first robin of spring, others maintain feeders, while the serious call themselves birders and ornithologists. *Alberta Birds, 1971-80* will appeal to the latter groups, particularly individuals who have a strong interest in bird distribution. Those looking for illustrations, identification tips, or location of hotspots will be disappointed.

The stated goal of the authors is to summarize and analyze reports of Alberta birds for the 1970s. The data have been extracted from natural history society records, museum specimens, nest records, and publications. Records noted include migratory information, range extensions, significant breeding and wintering records, resightings of "hypothetical" species, population changes, and habitat preferences.

There is little to quarrel with in this book. More records and discussion could be asked for but is likely not feasible. The introductory section is short; locations are listed and cross-referenced to a map, significance codes are listed, and species for which interesting records have occurred in the decade are listed according to category of significance. One shortfall is the lack of discussion of what constitutes significant records, but many are intuitive or recognizable to those with a knowledge of Alberta bird distribution.

Most accounts are about a page in length and contain as many as 15 records for the decade. Discussion of typical migratory and nesting patterns are included, as are particularly significant records or those of great interest. When records indicate differences from previously published references these are highlighted. Records have been listed by year and do not require reading of the text. Some significant records have been missed, but since most are likely not published or readily accessible to the authors, the authors are not to be faulted. If birders were asked for their records, this book could easily have increased by hundreds of pages.

One problematic aspect of this, and many other bird books is the use of the term "hypothetical". Hypothetical in this volume is applied to records for which material evidence does not exist and is applied to documented sight records that lack a specimen or photograph. Many rare bird committees and authors have discarded this term and are willing to accept well-documented conclusive written descriptions. A species such as Ivory Gull can be identified and separated from other species and albinistic individuals without the need for a specimen.

While a truly comprehensive book on the birdlife of Alberta is still warranted, this book, along with the recently published *The Atlas of Breeding Birds of Alberta* will help towards this goal. The present publication is commendable as many significant records have been compiled into a single accessible book. I look forward to reading Volume 2. Passerines.

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ENVIRONMENT

The Diversity of Life

By E. O. Wilson. 1992. The Belknap Press of Harvard University Press, Cambridge, Massachusetts. 424 pp., illus. U.S. $29.95

There is only one planet in the universe that is known to contain life, the one which we inhabit. Cataloguing the diversity of life on this little known planet has been an ongoing task for more than 2000 years and yet there are probably many generations of work left before it is complete. The greatest signiicance of the work completed in the last 100 years is not to be found in the tens of thousands of additions to the catalogue, but in the greater appreciation of how much is yet to be accomplished. The daunting work of the cataloguing is, however, being simplified by the rapid deletion of forms, as yet undocumented, at the hands of the cataloguers. The rate of elimination of species, prior to knowledge of their existence, ensures that the task is dwindling.

Wilson has produced a number of syntheses on a range of biological subjects that are a joy to read. His remarkably broad knowledge and writing ability have resulted in books that appeal to, and are read by, large audiences. Sometimes opinionated and controversial, they are always thought provoking. His talents are abundantly evident in the latest book, *The Diversity of Life*. In this book he tries to impress upon the reader the extraordinary multiplicity of life, the rapid rate of its diminution, and the significance of its loss. How life on earth became diverse is not dealt with in great detail (this is not a book about evolutionary process), but the trend and present pattern is admirably documented with extensive examples drawn from disparate sources. One is left staggered by the multiplicity and richness of pattern and with a sense of urgency as the riches slip through our fingers. Just what the author intended. Far from just telling a tale of woe, Wilson also puts forward a series of practical suggestions that could be initiated to moderate the loss of biodiversity.

As well as a glossary of terms, thirty-five pages of notes at the end of the book form a bibliography for further reading. These are thoughtful additions for a book intended for a general audience, especially as the concepts and deluge of details, names and terms may be a bit overwhelming for those with little formal biological training. This latter problem is inherent in the subject itself; life is very complex and the factors effecting ecosystem integrity are very complex. It is possible only to scratch the surface in 424 pages.

As biological forms that are adapted to perceive the special and temporal environment in which we move and spend our lives, it is with great difficulty that we appreciate environments of much greater or lesser magnitude. The "deep time" of the history of the earth, about 4.5 billion years, is practically an abstract concept for minds that operate on a scale of a few decades. The existence of many millions of species spread over the entire globe, on virtually every bit of surface and volume in the biosphere, is just as intractable to "visualize" as interstellar distances. Our inability to grasp scales of this magnitude is probably a key to some of the impending disaster society finds itself facing today. Reductionist procedure for understanding complex systems is the basic protocol for understanding function, but once the reassembly of components reach a "critical mass" the generalizations required to maintain the ecumenical perspective result in over-simplification and distortion. This flaw is evident in many "popular" works on biodiversity and ecosystems. Wilson's unapologetic approach to complexity and scale is a welcome contribution to environmental understanding.

Authors are not generally requested to justify their products. It is usually enough that the reader gets enjoyment and the publisher profit. Wilson may have better justification and competency than most to produce such a book. The publisher has indicated the use of 50% recycled fibre (minimum 10% post-consumer waste), but one should keep in mind the consumption required to produce even "environmentally conscious" books. Among the torrent of published material presently being produced in the name of environmentalism this book may be one of the least "evil", balancing benefit of education against habitat destruction. Product consumers can further weight the side of benefit by seeking out a library copy rather than purchasing their own. I have deposited the review copy at the Ottawa Public Library.

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The Scientific Management of Temperate Communities for Conservation: The 31st Symposium of the British Ecological Society, Southampton, 1989

Edited by I. F. Spellerberg, F. B. Goldsmith and M. G. Morris. 1991. Blackwell Scientific Publications, London. 566 pp.

The Scientific Management of Temperate Communities for Conservation is the symposium volume of the successful 31st symposium of the British Ecological Society which occurred on 4-6 April 1989 in Southampton. The editors hoped to provide a volume which relayed the enthusiasm of the participants of the symposium and to make a significant contribution to conservation literature.

The information found within this volume originates mainly in the northern hemisphere, with papers from the British Isles dominating. However, the information provided is not limited by geographical location. The information is presented in a well organized manner, starting with an introduction to the importance of conservation of temperate communities, followed with papers discussing conservation of flora and fauna of communities, then terrestrial and aquatic ecosystems, and wrapped up with discussion chapters on techniques and future research needs. Each chapter has been written by a recognized expert in the field and most were able to provide examples and discussion to promote further discussion and thought.

Unfortunately the book does have a flaw, although not a problem with the written contents. The publisher concedes all volumes of this printing are missing a number of columns on the left hand side of page 395 making this page difficult to read.

Without this defect, *The Scientific Management of Temperate Communities for Conservation* is another high quality British Ecological Society symposium proceedings. A book which would be an excellent addition to anyone's library who has an interest in temperate community conservation and management.

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Guide to the Natural History of the Niagara Region

Edited by J. C. Lewis. 1992. Available from the author, Biological Sciences, Brock University, St. Catharines, Ontario L2S 3A1. 470 pp., illus. $26.00.

The Niagara Peninsula is a unique and complex area. It is not only a geographical border between the US and Canada, but also a border between biotic and climatic zones: farthest south for some northern species, and farthest north for some southern species. It lies at the junction of five different weather systems which create a maelstrom of unpredictable and frequent surprises — often nasty.

This guide is usually comprehensive, and valuable for that reason. The first seven chapters set the natural history scene for the remainder of the book. In a very interesting way they cover the geological and archaeological history, and one chapter is a detailed guide to the geology and fossils of the cement quarry at Port Colborne. A good map is included.

The remaining 300 pages describe and discuss organisms. In addition to those usually found in a guide like this, such as trees and mammals, there are those which are rarely included: crustaceans, sponges, annelids, leeches, and fish. The fish section is particularly thorough and well illustrated, but for some other species, one would need an additional guide dedicated to the specific subject. The format ranges from narrative to lists, e.g. vascular plants. Some plant site guides would be helpful for a stranger to the area.

Just under half the chapters are written by university students who were employed by the Summer Canada Program to provide training. The other chapters are written by experts in their various fields, including the editor. The quality of the writing therefore tends to be uneven, and some sections could have benefitted from heavier editing, particularly the chapter on birds. There are a number of typographical errors.

The Guide is valuable for its wide ranging portrait of one area of Canada at a given point in time, and provides an important bench mark for those who will assess the effect of the changing environment on the flora and fauna of the Niagara Peninsula in the future.

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Monitoring Ecological Change

By Ian F. Spellerberg. 1991. Cambridge University Press, Cambridge. xvi + 334 pp., illus. U.S.$79.95.

The key purpose of this book is to introduce the reader, student, or general professional reader to the concepts and practices of biological monitoring. As a book of introduction, it does not set out to provide a strict methodology but provides a general inventory of methods.

The author has provided a book with an overview of the basics complete with references to more complete and specific discussions. Combined with this general overview of theory and methodology are examples to illustrate specific points and/or clarify certain methods. These examples are generally taken from the British Isles, the author's home base.

The author has taken great efforts to make the text readable and has succeeded overall. The book requires some acquaintance with ecological methodology, although not extensive. For anyone who has a lot of experience in the field the book would not likely contribute a lot to their knowledge base. For readers at the undergraduate level, or professionals with a general interest, the book should prove to be a handy reference to more detailed studies.

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MISCELLANEOUS

The Ruling Passion of John Gould

By Isabella Tree. 1992. Grove Weidenfeld, New York. vii + 248 pp., illus. U.S.$22.50.

In an England which had seen no international reputation in the biology of birds since Willoughby and Ray 150 years earlier, John Gould (1804-1881) became the dominant producer of illustrated works over the course of his long life. From a childhood in the family of a gardner, he rose to become taxidermist for the London Zoological Society (stuffing George VI's famous giraffe) and driving force behind the appearance of a panoply of volumes jointly covering most of the world. In what must stand as a record of managerial delegation to more talented workers Gould organized the efforts of his staff and oft-pregnant wife so that a total output of 2,999 plates resulted, none by himself who only sketched poorly. Professionally he was envied by Audubon, criticized by contemporaries, and eventually left behind as modern ornithology developed. But it was Gould who described Darwin's finches, an event which proved crucial for the development of the latter's thinking, and its documentation by Tree is the highlight for readers interested in the rise of evolutionary biology. Gould himself spent two years collecting in Australia, and the subsequent bungling by the British Museum so that this rich haul ended up in Philadelphia, is a lesson available to every collections manager in natural history. Tree chronicles his life against the major events of mid-century London such as the epidemic of cholera in 1854 which originated at the pump near his home. Three years earlier in the Great Exhibition his display of hummingbirds was highly popular and profitable, like his publication on this group which benefitted from techniques of metallic colouring developed across the Atlantic. In his old age Gould was the stimulus for Millais' sentimental but unrealistic *The Ruling Passion.*

Tree's text provides a succinct and pointed "warts-and-all" analysis of Gould, and the plates well illustrate the protagonists and the richness of the artwork. As an energetic entrepreneur catering to the Victorian appetite for lavish works in natural history, Gould has left a legacy which indeed makes him *the* bird man of his time. On the darker side remain his exploitation of his wife (who died at age 37) and workers, his ruthlessness in business, and his failure to join the forces pushing for ornithological conservation. The staff of the London Zoological Society were not well served by Gould: as its lithographer Edward Lear advanced the field of illustrating but was made miserable, while the death of its taxidermist John Gilbert on an expedition in Australia was not investigated by Gould. This mixture of accomplishments and failings provides the basis of a fascinating tale, especially for those curious in biological personages. Tree's biography is an excellent review of the life of a figure central to nineteenth-century natural history.

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NEW TITLES

Zoology

*__The animal rights/environmental ethics debate__. 1992. Edited by Eugene C. Hargrove. State University of New York Press, Albany. xxviii + 273 pp. U.S.$14.95.

Antarctic seals: research methods and techniques. 1993. Edited by Richard M. Laws. Cambridge University Press, New York. c350 pp., illus. U.S.$79.95.

*__The atlas of endangered animals.__ 1993. By Steve Pollock. Facts on File, New York. 64 pp., illus. U.S.$16.95; 21.95 in Canada.

*__Bats.__ 1992. By M. Brock Fenton. Facts on File, New York. 224 pp., illus. U.S.$45; $55 in Canada.

Beastly behaviors: what makes whales whistle, cranes dance, pandas turn somersaults, and crocodiles roar: a watcher's guide to how animals act and why. 1992. By Janine Benyus. Addison-Wesley, New York. x + 366 pp., illus. U.S.$29.95.

Big cats. 1993. By Susan Lumpkin. Facts on File, New York. 72 pp., illus. U.S.$17.95.

*__Bird Area.__ 1993. By Santa Barbara Software Products, Santa Barbara, California 93103. IBM compatible computer program.

*__Bird census techniques.__ 1992. By Colin J. Bibby, Neil D. Burgess, and David A. Hill. Academic Press, San Diego. xvii + 257 pp., illus. U.S.$19.50.

Birds. 1993. By Edward Ricciuti. Blackbirch Press, Woodbridge, Connecticut. 63 pp., illus. U.S.$16.95.

Butterfly conservation. 1992. Oxford University Press, New York. 223 pp., illus. U.S.$29.95.

*__Cormorants, darters, and pelicans of the world.__ 1993. By Paul A. Johnsgard. Smithsonian Institute Press, Washington. xiv + 445 pp. + plates, illus. U.S.$49 in U.S.A.; U.S. $58.75 foreign.

Current ornithology, volume 10. 1993. Edited by Dennis M. Power. Plenum, New York. c366 pp. U.S.$85.

The ecology of insect overwintering. 1993. By Simon R. Leather, Keith F. A. Walters,and Jeffrey S. Bale. Cambridge University Press, New York. c300 pp., illus. U.S. $89.95.

Fish. 1993. By Edward R. Ricciuti. Blackbirch Press, Woodbridge, Connecticut. 63 pp., illus. U.S.$16.95.

The fisher: life history, ecology, and behavior. 1993. By Roger A. Powell. 2nd edition. University of Minnesota Press, Minneapolis. 256 pp., illus. U.S.$16.95.

Going wild in Washington and Oregon: seasonal excursions to wildlife and habitats. 1993. By Susan Ewing. Alaska Northwest (Graphic Arts Center Publishing, Portland, Oregon). 224 pp., illus. U.S.$14.95.

*__Grizzly bears.__ 1993. By Candace Savage. Douglas and McIntyre, Vancouver. 176 pp., illus. $24.95.

*__Hawaiian insects and their kin.__ 1992. By F. G. Howarth and W. P. Mull. University of Hawaii Press, Honolulu. 160 pp., illus. U.S.$19.95.

*__Herpetology: an introductory biology of amphibians and reptiles.__ 1993. By George R. Zug. Academic Press (Harcourt Brace Jovanovich, San Diego). xv + 527 pp., illus. U.S.$50.

The hot-blooded insects: strategies and mechanisms of insect thermoregulation. 1993. By Bernd Heinrich. Harvard University Press, Cambridge, Massachusetts. 600 pp., illus. U.S.$75.

†**Introduction of foxes to Alaskan islands: history, effects on avifauna, and eradication.** 1993. By Edgar P. Bailey. U.S. Department of Interior, Fish and Wildlife Service, Fort Collins, Colorado. 53 pp., illus.

Larvae and evolution: toward a new zoology. 1992. By Donald I. Williamson. xvi + 215 pp., illus. U.S.$39.95.

*__Manual of ornithology: avian structure and function.__ 1993. By Noble S. Proctor and Patrick J. Lynch. Yale University Press, New Haven. U.S.$40.

†**Nymphs of North American stonefly genera (Plecoptera).** 1993. By Kenneth W. Stewart and Bill Stark. University of North Texas Press (Texas A&M University Press, College Station). 464 pp., illus. U.S.$34.50.

Picturing nature: American nineteenth-century zoological illustration. 1993. By Ann Shelby Blum. Princeton University Press, Princeton. 403 pp., illus. U.S.$59.50.

The practical entomologist: an introductory guide to observing and understanding the world of insects. 1992. By Rick Imes. Simon and Schuster, New York. 160 pp., illus. U.S.$15.

Raptor biomedicine. 1993. Edited by Patrick Redig, John E. Cooper, J. David Remple, and Bruce Hunter. University of Minnesota Press, Minneapolis. 288 pp., illus. U.S.$39.95.

The safari companion: a guide to watching African mammals. 1993. By Richard D. Estes. Chelsea Green, Pond Mills, Vermont. 470 pp. illus. U.S.$25.

A shadow and a song: the struggle to save an endangered species. 1992. By Mark Jerome Walters. Chelsea Green, Post Mills, Vermont. xvi + 256 pp., illus. U.S.$21.95.

Skua and penguin: predator and prey. 1993. By Evan Young. Cambridge University Press, New York. c450 pp., illus. U.S. $89.95.

Small cats. 1993. By Susan Lumpkin. Facts on File, New York. 72 pp., illus. U.S.$17.95.

The survival world of birds. 1993. By John Gooders. McGraw-Hill, New York. 224 pp., illus. U.S.$39.50.

†**Threatened birds of the Americas: the ICBP/IUCN red data book.** 1992. N. J. Collar, L. P. Gonzaga, N. Krabbe,

A.M. Nieto, L. G. Naranjo, T. A. Parker III, and D. C. Wege. 3rd edition. Smithsonian Institute Press, Washington. 1150 pp., illus. U.S.$75.

Botany

Bark: the formation, characteristics, and uses of bark around the world. 1993. By Ghillian Tolmie Prance and Anne E. Prance. Timber Press, Portland, Oregon. 176 pp., illus. U.S.$49.95.

Checklist of vascular plants of Thunder Bay District. 1993. By Joan Crowe. The Thunder Bay Naturalists, Thunder Bay. 51 pp. $2.

Leaf structure: coastal vegetation and mangroves of Venezuela. 1992. By Ingrid Roth. Gebruder Borntraeger, Berlin. x + 172 pp., illus. DM 136.

Meet the natives: the amateur's field guide to Rocky Mountain wildflowers, trees, and shrubs. 1992. By Walter M. Pesman. Roberts Rinehart, Niwot, Colorado. 227 pp., illus. U.S.$12.95.

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The patterned peatlands of Minnesota. 1992. Edited by H. E. Wright, Jr., Barbara Coffin, and Norman E. Aaseng. University of Minnesota Press, Minneapolis. 544 pp., illus. U.S.$44.95.

Phylogeny and classification of the orchid family. 1993. By Robert L. Dressler. Timber Press, Portland, Oregon. 316 pp., illus. U.S.$49.95.

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†**Texas range plants.** 1993. By Stephan L. Hatch and Jennifer Pluhar. Texas A&M University Press, College Station. 344 pp., illus. Cloth U.S.$35; paper U.S.$14.95.

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Environment

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Biogeography and ecology of the rain forests of eastern Africa. 1993. Edited by Jon C. Lovett and Samuel K. Wasser. Cambridge University Press, New York. c390 pp., illus. U.S. $110.

Biological diversity: the coexistence of species on changing landscapes. 1993. By Michael A. Huston. Cambridge University Press, New York. c600 pp., illus. Cloth U.S. $89.95; paper U.S. $34.95.

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†**Ecological integrity and the management of ecosystems**. 1993. Edited by Stephen Woodley, James Kay, and George Francis. St. Lucie Press, Delray Beach, Florida. viii + 220 pp., illus. U.S.$55.

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Ecology of greenways: design and function of linear conservation areas. 1993. Edited by Daniel S. Smith and Paul C. Hellmund. University of Minneapolis Press, Minneapolis. 308 pp., illus. U.S.$39.95.

Ecoside in the U.S.S.R.: health and nature under siege. 1992. By Murray Feshbach and Alfred Friendly, Jr. Basic Books, New York. 376 pp., illus. U.S.$24.

Everglades: the ecosystem and its restoration. 1993. Edited by Steve Davis and John Ogden. St. Lucie Press, Delray Beach, Florida. c900 pp. U.S.$89.95.

From coastal wilderness to fruited plain: a history of environmental change in temperate North America, 1500-present. 1993. By George G. Whitney. Cambridge University Press, New York. c400 pp., illus. U.S. $69.95.

*__Functions of nature.__ 1992. By Rudolph S. de Groot. Wolters-Noordhoff, Groningen, The Netherlands. 345 pp., illus. Hfl 80.

Great reefs of the world. 1993. By Carl Roessler. Pisces Books, Houston. x + 116 pp., illus. U.S.$19.95.

The greenhouse effect. 1992. By Philip Neal. 64 pp., illus. U.S.$24.95.

Managing sustainable development. 1993. By Michael Carley and Ian Christie. University of Minnesota Press, Minneapolis. 288 pp., U.S.$19.95.

Method in ecology: strategies for conservation. 1993. By Kristen S. Shrader-Frechette and Earl D. McCoy. Cambridge University Press, New York. c350 pp., illus. U.S. $79.95.

Realms of the sea. 1992. By Kenneth Brower. National Geographic Society, Washington. 274 pp., illus. U.S.$24.95.

†**Resume of catalogues of columns on nature and conservation in newspapers of London, Ontario, 1912-1992, with a catalogue of columns on nature by Thomas N. Hayman in London Free Press, 1963-1992.** 1993. By W. W. Judd. Phelps, London. 66 pp. $10.

Riparian landscapes. 1993. By George P. Malanson. Cambridge University Press, New York. c296 pp., illus. U.S. $64.95.

La Selva: ecology and natural history of a neotropical rainforest. 1993. Edited by Lucinda A. McDade, Kamaljit S. Bawa, Henry A. Hespenheide, and Gary S. Hartshorn. University of Chicago Press, Chicago. c592 pp., illus. Cloth U.S.$110; paper U.S.$34.95.

Southern ocean ecology: the biomass perspective. 1993. Edited by Sayed Z. El-Sayed. Cambridge University Press, New York. c312 pp., illus. U.S. $94.95.

Species diversity in ecological communities: historical and geographical perspectives. 1993. Edited by Robert E. Ricklefs and Dolph Schluter. University of Chicago Press, Chicago. c454 pp., illus. Cloth U.S.$105; paper U.S.$35.

State of the world 1993: a World Watch Institute report on progress towards a sustainable society. 1993. By Lester R. Brown, et al. Norton, New York. 259 pp. U.S.$10.95.

The trophic cascade in lakes. 1993. Edited by Stephen R. Carpenter and James F. Kitchell. Cambridge University Press, New York. c320 pp., illus. U.S. $89.95.

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Miscellaneous

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*__The ruling passion of John Gould.__ 1991. By Isabella Tree. Grove Weidenfeld, New York. 248 pp. + plates. U.S.$22.95.

*__Science and the Canadian Arctic: a century of exploration: 1818-1920.__ 1993. By Trevor H. Levere. Cambridge University Press, New York. xiv + 438 pp., illus. U.S.$49.95.

Science as a way of knowing: the foundations of modern biology. 1993. By John A. Moore. Harvard University Press, Cambridge, Massachusetts. 528 pp., illus. U.S.$29.95.

†**Science in the subarctic: trappers, traders, and the Smithsonian Institution.** 1993. By Debra Lindsay. Smithsonian Institution Press, Washington. xvii + 176 pp., illus. U.S.$34.

Books for Young Naturalists

Amazing bears. 1992. By Theresa Greenaway. Knopf, New York. 29 pp., illus. U.S.$9.99.

Amazing birds of prey. 1992. By Jemima Parry-Jones. Knopf, New York. 29 pp., illus. U.S.$9.99.

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The elephant, the peaceful giant. 1992. By Christine and Michel Denis-Huot. Charlesbridge, Watertown, Massachusetts. 28 pp., illus. U.S.$6.95.

Endangered species. 1992. By Terri Willis and Wallace B. Black. Childrens Press, Chicago. 128 pp., illus. U.S.$19.95.

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Global warming: a pop-up book of our endangered planet. 1992. Simon and Schuster, New York. 12 pp., illus. U.S.$15.

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Hummingbirds: jewel in the sky. 1992. By Esther Tyrrell. Crown, New York. 36 pp., illus. U.S.$14.99.

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The magic school bus on the ocean floor. 1992. By Joanna Cole. Scholastic, New York. 48 pp., illus. U.S.$14.95.

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The raggedy red squirrel. 1992. By Hope Ryden. Lodestar Books, New York. 48 pp., illus. U.S.$16.

Rain forest. 1992. By Paul Sterry and Michael H. Robinson. Readers Digest, Pleasantville, New York. 32 pp., illus. U.S.$14.

Saving endangered animals. 1993. By Alvin, Virginia, and Robert Silverstein. Enslow, Hillside, New Jersey. 128 pp., illus. U.S.$17.95.

Saving endangered mammals: a field guide to some of the earth's rarest animals. 1993. By Thame Maynard. Watts, New York. 60 pp., illus. U.S.$15.95.

Science dictionary of animals. 1992. By James Richardson. Troll, Mahwah, New Jersey. 48 pp., illus. Cloth U.S.$10.79; paper U.S.$3.95.

Sharks. 1992. By Miranda MacQuitty. Knopf, New York. 64 pp., illus. U.S.$15.99.

Spring pool: a guide to the ecology of temporary ponds. 1992. By Ann Downer. Watts, New York. 56 pp., illus. U.S.$15.95.

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What's happening to the ozone layer? 1992. By Isaac Asimov. Gareth Stevens, Milwaukee. 24 pp., illus. U.S.$15.95.

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Why are some beaches oily? 1992. By Isaac Asimov. Gareth Stevens, Milwaukee. 24 pp., illus. U.S.$15.93.

Wildcritters. 1993. By Tim Jones. Graphic Arts Centre Publishing, Portland, Oregon. 48 pp., illus. Cloth U.S.$15.95; paper U.S.$7.95.

A Yellowstone ABC. 1992. By Cyd Martin. Roberts Rinehart, Niwot, Colorado. 20 pp., illus. U.S.$5.95.

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ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 107, Number 4 **October-December 1993**

The Ottawa Field-Naturalists' Club

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The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

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Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club,* 1879-1886, and The Ottawa Naturalist, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Northern Bottlenose Whale, *Hyperoodon ampullatus,* in The Gully near Sable Island, Nova Scotia. Photograph courtesy of Hal Whitehead. See Status Report by Reeves, Mitchell and Whitehead pages 490–508.

The Canadian Field-Naturalist

Volume 107, Number 4 October–December 1993

Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports IX

R. R. CAMPBELL

Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3

Campbell, R. R. *Editor*. 1994. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports IX. Canadian Field-Naturalist 107(4): 395–401.

Fourteen status reports representing the 1992 and 1993 fish and marine mammal status assignments have been prepared for publication. Committee (COSEWIC) and Subcommittee (Fish and Marine Mammals) activities are briefly discussed. Tabular lists of fish and marine mammal species assigned status to April 1993, of species currently under consideration, and of those yet to be considered, are presented.

Quatorze rapports de statut relativement aux poissons et aux mammifères marins auxquelles ont été attribués un statut en 1992 et 1993 ont été préparés pour publication. Les activités du Comité (CSEMDC) et du sous-comité (des poissons et des mammifères marins) sont brièvement discutées. Les listes des espèces de poissons et de mammifères marin qui ont reçu un statut jusqu'en avril 1993, des espèces toujours à l'étude, et de celles à être considérées, sont présentées sous forme tabulaire.

Key Words: Rare and endangered species, fish, marine mammals, COSEWIC.

As indicated in previous annual summaries (Campbell 1984, 1985, 1987, 1988, 1989, 1990, 1991, 1992), a priority of the Subcommittee on Fish and Marine Mammals is to publish the status reports on those species of fish and marine mammals which the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reviewed, approved and used as a basis of assigning status where appropriate to species in jeopardy in Canada. The group of 14 reports presented herein represent the fish and marine mammal component of those species assigned status by COSEWIC in 1992 and 1993 (see Table 1). It is hoped that we will have the continuing financial support of Environment Canada to offer, in succeeding volumes, those reports reviewed in future years.

Progress

COSEWIC has undertaken to make available to all Canadians supporting information on each species classified (*see* Cook and Muir 1984). The Fish and Marine Mammal Subcommittee has been able to use this journal as one step in achieving the goal. A series of reports have appeared in various volumes and numbers from 1984 through 1992 [see *Canadian Field-Naturalist* 98(1): 63-133; 99(3): 404-450; 101(2): 165-309; 102(1): 81-176 and 102(2): 270-398; 103(2): 147-220; 104(1): 1-145; 105(2): 151-250; 106(1): 1-72].

Contributions to World Wildlife Fund Canada (WWF) by the Department of Fisheries and Oceans (DFO) and the Canadian Wildlife Service (CWS) of Environment Canada ($10 000 each) were matched by WWF funding and permitted the contracting of several new reports on various species of mammals, birds, fish and plants in 1992 and 1993. Commencing in April 1993, the Canadian Wildlife Federation has agreed to support COSEWIC report preparation through a similar system of matching grants and it is hoped that some $40 000 will be available to support the various subcommittees in 1993 through 1994.

As of April 1993, COSEWIC has reviewed the status of 79 fish species, one marine invertebrate, and 35 marine mammals (Table 1). Of the 115 species investigated, 6 are indeterminate (5 fish, 1 marine mammal) and 47 (19 fish, 27 marine mammals, 1 marine invertebrate) have been found not to require status designation. Another 40 (35 fish, one marine mammal) were designated as vulnerable, mainly due to natural rarity. The remaining 22 species are of immediate concern and therefore are of interest to RENEW (Recovery of Nationally Endangered Wildlife), an organization which was established in 1990 to oversee the development of recovery teams and plans for such species listed by COSEWIC (CWS 1993).

There are currently 32 status reports on fish species and 13 on marine mammal species under review or in preparation (Table 2). Several of these

TABLE 1. Fish and Marine Mammal Species with assigned COSEWIC status to 15 April 1993.

Species	Scientific Name	Status	Date Assigned
FISH			
Lake Sturgeon	*Acipenser fulvescens*	RANSDR[a]	April 1986
Bloater	*Coregonus hoyi*	RANSDR	April 1988
Blueback Herring	*Alosa aestivalis*	RANSDR	April 1980
Striped Shiner	*Luxilus chrysocephalus*	RANSDR	April 1993
Redfin Shiner	*Lythrurus umbratilis*	RANSDR	April 1988
Hornyhead Chub	*Nocomis biguttatus*	RANSDR	April 1988
River Chub	*Nocomis micropogon*	RANSDR	April 1988
Ghost Shiner	*Notropis buchanani*	RANSDR	April 1993
Leopard Dace	*Rhinichthys falcatus*	RANSDR	April 1990
Mountain Sucker	*Catostomus platyrhynchus*	RANSDR	April 1991
Golden Redhorse	*Moxostoma erythrurum*	RANSDR	April 1989
Least Darter	*Etheostoma microperca*	RANSDR	April 1989
Tesselated Darter	*Etheostoma olmstedi*	RANSDR	April 1993
River Darter	*Percina shumardi*	RANSDR	April 1989
Green Sunfish	*Lepomis cyanellus*	RANSDR	April 1987
Longear Sunfish	*Lepomis megalotis*	RANSDR	April 1987
Spoonhead Sculpin	*Cottus ricei*	RANSDR	April 1989
Brook Silverside	*Labidesthes sicculus*	RANSDR	April 1989
Y-Prickleback	*Allolumpenus hypochromus*	RANSDR	April 1991
Darktail Lamprey	*Lethenteron alaskense*	RAISIFSD[b]	April 1990
Bering Cisco	*Coregonus laurettae*	RAISIFSD	April 1990
Flathead Catfish	*Pylodictis olivaris*	RAISIFSD	April 1993
Northern Madtom	*Noturus stigmosus*	RAISIFSD	April 1993
Pixy Poacher	*Occella impi*	RAISIFSD	April 1991
Lake Lamprey[c]	*Lampetra macrostoma*	Vulnerable[d]	April 1986
Chestnut Lamprey	*Ichthyomyzon castaneus*	Vulnerable	April 1991
Northern Brook Lamprey	*Ichthyomyzon fossor*	Vulnerable	April 1991
Shortnose Sturgeon	*Acipenser brevirostrum*	Vulnerable	April 1980
Green Sturgeon	*Acipenser medirostris*	Vulnerable	April 1987
White Sturgeon	*Acipenser transmontanus*	Vulnerable	April 1990
Spotted Gar	*Lepisosteus oculatus*	Vulnerable	April 1983
Spring Cisco[c]	*Coregonus* sp.	Vulnerable	April 1992
Squanga Whitefish[c]	*Coregonus* sp.	Vulnerable	April 1988
Kiyi	*Coregonus kiyi*	Vulnerable	April 1987
Pacific Sardine	*Sardinops sagax*	Vulnerable	April 1987
Redside Dace	*Clinostomus elongatus*	Vulnerable	April 1987
Silver Chub	*Macrhybopsis storeriana*	Vulnerable	April 1985
Pugnose Shiner	*Notropis anogenus*	Vulnerable	April 1985
Bigmouth Shiner	*Notropis dorsalis*	Vulnerable	April 1985
Silver Shiner	*Notropis photogenis*	Vulnerable	April 1983[e]
Pugnose Minnow	*Opsopoeodus emiliae*	Vulnerable	April 1985
Speckled Dace	*Rhinichthys osculus*	Vulnerable	April 1980[f]
Umatilla Dace	*Rhinichthys umatilla*	Vulnerable	April 1988
Central Stoneroller	*Campostoma anomalum*	Vulnerable	April 1985
Banded Killifish — Newfoundland	*Fundulus diaphanus*	Vulnerable	April 1989
Blackstripe Topminnow	*Fundulus notatus*	Vulnerable	April 1985
Bigmouth Buffalo	*Ictiobus cyprinellus*	Vulnerable	April 1989
Black Buffalo	*Ictiobus niger*	Vulnerable	April 1989
Spotted Sucker	*Minytrema melanops*	Vulnerable	April 1983
River Redhorse	*Moxostoma carinatum*	Vulnerable	April 1983[e]
Greenside Darter	*Etheostoma blennioides*	Vulnerable	April 1990
Brindled Madtom	*Noturus miurus*	Vulnerable	April 1985
Redbreast Sunfish	*Lepomis auritus*	Vulnerable	April 1989
Orangespotted Sunfish	*Lepomis humilis*	Vulnerable	April 1989
Fourhorn Sculpin — Arctic Islands	*Myoxocephalus quadricornis*	Vulnerable	April 1989
Giant Stickleback[c]	*Gasterosteus* sp.	Vulnerable	April 1980
Unarmoured Stickleback[c]	*Gasterosteus* sp.	Vulnerable	April 1983
Blackline Prickleback	*Acantholumpenus mackayi*	Vulnerable	April 1989
Bering Wolffish	*Anarhichas orientalis*	Vulnerable	April 1989

Continued

TABLE 1. *Continued.*

Species	Scientific Name	Status	Date Assigned
FISH (*Continued*)			
Lake Simcoe Whitefish[c]	*Coregonus clupeaformis* ssp.	Threatened	April 1987
Blackfin Cisco	*Coregonus nigripinnis*	Threatened	April 1988
Shortnose Cisco	*Coregonus reighardi*	Threatened	April 1987
Shortjaw Cisco	*Coregonus zenithicus*	Threatened	April 1987
Black Redhorse	*Moxostoma duquesnei*	Threatened	April 1988
Copper Redhorse[c]	*Moxostoma hubbsi*	Threatened	April 1987
Channel Darter	*Percina copelandi*	Threatened	April 1993
Margined Madtom	*Noturus insignis*	Threatened	April 1989
Enos Lake Stickleback[c]	*Gasterosteus* sp.	Threatened	April 1988
Shorthead Sculpin	*Cottus confusus*	Threatened	November 1983
Deepwater Sculpin — Great Lakes	*Myoxocephalus thompsoni*	Threatened	April 1987
Acadian Whitefish[c]	*Coregonus huntsmani*	Endangered	April 1983
Aurora Trout[c]	*Salvelinus fontinalis timagamiensis*	Endangered	April 1987
Salish Sucker	*Catostomus* sp.	Endangered	April 1986
Paddlefish	*Polyodon spathula*	Extirpated	April 1987
Gravel Chub	*Erimystax x-punctata*	Extirpated	April 1987[g]
Longjaw Cisco	*Coregonus alpenae*	Extinct	April 1988
Deepwater Cisco	*Coregonus johannae*	Extinct	April 1988
Banff Longnose Dace[c]	*Rhinichthys cataractae smithi*	Extinct	April 1987
Blue Walleye	*Stizostedion vitreum glaucum*	Extinct	April 1985
MARINE MOLLUSCS			
Northern Abalone	*Haliotis kamtschatkana*	N/A[h]	April 1988
MARINE MAMMALS			
Sea Otter	*Enhydra lutris*	Endangered	May 1978[i]
Sea Mink	*Mustela macrodon*	Extinct	April 1985
Hooded Seal	*Cystophora cristata*	RANSDR	April 1986
Northern Elephant Seal	*Mirounga angustirostris*	RANSDR	April 1986
Ringed Seal	*Phoca hispida*	RANSDR	April 1989
Steller Sea Lion	*Eumetopias jubatus*	RANSDR	April 1987
California Sea Lion	*Zalophus californianus*	RANSDR	April 1987
Atlantic Walrus	*Odobenus rosmarus rosmarus*		
Eastern Arctic		RANSDR	April 1987
Northwest Atlantic		Extirpated	April 1987
Baird's Beaked Whale	*Berardius bairdii*	RANSDR	April 1992
Beluga	*Delphinapterus leucas*		
Beaufort Sea		RANSDR	April 1986
Western and Southern Hudson Bay		RANSDR	April 1993
High Arctic		Vulnerable	April 1992
Eastern Hudson Bay		Threatened	April 1988
St. Lawrence River		Endangered	April 1983
S.E. Baffin Island		Endangered	April 1990
Ungava Bay		Endangered	April 1988
Common Dolphin	*Delphinus delphis*	RANSDR	April 1991
Grey Whale	*Eschrichtius robustus*		
Northeast Pacific		RANSDR	April 1987
Northwest Atlantic		Extirpated	April 1987
Risso's Dolphin	*Grampus griseus*	RANSDR	April 1990
Short-finned Pilot Whale	*Globicephala macrorhynchus*	RANSDR	April 1993
Northern Bottlenose Whale	*Hyperoodon ampullatus*	RANSDR	April 1993
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	RANSDR	April 1991
Pacific White-sided Dolphin	*Lagenorhynchus obliquidens*	RANSDR	April 1990
Northern Right Whale Dolphin	*Lissodelphis borealis*	RANSDR	April 1990
Hubbs' Beaked Whale	*Mesoplodon carlhubbsi*	RANSDR	April 1989
Blainville's Beaked Whale	*Mesoplodon densirostris*	RANSDR	April 1989
True's Beaked Whale	*Mesoplodon mirus*	RANSDR	April 1989
Stejneger's Beaked Whale	*Mesoplodon stejnegeri*	RANSDR	April 1989
Narwhal	*Monodon monoceros*	RANSDR	April 1986[e]
Dall's Porpoise	*Phocoenoides dalli*	RANSDR	April 1989
False Killer Whale	*Pseudorca crassidens*	RANSDR	April 1990
Striped Dolphin	*Stenella coeruleoalba*	RANSDR	April 1993
Bottlenose Dolphin	*Tursiops truncatus*	RANSDR	April 1993
Cuvier's Beaked Whale	*Ziphius cavirostris*	RANSDR	April 1990
Blue Whale	*Balaenoptera musculus*	Vulnerable	April 1983[f]
Fin Whale	*Balaenoptera physalus*	Vulnerable	April 1987
Sowerby's Beaked Whale	*Mesoplodon bidens*	Vulnerable	April 1989

Continued

TABLE 1. *Concluded.*

Species	Scientific Name	Status	Date Assigned
MARINE MAMMALS (*Continued*)			
Harbour Porpoise	*Phocoena phocoena*		
Northwest Pacific		RAISIFSD	April 1991
Northwest Atlantic		Threatened	April 1990
Humpback Whale	*Megaptera novaeangliae*		
Northwest Atlantic		Vulnerable	April 1985
Northeast Pacific		Threatened	April 1982[j]
Bowhead Whale	*Balaena mysticetus*	Endangered	April 1980[i]
Right Whale	*Eubalaena glacialis*	Endangered	April 1980[k]

[a] RANSDR — use of NIAC (Not in Any Category) dropped in 1988 and subsequently converted. RANSDR is not a category = Report Accepted No Status Designation Required.

[b] RAISIFSD - the use of a new list "Report Accepted Insufficient Scientific Information For Status Designation" was approved at the 1990 General Meeting.

[c] Endemic to Canada

[d] Vulnerable — "Rare" category changed to "Vulnerable" in 1988. Dates Assigned of 1988 or earlier indicate date of original Rare status assignment. These were subsequently converted to Vulnerable at the 1990 General Meeting based on the advice of the Fish and Marine Mammal Subcommittee.

[e] Updated April 1987 — no status change.

[f] Updated April 1984 — no status change.

[g] Updated April 1987 — previous status of "Endangered" assigned April 1985.

[h] N/A — Status Not Assigned. COSEWIC has no mandate for invertebrates. Report accepted and recommended RANSDR Status agreed to, but not assigned.

[i] Updated April 1986 — no status change.

[j] Updated April 1985 — North Atlantic stock downlisted to "Vulnerable".

[k] Updated April 1985 and April 1990 — no status change.

TABLE 2. Fish and Marine Mammal Species for which Status Reports are in preparation, or under review — to 15 April 1993.

Species	Scientific Name	Proposed Status
FISH		
Atlantic Sturgeon	*Acipenser oxyrhynchus*	?
Lake Sturgeon[o]	*Acipenser fulvescens*	?
Red (Arctic) Char	*Salvelinus alpinus* ssp.	?
Bull Trout	*Salvelinus confluentus*	Vulnerable
Mira Whitefish*	*Coregonus* sp.	Vulnerable
Opeongo Whitefish*	*Coregonus* sp.	Threatened
Lake Herring	*Coregonus artedi*	Endangered
Lake Whitefish	*Coregonus clupeaformis*	Threatened — Lake Erie, ON
Pygmy Whitefish	*Prosopium coulteri*	?
Round Whitefish	*Prosopium cylindraceum*	Vulnerable
Pygmy Smelt	*Osmerus spectrum*	Vulnerable
Redfin Pickerel	*Esox americanus americanus*	Vulnerable — Quebec
Grass Pickerel	*Esox americanus vermiculatus*	Vulnerable
Chain Pickerel	*Esox niger*	Vulnerable — PQ, NB, NS
Chiselmouth	*Acrocheilus alutaceus*	Vulnerable — BC
Cutlips Minnow	*Exoglossum maxillingua*	Vulnerable
Western Silvery Minnow	*Hybognathus argyritis*	?
Eastern Silvery Minnow	*Hybognathus nuchalis regius*	Vulnerable
Blackchin Shiner	*Notropis heterodon*	Vulnerable
Rosyface Shiner	*Notropis rubellus*	Vulnerable
Weed Shiner	*Notropis texanus*	Vulnerable
Bluntnose Minnow	*Pimephales notatus*	Vulnerable
Jasper Longnose Sucker*	*Castostomus castostomus lacustris*	Vulnerable
Lake Chubsucker	*Erimyzon sucetta*	Vulnerable
Warmouth	*Lepomis gulosus*	Vulnerable
Eastern Sand Darter	*Ammocrypta pellucida*	Vulnerable
Spinynose Sculpin	*Asemichthys taylori*	Vulnerable — BC
Cultus Pygmy Coastrange Sculpin*	*Cottus aleuticus*	Threatened — BC
Mottled Sculpin	*Cottus bairdi*	Vulnerable — BC, Alberta
Shorthead Sculpin[o]	*Cottus confusus*	Vulnerable

Continued

TABLE 2. *Concluded.*

Species	Scientific Name	Proposed Status
FISH *(continued)*		
Texada Stickleback*	*Gasterosteus* sp.	Vulnerable
Bluefin Tuna	*Thunnus thynnus*	?
MARINE MAMMALS		
Minke Whale	*Balaenoptera acutorostrata*	?
Sei Whale	*Balaenoptera borealis*	?
Bowhead Whale[O]	*Balaena mysticetus*	Endangered
Blue Whale[O]	*Balaenoptera musculus*	Vulnerable
Long-finned Pilot Whale	*Globicephela malaena*	?
Pygmy Sperm Whale	*Kogia breviceps*	Vulnerable
Dwarf Sperm Whale	*Kogia simus*	Vulnerable
White-beaked Dolphin	*Lagenorhynchus albirostris*	?
Killer Whale	*Orcinus orca*	?
Sperm Whale	*Physeter catadon*	?
Northern Fur Seal	*Callorhinus ursinus*	?
Bearded Seal	*Erignathus barbatus*	?
Harp Seal	*Phoca groenlandica*	?

* Endemic to Canada ON = Ontario BC = British Columbia

[O] Updated Status Report PQ = Quebec NS = Nova Scotia NB = New Brunswick

TABLE 3. Fish and Marine Mammal Species of Interest to COSEWIC — April 1993 (Not listed by Priority)

Species	Scientific Name	Possible Status
SPECIES UPDATES		
Fish		
Shortnose Sturgeon	*Acipenser brevirostrum*	Vulnerable April 1980
Spotted Gar	*Lepisosteus oculatus*	Vulnerable April 1983
Acadian Whitefish*	*Coregonus huntsmani*	Endangered April 1983
Blueback Herring	*Alosa aestivalis*	RANSDR April 1980
Speckled Dace	*Rhinichthys osculus*	Vulnerable April 1980
Spotted Sucker	*Minytrema melanops*	Vulnerable April 1983
Giant Stickleback*	*Gasterosteus* sp.	Vulnerable April 1980
Unarmoured Stickleback*	*Gasterosteus* sp.	Vulnerable April 1983
Marine Mammals		
St. Lawrence River Beluga	*Delphinapterus leucas*	Endangered April 1983
SPECIES YET TO BE CONSIDERED		
Fish		
Spiny Dogfish	*Squalus acanthias*	?
Smooth Skate	*Malacoraja senta*	?
Thorny Skate	*Raja radiata*	?
American Eel	*Anguilla rostrata*	Vulnerable
American Shad	*Alosa sapidissima*	?
Atlantic Herring	*Clupea harengus*	?
Liard Hotspring Lake Chub*	*Couesius plumbeus* ssp.	Vulnerable — BC
Creek Chubsucker	*Erimyzon oblongus*	Extirpated ?
Brassy Minnow	*Hybognathus hankinsoni*	?
Pearl Dace	*Margariscus margarita*	? — BC
Emerald Shiner	*Notropis atherinoides*	Threatened — BC
Spottail Shiner	*Notropis hudsonius*	Threatened — BC
Fathead Minnow	*Pimephales notatus*	Threatened — BC
Nooksack Dace*	*Rhinichthys cataractae* ssp.	Vulnerable — BC
Stonecat	*Noturus flavus*	? — Alberta
Capelin	*Mallotus villosus*	?
Pygmy Longfin Smelt*	*Spirinchus thaleichthys*	Vulnerable — Lake Harrington BC
Broad Whitefish	*Coregonus nasus*	Threatened — BC
Least Cisco	*Coregonus sardinella*	Threatened — BC
Giant Pygmy Whitefish	*Prosopium* sp.	Threatened — BC

Continued

TABLE 3. *Concluded.*

Species	Scientific Name	Possible Status
Fish (*Continued*)		
Pacific Salmonids	*Oncorhynchus* sp.	?
Atlantic Salmon	*Salmo salar*	?
Monkfish	*Lophius americanus*	?
Northern Cod	*Gadus morhua*	?
Tomcod	*Microgadus tomcod*	Vulnerable — Quebec
Haddock	*Melanogrammus aeglefinus*	?
Silver Hake	*Merluccius bilinearis*	?
Pollock	*Pollachius virens*	?
Red Hake	*Urophycis chuss*	?
Rock Grenadier	*Coryphaenoides rupestris*	?
Balkwill Lake Benthic Stickleback	*Gasterosteus* sp.	Threatened — BC
Balkwill Lake Limnetic Stickleback	*Gasterosteus* sp.	Threatened — BC
Emily Lake Benthic Stickleback	*Gasterosteus* sp.	Threatened — BC
Emily Lake Limnetic Stickleback	*Gasterosteus* sp.	Threatened — BC
Hadley Lake Benthic Stickleback	*Gasterosteus* sp.	Threatened — BC
Hadley Lake Limnetic Stickleback	*Gasterosteus* sp.	Threatened — BC
Paxton Lake Benthic Stickleback	*Gasterosteus* sp.	Threatened — BC
Paxton Lake Limnetic Stickleback	*Gasterosteus* sp.	Threatened — BC
Priest Lake Benthic Stickleback	*Gasterosteus* sp.	Threatened — BC
Priest Lake Limnetic Stickleback	*Gasterosteus* sp.	Threatened — BC
Ninespine Stickleback	*Pungitius pungitius*	Threatened — BC
Golden Rockfish	*Sebastes norvegicus*	?
Rainbow Darter	*Etheostoma caeruleum*	?
Lumpfish	*Cyclopterus lumpus*	?
Wolffish	*Anarhichas lupus*	?
Atlantic Mackeral	*Scomber scombrus*	?
Swordfish	*Xiphias gladius*	?
Summer Flounder	*Paralichthys dentatus*	?
Witch Flounder	*Glyptocephalus cynoglossus*	?
American Plaice	*Hippoglossoides platessoides*	?
Atlantic Halibut	*Hippoglossus hippoglossus*	?
Winter Flounder	*Pleuronectes americanus*	?
Yellowtail Flounder	*Pleuronectes ferrugineus*	?
Greenland Halibut	*Reinhardtius hippoglossoides*	?
Marine Mammals		
Grey Seal	*Halichoerus grypus*	?
Harbour Seal	*Phoca vitulina*	?
Marine Invertebrates		
Crustaceans		
Aesop Shrimp	*Pandalus montagui*	?
Atlantic Rock Crab	*Cancer irroratus*	?
Atlantic Lyre Crab	*Hyas araneus*	?
King Crab	*Neolithodes grimaldi*	?
Molluscs		
Iceland Scallop	*Chlamys islandica*	?
Blue Mussel	*Mytilus edulis*	?
Softshell Clam	*Mya arenaria*	?
Arctic Surfclam	*Mactromeris polynyma*	?
Atlantic Surfclam	*Spisula solidissima*	?
Ocean Quahog	*Arctica ilandica*	?
Waved Whelk	*Buccinum undatum*	?
Northern Shortfin Squid	*Illex illecebrosus*	?

* Endemic to Canada BC = British Columbia

will be presented to the Committee for status assignment in 1994. As well, some 54 additional species of fish, two marine mammals, and 12 marine invertebrates have been identified as being worthy of consideration (Table 3). Although many may be found to not require status designation, the process serves to bring together documented information necessary to make the appropriate decisions.

In addition to soliciting further status reports on species of potential concern, the Subcommittee continues to obtain updates on the status of selected species as new information becomes available. In the past year an automatic 10-year review process was instated (Table 3) for those species which had not already received further examination following an initial assignment of status.

Concluding Remarks

The 14 reports included in the following series are reports on the status of the respective species in Canada. Status was assigned by consensus of the COSEWIC Committee based on these reports which are published under the name(s) of the original author(s). The reports have undergone minor editing to provide a brief introduction and some degree of consistency in format and presentation.

It is hoped that the production of these reports provides a service to the public and the readers. The publication of the tables in this introduction, particulary Table 3, may attract the interest of researchers who may have expertise with a particular species that is listed. Curious parties, particularly potential authors are invited to contact the Subcommittee chair.

Acknowledgments

The members of COSEWIC and the Fish and Marine Mammal Subcommittee would like to extend their thanks to the various authors who have so generously contributed their time and talents in support of COSEWIC. The Committee also wishes to acknowledge the members of the Subcommittee for their unstinting efforts in reviewing the reports and their helpful comments.

COSEWIC is grateful to World Wildlife Fund Canada, the Canadian Wildlife Service, the Canadian Museum of Nature, and the Royal Ontario Museum for assistance provided in cash and kind. A special mention to Francis Cook and *The Canadian Field-Naturalist* for assistance in editing for publication and to all members of COSEWIC for their dedication and interest in the future of Canada's flora and fauna. We gratefully acknowledge the financial support provided through the Department of Fisheries and Oceans, Environment Canada and World Wildlife Fund Canada which has permitted the production of several new reports in 1992 and 1993.

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Accepted 15 August 1993

Statut de la Population de Cisco de Printemps, *Coregonus* sp., au Lac des Écorces, Québec, Canada*

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Hénault, Michel, et Réjean Fortin. 1993. Statut de la population de cisco de printemps, *Coregonus* sp., au lac des Écorces, Québec, Canada. Canadian Field-Naturalist 107(4): 402–409.

La fraie de printemps est très rare chez le genre *Coregonus*. À l'exception des Grands Lacs Laurentiens, elle n'est connue qu'au lac des Écorces (Québec), pour une population possiblement apparentée au complexe spécifique *Coregonus artedi*. Cette population se distingue des stocks environnants par des différences morphométriques et méristiques, dont une différence élevée au niveau du décompte des branchicténies. L'abondance de la population semble se maintenir depuis sa découverte, en 1981. Cependant, les eaux du lac ont connu une eutrophisation rapide depuis les vingt dernières années et la condition générale se détériorera si aucune action n'est entreprise. La fraie a lieu en eau profonde, d'où une sensibilité des oeufs à l'anoxie et à l'augmentation de la sédimentation. Le Cisco de lac est une espèce généralement vulnérable à la dégradation de la qualité de l'habitat et à la prédation. Suite à ces constatations et à l'unicité de la population, il appert que le cisco de printemps est un écotype vulnérable au Canada.

Spring spawning is very rare in the genus *Coregonus*. Outside of the Great Lakes, it is known in Canada only in Lake des Ecorces (Quebec), for a population possibly linked to the *Coregonus artedi* complex. This population is distinguished from other local stocks by differences in meristic and morphometric characters, including a marked difference in the number of gill rakers. The abundance of the population seems to have remained the same since its discovery in 1981. However, Lake des Ecorces has been undergoing rapid eutrophication during the past twenty years, and general conditions will deteriorate if no action is taken. Spawning takes place in deep water, hence the sensitivity of the eggs to oxygen depletion and increased sedimentation. The Lake Cisco is a species which is generally vulnerable to predation and to the deterioration of the quality of its habitat. Based on these observations and on the uniqueness of the population, it appears that the Spring Cisco of Lake des Ecorces is a vulnerable population in Canada.

Mot clefs: Cisco de printemps, Spring-Spawning Cisco, *Coregonus*, Salmonidae, coregonids, poissons rares et menacés.

Le genre *Coregonus*, et particulièrement le sous-genre *Leucichthys*, ont été depuis longtemps reconnus pour leur plasticité écologique et morphologique (Scott et Crossman 1973). Malgré cela, on ne connaît chez ces poissons que quelques populations frayant au printemps. Parmi les populations apparentées au complexe *Coregonus artedi*, Pariseau et al. (1983) ont rapporté l'existence de la seule population canadienne présentant cette caractéristique, et Todd (1981) a observé quelques ciscos de printemps au Lac Supérieur.

La population de cisco de printemps du lac des Écorces[1] est celle qui est la mieux connue, suite aux travaux effectués par Pariseau et al. (1983), Hénault (1986), Hénault et Fortin (1989, 1991). Cette population est allopatrique et se distingue des populations frayant l'automne dans le même bassin hydrographique par plusieurs caractéristiques morphométriques et méristiques (Hénault et Fortin 1989). En fait, le cisco de printemps possède typiquement une tête et des parties anatomiques céphaliques plus petites, un corps plus haut et un pédoncule caudal moins large que les ciscos d'automne des lacs voisins (Figure 1). Au niveau des caractères méristiques, on observe chez les premiers un nombre plus faible de branchicténies, de rayons aux nageoires impaires et d'écailles sur la ligne latérale. Plusieurs de ces caractéristiques morphométriques et méristiques peuvent être associées aux conditions environnementales lors des premiers développements. Cependant, le décompte des branchicténies montre un large écart entre le stock de printemps (moyenne: 42,7; étendue 39-47) et les stocks d'automne environnants (50,5; 46-57), ainsi

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*Rapport accepté par le CSEMDC et un statut de vulnérable assigné le 7 avril 1992.

[1] Notez que le cisco de printemps désignera dans la suite du texte la population du lac des Ecorces et que le Cisco de lac réfèrera aux populations frayant l'automne.

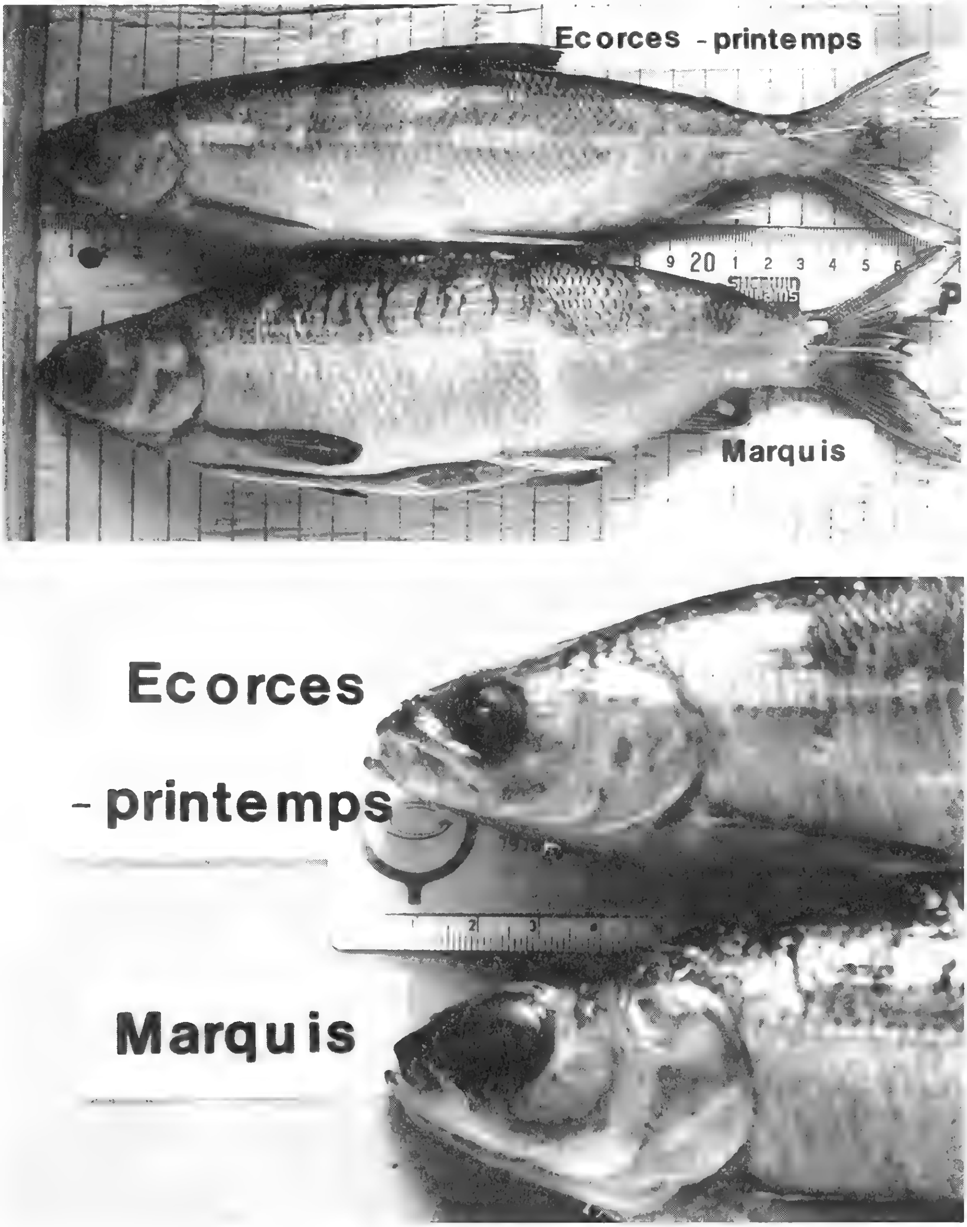

FIGURE 1. Exemple des différences morphométriques entre ciscos de printemps et d'automne. En haut: spécimens de même longueur; en bas : vue agrandie de la tête des même spécimens.

qu'une absence de recoupement dans la distribution de fréquence du nombre de branchicténies sur le limbe inférieur de l'arc branchial, ce qui suggère l'existence de différences génotypiques (Hénault et Fortin 1989).

Un décalage de la période de fraie de l'automne au printemps procure un isolement reproducteur parfait, et ces deux formes de cisco pourraient représenter deux espèces distinctes, ou en cours de spéciation (Pariseau et al. 1983). Face à des populations semblables de Petite Marène (*Coregonus albula*) en Europe, Svärdson (1979) a identifié la forme frayant au printemps comme étant *Coregonus trybomi*. Cependant, cette désignation a été contestée, sur la base de la faible divergence au niveau des fréquences alléliques d'isozymes entre les deux formes et de la distance génétique élevée entre deux populations frayant le printemps (Vuorinen et al. 1981). En règle générale chez les Coregoninae, on considère qu'il est peu approprié d'identifier des espèces distinctes à partir de caractéristiques biologiques (Todd 1981; Lindsey 1988). Selon les connaissances actuelles nous considérons le cisco de printemps comme un écotype particulier de *Coregonus artedi*; les comparaisons avec la littérature seront donc effectuées en référence à cette espèce.

Répartition

La fraie de printemps a été observée ponctuellement chez le genre *Coregonus*. Parmi les populations rattachées au complexe spécifique *Coregonus artedi*, le phénomène n'a été rapporté aux États-Unis que près de Copper Harbor dans le Lac Supérieur, où 19 spécimens ont été récoltés (Todd 1981; National Fisheries Research Center-Great Lakes, Ann Arbor, Michigan; communication personnelle) alors qu'au Canada il n'est connu qu'au lac des Écorces (46°32′N, 75°25′O; Figure 2). Par ailleurs , quelques populations frayant possiblement au printemps ont été signalées. Celle du lac Chandos (Havelock, Ontario) a fait l'objet de vérifications sur le terrain, sans toutefois montrer de comportement reproducteur printanier (Don E. McAllister, Canada Museum of Nature, Ottawa, Ontario; communication personnelle). Celle du lac Gilles (péninsule de Bruce, en Ontario) reste à examiner (R. R. Campbell, Environnement Canada, Ottawa, Ontario; communication personnelle).

Le décalage de la période normale de fraie a aussi été observé chez d'autres espèces de Coregoninae. Ainsi, on connaît quatre populations de Petite Marène de printemps en Suède (Svärdson 1979) et une en Finlande (Airaksinen 1968). En Amérique du Nord, *Coregonus zenithicus* fraie normalement à l'automne, mais des populations frayant le printemps sont bien représentées dans les Grands Lacs (Todd et Smith 1980), et l'inverse a déjà été observé ponctuellement pour *Coregonus reighardi* (Smith 1964). Il semble donc que le groupe *Coregonus artedi* ne représente qu'une fraction de l'ensemble des ciscos frayant au printemps dans les Grands Lacs. Toutefois, l'abondance du Cisco de lac frayant le printemps dans les Grands Lacs est actuellement inconnue, mais sa présence est probablement inusitée.

Protection

Au même titre que toutes les populations canadiennes de poissons, la population de ciscos de printemps du lac des Écorces est protégée par le régime général de la Loi fédérale sur les pêcheries; elle est protégée également par les lois québécoises touchant l'environnement, d'une part, et celle de la conservation et de la mise en valeur de la faune, d'autre part (L.R.Q., c. Q-2 et c. C-61.1). Cependant, aucune limite de prise ou de possession n'est en vigueur pour le Cisco de lac.

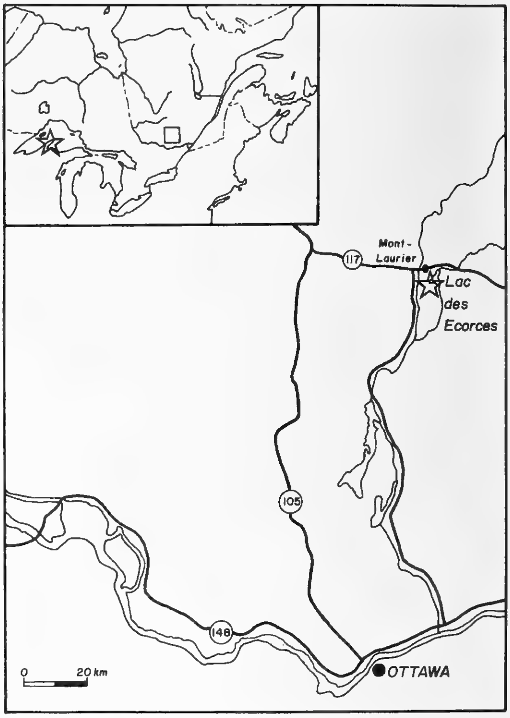

FIGURE 2. Localisation des endroits où des ciscos de printemps (*Coregonus artedi*) ont été observés.

Par ailleurs, le Québec s'est doté récemment d'une loi protègeant les espèces désignées menacées ou vulnérables, qui pourrait s'appliquer plus directement à la population de ciscos du lac des Écorces.

Nombre et Tendances Démographiques

Il n'est pas possible d'estimer l'effectif de la population de ciscos de printemps du lac des Écorces. Les pêches au filet effectuées en 1983 et 1984 ont permis la capture de 909 spécimens en 2100 heures de pêche. Toutefois, il est permis d'évaluer qualitativement les tendances de la population en utilisant les relevés effectués au moyen d'échosondeurs en août 1984 et 1989. Ceux-ci ont montré peu de différences entre les deux années (Figure 3), suggérant que l'abondance de la population se maintient depuis cinq ans. Dans d'autres plans d'eau, notamment au Lac Mendota, le Cisco de lac a déjà montré d'importantes fluctuations annuelles d'abondance (John et Hasler 1956). La population du lac des Écorces n'est connue que depuis 1981 et une tendance claire n'est pas encore apparente.

Habitat

Le Cisco de lac a toujours montré une préférence pour les eaux froides et bien oxygénées des lacs. En été, on retrouve le cisco de printemps dans l'hypolimnion, où il y effectue des migrations journalières qui ont été observées à l'aide de méthodes hydroacoustiques (Hénault, données non publiées). Durant l'automne et l'hiver, il est toujours capturé à plus de 12 m de la surface. Au printemps, pendant la fraie, les ciscos de printemps sont capturés surtout dans le bassin principal du lac, à des profondeurs de 20 à 30 m (Hénault et Fortin 1991). Ces sites sont caractérisés le plus souvent par un fond mou, composé principalement d'une épaisse couche de vase fluide, probablement semblable à ce qui a été décrit par Emery (1973) pour les lacs du bouclier pré-cambrien.

Les eaux du lac des Écorces ont connu une eutrophisation rapide au cours des vingt dernières années. La cause la plus importante de cette dégradation de l'habitat est le rejet des eaux usées du village de Lac-des-Écorces (850 habitants), situés en amont sur le principal tributaire de ce plan d'eau, la rivière Kiamika. En effet, ceci entraîne une baisse en oxygène dissout suffisante pour limiter les usages biologiques de ce tronçon de rivière (Richard 1980). On retrouve aussi 16 fermes bovines, porcines et avicoles le long de cet affluent principal du lac des Écorces; 950 et 105 ha sont aussi utilisés pour la production de fourrage et de céréales, respectivement (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, données non publiées). Ce lac a un taux de renouvellement élevé, soit sept fois par année, dû au débit de cette rivière (Pariseau et al. 1983).

D'autres facteurs doivent aussi être considérés, notamment le développement rapide des rives, d'abord pour la villégiature, et maintenant pour l'établissement de quartiers résidentiels. Selon des riverains de longue date, ce lac était autrefois cristallin et on y retrouvait du Touladi (*Salvelinus namaycush*), espèce maintenant disparue du plan d'eau. Aussi, les plantes aquatiques sont de plus en plus abondantes dans les baies du lac. Cet envahissement pourrait être imputable à la charge en phosphore, laquelle accélère l'eutrophisation.

Il est suggéré par Hénault et Fortin (1991) que la fraie de printemps au lac des Écorces serait due, du moins en partie, aux conditions thermiques marginales observées dans ce plan d'eau. En effet, la température estivale dans l'hypolimnion y est relativement élevée (7°C) et le refroidissement automnal est tardif. Ces conditions thermiques ne sont observées que rarement dans les autres lacs de la région (Ministère du Loisir, de la Chasse et de la Pêche, données non publiées). Le lac des Écorces pourrait ainsi représenter un habitat propice au développement ou au maintien de la fraie de printemps, même si les différences au niveau du nombre de branchicténies suggèrent que d'autres pressions sélectives ou des facteurs historiques pourraient aussi être impliqués (Hénault et Fortin 1989).

Biologie Générale

Reproduction

Les femelles et les mâles atteignent la maturité sexuelle à l'âge 3. La fécondité relative moyenne est de 50 222 oeufs·kg^{-1}; elle se situe ainsi à l'intérieur des limites déjà observées pour l'espèce, mais est cependant légèrement plus élevée que dans les populations de latitudes équivalentes (Hénault 1986).

La fraie de printemps entraîne une modification du cycle de développement des gonades. Tout comme chez la plupart des Salmonidés, la gamétogénèse débute concurremment au raccourcissement de la photopériode. Cependant, la maturation des oocytes ralentit à la fin de l'automne pour ne reprendre qu'au moment du dégel printanier, quelques semaines avant la fraie qui a lieu de la mi-mai au début du mois de juin (Hénault et Fortin 1991).

Mouvements Migratoires

Après l'éclosion qui a lieu vers la fin de juillet, les larves effectuent une migration vers la surface; elles ne fréquentent pas le mètre supérieur, probablement à cause des températures épilimnétiques trop élevées (>21°C), létales pour cette espèce d'eau froide (Hénault et Fortin 1991). Les adultes sont dispersés dans le bassin principal du Lac des Écorces au cours de l'année. Ils se concentrent à plusieurs endroits lors de la reproduction. Les sites de fraie n'ont pu être délimités précisément; cependant quelques oeufs ont été récoltés à des profondeurs dépassant 20 m (Hénault et Fortin 1991).

Comportement/Adaptabilité

Le Cisco de lac est une espèce qui fréquente l'hypolimnion en été. Ce comportement pourrait causer des mortalités importantes dans les cas où la teneur en oxygène y deviendrait limitante (Scott et Crossman 1973). Suite aux fluctuations importantes observées dans les Grands Lacs, Todd et Stedman (1989) considèrent que les populations de ciscos sont fragiles : seul le cisco de fumage (*Coregonus hoyi*) a pu récupérer après un déclin important, entraînant une hybridation avec les autres espèces de ciscos. Cependant, ces auteurs mentionnent que d'autres facteurs pourraient être impliqués, notamment la vulnérabilité aux engins de pêche, la survie des larves ou la fécondité.

Colby et al. (1972) considèrent que le Cisco de lac, une espèce planctonophage, est moins vulnérable à une extinction due à l'eutrophisation que le Grand Corégone (*Coregonus clupeaformis*), une espèce benthophage; en effet, dans la portion méridionale de son aire de répartition, ce dernier fréquente les zones les plus profondes des plans d'eau. Cependant, le cisco de printemps du lac des Écorces fraie en eau profonde, où l'accumulation de matières organiques peut causer une anoxie sur les sites de fraie et une plus grande mortalité des oeufs.

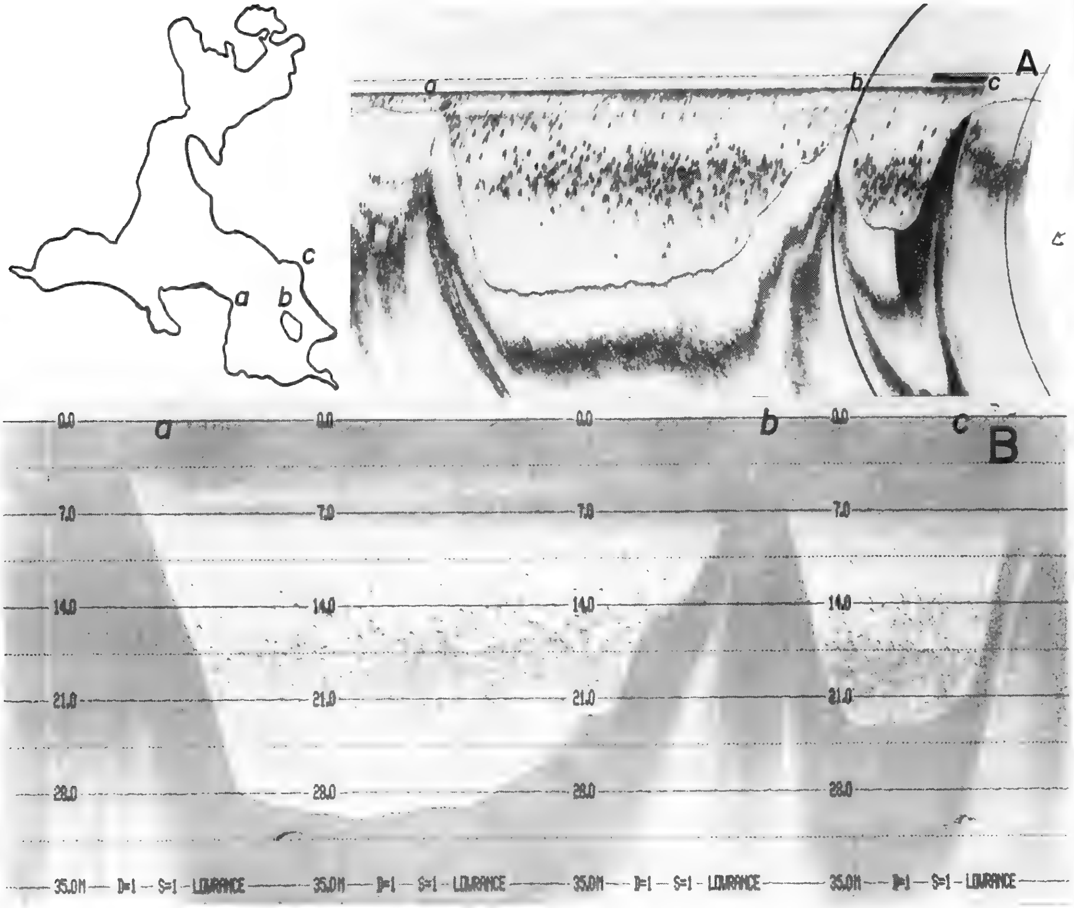

FIGURE 3. Relevés effectués à l'aide d'un échosondeur Furuno le 21 août 1984 (A) et d'un sonar Lowrance le 18 août 1989 (B). Les signaux enregistrés correspondent à des ciscos de printemps, seule espèce capturée à des profondeurs supérieures à 12 m.

Facteurs Limitants

Trois facteurs sont susceptibles de faire obstacle à la conservation de la population du lac des Écorces : l'eutrophisation, l'introduction accidentelle d'espèces indésirables et l'ensemencement de prédateurs. L'eutrophisation accélérée modifie les conditions abiotiques. Ce facteur a contribué à une diminution marquée des populations de Petite Marène en Europe Centrale (Lelek 1987). Aussi, la population de Petite Marène frayant le printemps au lac Halsjön est menacée d'extinction à cause de la pollution (Svärdson 1979).

La pollution peut aussi ajouter un stress supplémentaire à une population menacée par d'autres facteurs, tels la prédation ou la compétition alimentaire (Regier et Loftus 1972). Le Cisco de lac pourrait devenir très vulnérable suite à l'introduction d'Éperlan arc-en-ciel (*Osmerus mordax*), puisque cette espèce est prédatrice des larves de ciscos (Selgeby et al. 1978; Loftus et Hulsman 1986). McLain et Magnuson (1988) considèrent que l'introduction d'Éperlan arc-en-ciel dans quelques lacs du Wisconsin y a causé l'élimination du cisco, par prédation ou par compétition pour des ressources alimentaires limitées. L'interdiction de pêcher avec des poissons-appâts vivants, qui est en vigueur au Québec depuis 1990, sera profitable pour le cisco de printemps en diminuant les probabilités d'introduction accidentelle d'Éperlan arc-en-ciel, déjà présent dans d'autres lacs de la région.

On retrouve dans la communauté piscicole du lac des Écorces le Doré jaune (*Stizostedion vitreum*), le Grand Brochet (*Esox lucius*) et le Maskinongé (*Esox maskinongy*). Cependant, de fréquentes demandes d'ensemencement de Salmonidés sont formulées par les associations de pêcheurs de la région (J. Provost, Ministère du Loisir, de la Chasse et de la Pêche, Mont-Laurier, Québec; communication personnelle), en dépit du fait que l'introduction de prédateurs tels la Truite moulac (*Salvelinus fontinalis* × *Salvelinus namaycush*), la Truite arc-en-ciel (*Oncorhynchus mykiss*), le Saumon coho (*Oncorhynchus kisutch*), ou le Touladi ait influencé à la baisse la densité de Cisco de lac dans certaines communautés (Clady 1967; Hoff et Serns 1983; Evans et Waring 1987). L'introduction d'espèces prédatrices ou compétitrices dans les quelques lacs où l'on retrouve le Corégone du Squanga (*Coregonus* sp.) a été fortement désapprouvée dans le but d'assurer la protection de ce corégone nain, vivant en sympatrie avec le Grand Corégone (McAllister et al. 1985; Bodaly et al. 1988).

Intérêt Spécial de la Population

Le genre *Coregonus* regroupe les espèces les plus polytypiques de la faune piscicole nord-américaine. La fraie de printemps n'est qu'un exemple de cette grande variabilité. À l'examen de la distribution mondiale des Coregoninae, on constate que le sous-genre *Leucichthys* nord-américain montre autant de diversité que le genre *Coregonus* présent en Europe (Smith 1957). Cependant, plusieurs formes sont maintenant disparues ou en voie d'extinction généralement en raison de l'action conjuguée de l'exploitation commerciale et de la dégradation du milieu. Le Cisco de profondeur (*Coregonus johannae*) et le Cisco à grande bouche (*Coregonus alpenae*) sont maintenant éteints (Parker 1989a; Campbell 1987). Le Cisco à nageoires noires (*Coregonus nigripinnis*) n'est plus présent qu'au lac Nipigon, où il est rare (Parker 1989b). Le Cisco à museau court (*Coregonus reighardi*) a été éliminé des lacs Ontario et Michigan; il est menacé au lac Huron (Parker 1988). Le Cisco à mâchoires égales (*Coregonus zeneithicus*) est éliminé des lacs Huron et Michigan et menacé au lac Supérieur (Houston 1988). Le Cisco kiyi (*Coregonus kiyi*) est disparu de son aire de répartition originale, sauf au lac Supérieur où il est rare (Parker 1989c). Le Corégone atlantique (*Coregonus huntsmani*) est en danger d'extinction (Edge 1984), alors que plusieurs populations de *Coregonus* présentant des caractéristiques uniques sont aussi menacées, soit le Corégone du lac Simcoe (Evans et al. 1988), et le Corégone de l'Opeongo (McAllister et al. 1985).

Bien que la population du lac des Écorces soit actuellement rattachée au complexe *Coregonus artedi*, un examen approfondi de son statut taxonomique pourrait être entrepris. Hénault (1986) avait effectué un survol électrophorétique de quelques isozymes, mais des méthodes plus efficaces (e.g. ADN mitochondrial, compléments chromosomiques) pourraient apporter un éclairage nouveau à cette question.

La population de ciscos du lac des Écorces représente, dans l'état actuel des connaissances sur les Coregoninae, la seule mention en Amérique du Nord d'une population allopatrique montrant un décalage aussi important de la période de fraie. Puisque la diversité génétique d'une espèce est en fonction de sa répartition et de l'adaptation locale de ses stocks, Evans et al. (1988) suggèrent que la menace de perte d'un de ces stocks est en fait une menace pour l'espèce elle-même. Ces auteurs ajoutent aussi que la perte est encore plus grande si le stock présente des caractéristiques uniques. En plus de sa valeur biologique intrinsèque, la population du lac des Écorces pourrait aussi constituer un sujet intéressant pour l'étude du phénomène de décalage de la période normale de la fraie. Cette caractéristique a été observée chez d'autres Salmonidés, mais elle n'est pas encore expliquée et mériterait une attention de la part des chercheurs (Spangler et al. 1981; Svärdson 1988).

L'introduction du cisco de printemps dans un nouveau plan d'eau serait de nature à augmenter nos connaissances sur le phénomène du décalage de la période normale de fraie. En effet, Hénault et Fortin (1991) ont suggéré que la cause de la fraie de printemps pour le Cisco de lac serait de nature environnementale. Cette proposition était basée sur la condition allopatrique de la population, ainsi que sur une hypothèse suggérant que le développement normal des gonades serait entravé par des températures relativement élevées dans l'hypolimnion en été et en automne. Si la période de fraie printanière devait persister suite à une introduction dans un nouveau plan d'eau, on pourrait conclure à sa fixation génétique et étudier par la suite la possibilité d'utiliser cet écotype pour des ensemencements dans des réservoirs à fort marnage automnal et hivernal. En effet, l'utilisation du cisco de printemps comme espèce-fourrage pourrait constituer une mesure d'aménagement intéressante pour ce type de milieu (Pariseau et al. 1983).

Évaluation

Compte tenu de la dégradation de la qualité de l'habitat causée par l'eutrophisation au lac des Écorces, du déboisement accéléré des berges pour la villégiature et le développement résidentiel, et de l'unicité de cette population, nous estimons que le cisco de printemps du lac des Écorces devrait être considéré comme un écotype vulnérable au Canada.

Remerciements

Ce rapport de situation a pu être produit grâce aux travaux effectués au lac des Écorces, lesquels ont été subventionnés par le Ministère du Loisir, de la Chasse et de la Pêche du Québec, et par une bourse de la Société zoologique de Québec à Michel Hénault. Nous sommes également reconnaissants envers les membres du sous-comité des poissons et mammifères marins du CSEMDC, et MM. Pierre

Dumont et François Duchesneau qui ont aimablement révisé diverses versions du manuscrit.

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Accepted 15 August 1993

Status of the Flathead Catfish, *Pylodictis olivaris*, in Canada*

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Goodchild, Cheryl D. 1993. Status of the Flathead Catfish, *Pylodictis olivaris*, in Canada. Canadian Field-Naturalist 107(4): 410–416.

The Flathead Catfish, *Pylodictis olivaris*, is a large catfish only recently discovered in Canada. There have been only two reported captures both from Ontario; from Lake Erie in 1978 and the Thames River in 1989. Data are insufficient to determine if breeding populations exist in Canada or if its occurrence resulted from accidental introductions. Alternately, Flathead Catfish may be dispersing into southwestern Ontario due to more favourable climatic conditions. There is insufficient scientific information for assignment of COSEWIC status to this species.

La barbue à tête plate, *Pylodictis olivaris*, est un gros ictaluridé signalé récemment au Canada. Seules deux captures ont été enregistrées en Ontario; une dans le lac Érié en 1978 et l'autre dans la rivière Thames en 1989. Il n'y a aucune preuve de la présence de populations se reproduisant au Canada ou si sa présence est le résultat d'une introduction accidentelle. On croit que la barbue à tête plate pourrait envahir les eaux du sud-ouest ontarien à cause de réchauffement des températures. Il n'y a pas assez des informations scientifiques pour assigner un statut de CSEMDC à cette espèce.

Key Words: Flathead Catfish, Barbue à tête plate, *Pylodictis olivaris*, rare and endangered fishes.

The Flathead Catfish, *Pylodictis olivaris* (Rafinesque 1819), family Ictaluridae (Figure 1), is a relatively large catfish, first reported from Canadian waters in 1978 (Crossman and Leach 1979). This species is the only member of the monotypic genus *Pylodictis*, and is readily distinguished from other large catfish species, although small fish may resemble some of the madtoms that occur in the same habitats. According to Smith (1979), there is considerable individual variation but little geographic variation in Flathead Catfish. Its recent discovery in Canada, limited distribution, and apparent rarity make this a species of interest to COSEWIC and this report was prepared to summarize the status of the species for that organization.

Description

The Flathead Catfish can be distinguished from other ictalurids by the notable flattening of the head between the eyes; the longer projecting lower jaw; adipose fin large and separate from the caudal and forming a free flaplike lobe; relatively short anal fins with 14 to 17 rays; squarish caudal fin; elongate backward extensions on the premaxillary band of teeth; 50 to 51 vertebrae; saw-edged pelvic spine; and 9 pelvic fin rays.

Although colour is variable with size and habitat, it can usually be described as light brown to yellow mottled with dark brown or black. Mottling tends to disappear in larger adult specimens. The belly is yellowish to cream coloured and the caudal fin is darkly pigmented except for a distinct white patch along the dorsal border that evidently disappears with age. Other fins are similar in colour to adjacent parts of the body. Cross (1967) described specimens from clear water as the most darkly pigmented and those from muddy water as pale.

Sexual dimorphism is more pronounced in adults during the spawning season. Males have a single urogenital opening behind the anus unlike females which have two separate urinary and genital openings (Becker 1983).

Adult Flathead Catfish commonly attain up to one metre in length. The largest reported specimen from the Ohio River was 1350 mm long and weighed 37.2 kg (Trautman 1981). Most adults, however, are in the range of 356 to 1140 mm in length and 0.5 to 20.4 kg in weight.

Distribution

North America

The distribution (Figure 2) of *Pylodictis olivaris* includes the large rivers of the Mississippi, Missouri, Ohio and Gulf coast drainages. It is absent from Atlantic coastal streams (Glodek 1980; Cooper 1983).

Its range extends from North and South Dakota, through Iowa, Wisconsin and Illinois, Michigan tributaries of Lake Michigan, Ohio (rare in Lake Erie), and western Pennsylvania, south in the Mississippi Valley (West Virginia, Tennessee) to the Gulf slope of Alabama, through to northeast Mexico, north through Texas, Oklahoma (Arkansas River), to Kansas (Hubbs and Lagler 1967; Becker 1983).

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*Reviewed and approved by COSEWIC 15 April 1993, report accepted, insufficient scientific information for status designation.

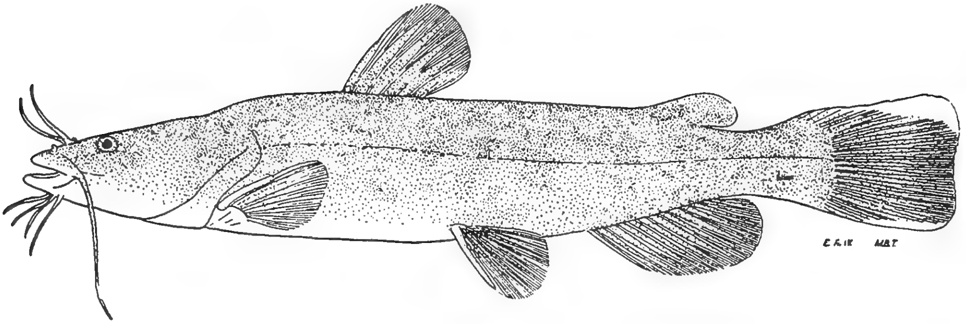

FIGURE 1. Drawing of the Flathead Catfish, *Pylodictis olivaris*, from Trautman (1981) by permission.

A "relict" colony has been recorded in the Ohio waters of Lake Erie since 1892 but only four specimens have been collected and preserved from the United States waters of the lake since 1938 (Cleveland Museum collection and Ohio State University Museum; OSUM 1866, 6664, 8467). A small population of Flathead Catfish also exists in the Huron River where they are taken yearly (Trautman 1981).

The Flathead Catfish has been sparingly introduced outside its native range. Cahn (1927) reports unsuccessful introductions of *Pylodictis olivaris* from the Mississippi River into Oconomowoc and Nagawicka lakes, in Wisconsin. Introductions into the Colorado River, Arizona, in 1962, however, appear to have been successful. As a result of the Arizona stocking, it is now established in the Highland Canal, Imperial County, California (Bottroff et al. 1969).

Canada

Pylodictis olivaris was unknown from Canadian waters until 1978 when it was captured in a commercial trapnet in Lake Erie, west of Point Pelee (Royal Ontario Museum, Toronto; ROM 34561). This constituted a range extension of 30 km north of previous records (Figures 3, 4), although Flathead Catfish are caught occasionally in the United States portion of Lake Erie (Crossman and Leach 1979).

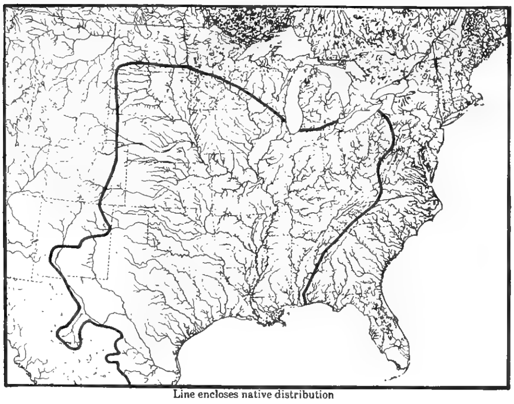

FIGURE 2. Limits of the North American distribution (shown by heavy line) of the Flathead Catfish, *Pylodictis olivaris*, from Glodek (1980).

Since that time, only one other specimen has been found in Canada. In the summer of 1989, a Flathead Catfish was caught by a commercial longline in the Thames River (Figure 4), 3.2 km (2 miles) from the mouth (ROM 57057). This is also a considerable range extension of this species in Canada.

The shallow waters of western Lake Erie and Lake St. Clair have contributed most of the records of freshwater fishes that have moved north into Canadian waters in the past 25 years (Crossman and Leach 1979). Temperature is believed to limit the geographic distribution of many freshwater fishes. An increase in temperature that would occur during a period of climatic warming, would result in a northward shift in the boundaries of species' ranges, altering fish communities in the Great Lakes area. Based on several ecological characteristics, Flathead Catfish were judged to have the potential to further invade the Great Lakes basin during a warming trend (Mandrak 1989).

If Flathead Catfish are becoming established in southwestern Ontario, they probably dispersed northward through Lake Erie or around the western periphery of Lake Erie from the Huron River, Ohio. The Huron River is due south of Point Pelee. Subsequently Flathead Catfish may have moved through western Lake Erie to the Detroit River, through Lake St. Clair and the Thames River.

Despite the intensive commercial fishery in that area, it is also possible that a small population similar to that found in southern Lake Erie has been established in the Point Pelee area but not previously reported.

Protection

No specific protection exists for Flathead Catfish in Canada except that generally provided by the Fish Habitat Sections of the federal Fisheries Act.

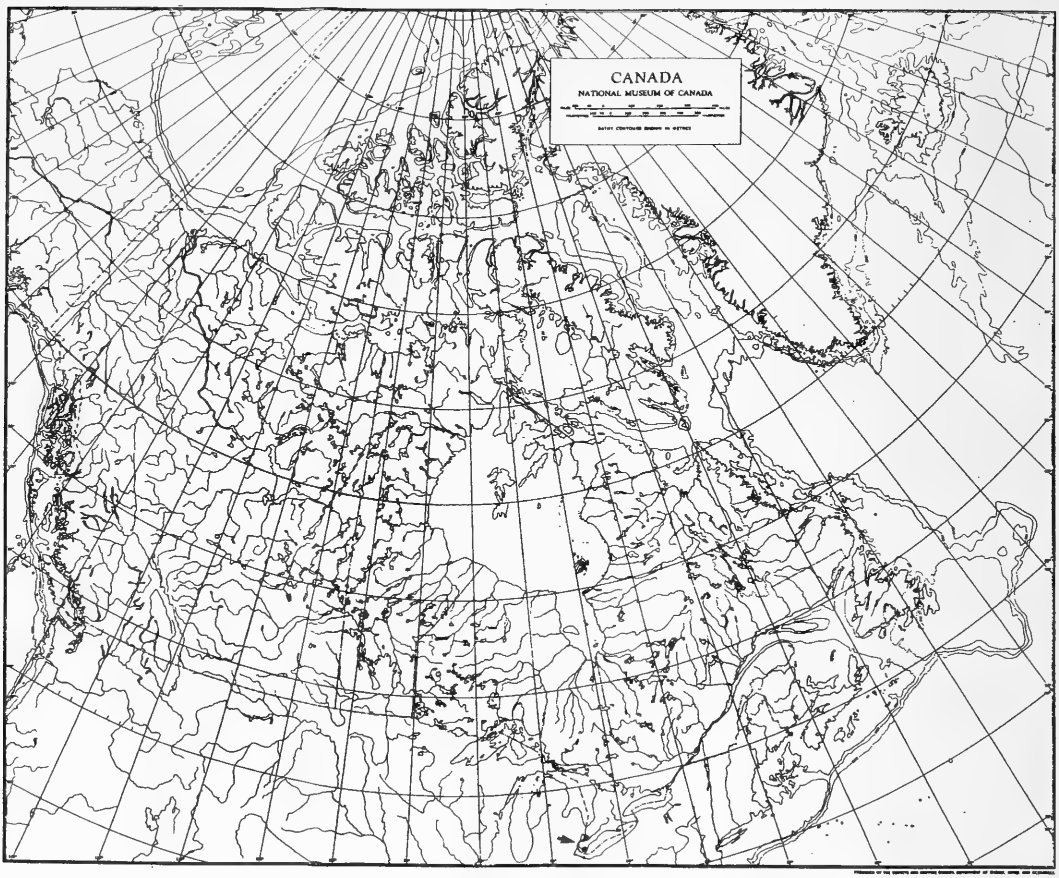

FIGURE 3. Canadian distribution of the Flathead Catfish, *Pylodictis olivaris*.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) indicated that the status of Flathead Catfish in Ontario was questionable (Campbell 1988, 1989, 1990).

In the United States, the Flathead Catfish is listed as rare in North Dakota and Michigan by Miller (1972) and of special concern in North Dakota by Johnson (1987). Throughout its overall range in the United States, it is not considered in any jeopardy (Deacon et al. 1979; Williams et al. 1989).

Population Size and Trends

No population estimates have been made for Flathead Catfish in Canada. Over much of its range in the United States, however, populations are stable with no apparent reduction in numbers. Although considered rare in North Dakota and Michigan, in other areas there is an indication that populations may be expanding slightly. Harlan and Speaker (1956) reported a noteworthy increase of populations in Iowa, especially those from the Iowa and Des Moines rivers. Also, in Missouri and Alabama, Flathead Catfish are common in large rivers. They are among the most abundant of the larger catfishes in the Missouri and Mississippi rivers (Smith-Vaniz 1968; Pflieger 1975). Populations of Flathead Catfish may be stable in Illinois, and are probably more prevalent than distribution records would indicate (Smith 1979).

Although Flathead Catfish are common in rivers of eastern Kansas, it is scarce in the western part of the state. Cross (1967) hypothesized that occurrence may vary in relation to weather cycles and stream levels. Throughout various localities in Wisconsin, Flathead Catfish are considered rare to common. Large Flathead Catfish are reported yearly from the Lake Michigan basin but represent less than one percent of the total catch of all species (Becker 1983). Commercial fishermen believe that population numbers are declining in the Mississippi River, probably a result of over-exploitation (Becker 1983).

Populations in the Muskingum River, Ohio appear to have remained constant from 1955 to 1980. However, there has been a drastic decrease in the

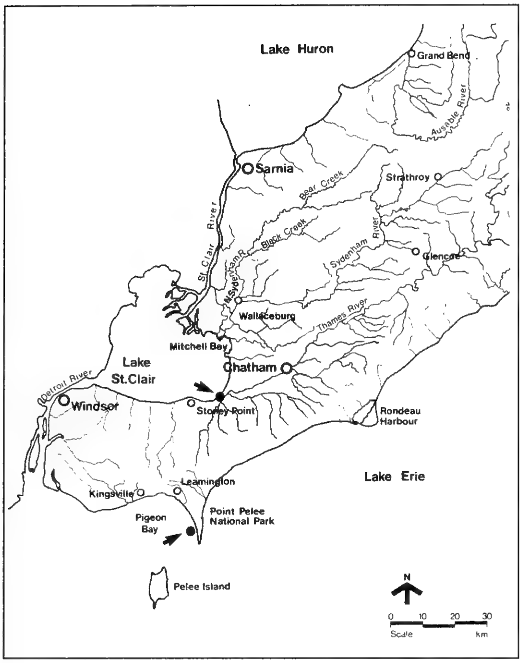

FIGURE 4. Location of capture of Flathead Catfish, *Pylodictis olivaris*, in southwestern Ontario, Canada.

number of Flathead Catfish in the Scioto River, Ohio, associated with a major increase in pollution since 1950. Yet, in the Lake Erie drainage, a small population has tenaciously remained in the Huron River, Ohio, despite severe pollution. Fishermen continue to catch a few individuals each year (Trautman 1981).

Habitat

Pylodictis olivaris is found in a variety of habitats. Flathead Catfish avoid rivers with high gradients or intermittent flow (Pflieger 1975). During the day, adults usually occupy deep pools with submerged cover in low-gradient portions of streams. When the Flathead Catfish is forced to inhabit extremely turbid streams, it is usually found over hard bottoms or where silt deposition is very low and where water is deeper than 15 m (Trautman 1981). In Kansas, Flathead Catfish are abundant in some turbid lakes as well as rivers, indicating an ability to reproduce under diverse habitat conditions (Cross 1967). Although dams and reservoirs are thought to be detrimental by some (Cooper 1983), others have suggested that the deep pools created by swirling current in front of small dams or bridge-supports are favoured locations (Harlan and Speaker 1956; Cross 1967).

Adult Flathead Catfish greater than 400 mm (16 inches) move in a nocturnal cyclic pattern to shallow riffles (depth often less than 1.5 m) to feed. They have been observed feeding at night in water so shallow that their dorsal fins were viewed above the water (Trautman 1981).

In contrast, young Flathead Catfish remain in riffle areas until they attain approximately 100 mm (four inches) in length (Cooper 1983). For example, in a study of habitat partitioning by stream larval fishes, Floyd et al. (1984) captured juvenile *Pylodictis olivaris* at only one station, described as a riffle-chute area, 50 cm deep, with gravel-rubble substrate.

Gradients recorded from two sites on the East River, West Virginia, where Flathead Catfish were collected were two of the lowest recorded in the stream (3.8 m/km and 1.9 m/km) compared to an average stream gradient of 8.56 m/km (Stauffer et al. 1975).

The optimum temperature range preferred by Flathead Catfish is 31.5 to 33.5°C (Becker 1983). Density of Flathead Catfish populations and year class strength increases where heated effluent are released into streams. Floyd et al. (1984) reported increased numbers of Flathead Catfish when water temperature increased accompanied by a decrease in stream flow.

General Biology

Reproductive Capability

In the United States, Flathead Catfish normally attain sexual maturity by three to six years of age but size at maturity may vary considerably. Minckley and Deacon (1959) suggest that maturity may be evident morphologically by the loss of the light patch at the tip of the upper lobe of the caudal fin. Males apparently reach maturity earlier and at smaller size; in three to five years at a length of from 375 to 470 mm (15 to 18 inches) total length (TL). Females attained maturity in four to six years at a length of 470 to 500 mm (18 to 20 inches) TL (Minckley and Deacon 1959). Data from Perry and Carver (1977) are similar except they found only five out of 15 females between 490 to 539 mm TL were mature.

Minckley and Deacon (1959) determined a 1:1 sex ratio for Flathead Catfish. Each breeding pair probably spawns only once per year (Cross 1967) and there is evidence that not all mature individuals spawn every year. In Oklahoma, Turner and Summerfelt (1971) estimated that 45% of sexually mature females probably did not spawn and eggs were resorbed.

Spawning occurs in June and July throughout the range of the Flathead Catfish. Cooper (1983) noted that Flathead Catfish spawned somewhat later than Channel Catfish, *Ictalurus punctatus*. Water temperatures of 22.2 to 23.9°C were recorded in Wisconsin during spawning (Becker 1983).

Pairs construct nests in depressions or natural cavities similar to those used by Channel Catfish (Cross 1967; Cooper 1983). Nest construction has been observed in the Dallas Aquarium and the Shedd Aquarium, Chicago. In both instances, the spawning pair used their tails and mouths to prepare a large (1.5 m) hollow in the sand down to bare gravel and rock (Breder and Rosen 1966).

During spawning the male swims with the female gently rubbing his belly on her back and sides and bringing his barbels into play. Each breeding pair comes to rest on the bottom, the caudal peduncle and caudal fin of the male encircling the female. The female expels the eggs in batches that are then fertilized by the male.

Both males and females actively participate in nest building but after the eggs are laid and fertilized the male provides parental care of the eggs and larvae. In observations made at the Dallas Aquarium, the male became intensely aggressive toward the female (Breder and Rosen 1966). Observations in Texas hatchery ponds indicate that while guarding eggs, males killed several spent females (Becker 1983).

The number of eggs laid by female Flathead Catfish is directly correlated with body size. An egg mass deposited in the Shedd Aquarium by a large female contained an estimated 100 000 eggs. Females weighing between 1.05 to 11.66 kg contained between 4076 to 31 579 eggs (Becker 1983). In another study of Flathead Catfish, the mean number of eggs per fish was calculated to be 13 250 (Summerville and Crawley 1970). Ripe eggs average 2.8 to 3.7 mm in diameter and eggs hatch in six to seven days at temperatures of 23.9 to 27.8°C (Minckley and Deacon 1959).

Once the young leave the nest they are found in shallow riffles beneath stones or other cover (Cross 1967). An estimated 162 000 larval Flathead Catfish ranging in size from 18 mm and 21 mm were collected in August from the New River, North Carolina (Potter et al. 1978).

Growth of Flathead Catfish is rapid. Young may reach a length of 50 to 150 mm (2 to 6 inches) in the first year with substantial gains each following year. Adults can grow to an immense size, specimens up to 45 kg (100 lb) have been reported, and may live 20 years or more (Harlan and Speaker 1956). In Missouri, only the Blue Catfish, *Ictalurus furcatus,* attains a greater size (Pflieger 1975).

Species Movement

Tagging studies indicate that Flathead Catfish tend to remain in one area. The following summarizes data gathered during tagging studies by Funk (1957): nearly half of the tagged Flathead Catfish were recaptured less than 1.6 km (1 mi) from point of initial capture, nearly all within 40 km (25 mi), and no fish were recovered more than 80 km (50 mi) from the point of release. Scott (1951) also found a high incidence of local recapture during population studies of tagged fish.

Ultrasonic transmitter studies of movements also confirmed a strong tendency for Flathead Catfish to return to the point of capture (Becker 1983). Two out of three fish implanted with transmitters and displaced between 1.3 to 2.7 km returned to their site of capture. There is some indication, however, that portions of larger populations are mobile. These transient fish may be wandering to find suitable prey. Large Flathead Catfish have been collected in open water, over sandbars in uncharacteristic areas that were apparently unsuitable (Minckley and Deacon 1959).

Behaviour/Adaptability

Both juvenile and adult Flathead Catfish are active and feed primarily at night. Collection during the night with an electric fish shocker yielded greater numbers of Flathead Catfish, a result presumably due to greater nocturnal than diurnal activity (Minckley and Deacon 1959).

Minckley and Deacon (1959) discuss food and feeding habits of Flathead Catfish in considerable detail. There is a change in preferred dietary items as the species grows. Young-of-the-year Flathead Catfish feed almost entirely on aquatic insects. Juveniles include crayfish and some fishes in their diet while adults are largely piscivorous. In Flathead Catfish measuring more than 250 mm, fishes occurred in 90% of stomachs examined, and comprised 70% of the estimated volume. In Wisconsin, large Channel Catfish and Northern Pike, *Esox lucius,* have been taken from stomachs of large Flathead Catfish (Becker 1983).

Hoffman (1967) lists the following parasites from *Pylodictis olivaris*: Protozoa, Trematoda, Cestoda, Nematoda, Acanthocephala, leeches. Over half of the specimens of Flathead Catfish examined for parasites by Minckley and Deacon (1959) contained cestodes and only three specimens contained nematodes. The Flathead Catfish is reportedly host to the glochidia of several freshwater mussels (Becker 1983).

Adult Flathead Catfish are not particularly vulnerable to predators because of their size and secretive habits; however, juvenile survival may be extremely low. Becker (1983) reports that only 0 to 1.5 % of fingerlings stocked in ponds with other fish species survived. Mortality was very high in ponds where large numbers of crayfish were present.

Limiting Factors

Water pollution may be one of the primary limiting factors for Flathead Catfish populations. Trautman (1981) correlates the drastic decline of populations in Ohio with concurrent increases in pollution. The effect of pollution may be in severely limiting the amount of available prey. The Lake St. Clair area of Ontario has been identified as one of the most obviously polluted water bodies in the Great Lakes region (Great Lakes Water Quality Board 1985).

Despite high fecundity, very low juvenile survival limits Flathead Catfish populations. Proportionally far fewer Flathead Catfish are caught by fishermen than other available species. Attempts to artificially propagate Flathead Catfish have been largely unsuccessful as a result of poor pond survival of fingerlings (Cross 1969; Becker 1983).

Flathead Catfish have a low tolerance for fluctuating water levels and they are usually absent from intermittent streams (Minckley and Deacon 1959). In addition, high gradient streams likely present barriers to the distribution of Flathead Catfish; the species is commonly found only in low gradient portions of streams.

Low water temperatures may be the primary limiting factor preventing further distribution of Flathead Catfish into northern Canadian waters. Therefore, the current warming trend may encourage dispersal further north and more captures may be made in Ontario.

Special Significance

In warm water environments, *Pylodictis olivaris* is a commercial species although not one of the most economically rewarding due to its low capture ratio. For instance, in commercial fishery statistics for the Mississippi River, the ratio of Flathead Catfish to Channel Catfish was 1:49 (Becker 1983). Flathead Catfish are difficult to capture using conventional techniques; however, specimens from Canada were caught in a commercial trapnet and by a commercial longline.

In some areas in the United States, Flathead Catfish is valued as a game species due to its large size and reportedly fine flavour. Some sports fishermen specialize in catching it by setline or bank pole, using live or freshly killed bait.

In Canada, the presence of *Pylodictis olivaris* may be indicative of the general trend toward species invading due to more favourable climatic conditions.

Evaluation

Only two specimens of *Pylodictis olivaris* have been reported from Ontario. There are insufficient data to determine if breeding populations of Flathead Catfish exist in Ontario, or if its occurrence resulted from accidental introductions or strays. It is also conceivable that Flathead Catfish are currently dispersing into southwestern Ontario from Lake Erie and the Huron River, in the United States. The possibility that it has been here all along but avoided capture or was misidentified, likely as Channel Catfish, also exists. For instance, very few individuals have been collected from the small populations in the United States portion of Lake Erie and in the Huron River, yet these populations have been known for a long time. If one assumes that museum specimens represent a minimum of 1% of those occurring in the wild, then at least a hundred Flathead Catfish may have occurred in Ontario in the past few years and it is possible that some spawned successfully (D. E. McAllister, Canadian Museum of Nature, Ottawa, Ontario; personal communication).

There is insufficient scientific information to determine if the Flathead Catfish fits into any COSEWIC designation based on present knowledge. The possibility that a small, viable population exists cannot be completely ignored. Therefore if any additional specimens are reported from Canada, the status of *Pylodictis olivaris* should be re-examined.

Acknowledgments

This report was funded by the Department of Fisheries and Oceans, Canada. Sincere thanks to R. R. Campbell, Canadian Wildlife Service for support during preparation of the manuscript.

The assistance of Erling Holm, Royal Ontario Museum; D. E. McAllister and Sylvie Laframboise, Canadian Museum of Nature; George E. Gale and Gareth A. Goodchild, Ontario Ministry of Natural Resources, in providing access to records and reports was invaluable.

Comments and suggestions provided by N. Mandrak, Department of Zoology, University of Toronto; as well as for those received through The COSEWIC Fish and Marine Mammals Subcommittee were greatly appreciated.

Lynne Bonenberger, Assistant Editor, Ohio State University Press, graciously granted permission to use the drawing of the Flathead Catfish, *Pylodictis olivaris*, from the book *Fishes of Ohio* by M. B. Trautman.

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Accepted 15 August 1993

Status of the Northern Madtom, *Noturus stigmosus*, in Canada*

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Goodchild, Cheryl D. 1993. Status of the Northern Madtom, *Noturus stigmosus*, in Canada. Canadian Field-Naturalist 107(4): 417–422.

The Northern Madtom, *Noturus stigmosus*, is a secretive fish naturally rare throughout its North American range. It is known in Canada from a single record from Lake St. Clair, Ontario. Northern Madtoms have been reported from nearby locations on the United States side of the Detroit River. Since species of madtoms are elusive and seldom captured except by specialized techniques, there is a slight possibility that a remnant indigenous population exists in Canada, or that one has been extirpated. There is insufficient scientific information for consideration of COSEWIC status designation.

Une seule capture du chat-fou du Nord, *Noturus stigmosus*, a été signalée au Canada. Le spécimen avait été capturé dans le lac Sainte-Claire, en Ontario, en 1963. Rien ne laisse supposer l'existence d'une population indigène au Canada, bien que le chat-fou du Nord soit une espèce cachottière naturellement rare dans son aire de répartition nord-américaine. Le CSEMDC n'a pas assez d'information scientifique pour le classifier.

Key Words: Northern Madtom, *Noturus stigmosus*, chat-fou du Nord, Ictalurids, rare and endangered species.

Noturus stigmosus Taylor 1969, the Northern Madtom (family Ictaluridae) has been reported from only one location in Canada since it was recognized as a distinct species by Taylor (1969). A member of the *Noturus furiosus* species group, it is most closely related to *Noturus munitus*, Frecklebelly Madtom, in geographic distribution and general morphology. It has been misidentified as several other species of *Noturus,* most notably: *Noturus eleutherus*, Mountain Madtom, because of presumed sexual dimorphism, and *Noturus furiosus*, the Carolina Madtom, particularly in Pennsylvania (Cooper 1983). In Canada, it could potentially be misidentified as *Noturus miurus*, the Brindled Madtom (Scott and Crossman 1973). Since the species is only known from a single record in Canada it is of interest to COSEWIC.

Description

The Northern Madtom (Figure 1) is very similar in colour, and almost identical in meristic characters, to the Brindled Madtom, the only species of madtom in Canada with which it is likely to be confused. Northern Madtoms should be watched for in collections of Brindled Madtom from southwestern Ontario (Scott and Crossman 1973). Presence of dark saddles or bars and very strong serrae (barbs) on pectoral spines are characters used to differentiate Brindled Madtoms from other madtoms in Canada. As these are characteristic of the Northern Madtom as well there is a possibility that specimens of *Noturus stigmosus* might be misidentified.

Northern Madtoms can be distinguished by the interrupted dark saddle-band on the caudal peduncle which does not extend upward to the distal edge of the adipose fin, prominent anterior serrae on the pectoral fin, 11 preoperculomandibular pores, and by the almost complete separation of the caudal and adipose fins.

Noturus stigmosus may attain a size of 130 mm (Trautman 1981), but specimens examined by Taylor (1969) did not exceed 100.5 mm standard length (SL). In live specimens the body is pinkish, yellowish or medium tan with markings varying from brown to dark grey or black. The Northern Madtom has four prominent saddle-bands, sides heavily mottled with clumps of dark pigment, abdomen dull white except a bridge of brown in front of pectoral fins, dorsal fin with a whitish margin and sub-distal dusky bar (absent only in small specimens), pectoral fins prominently spotted (usually), and caudal fin with brown bands (mid-caudal crescent most distinct).

In spawning males, the head flattens and broadens, cheeks bulge and the anterior half of the body turns dusky (Taylor 1969). External sexual differences, except in breeding males are slight. Plots of the number of pectoral spine serrae in *Noturus stigmosus* suggest a slight sexual difference, the female possibly averaging more. There is no evident variance in the number of fin rays.

Distribution

North America

The Northern Madtom occurs in freshwater drainages of east-central North America (Figure 2). Absent from the Atlantic slope, its range extends

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*Reviewed and approved by COSEWIC 15 April 1993, report accepted, insufficient scientific information for status designation.

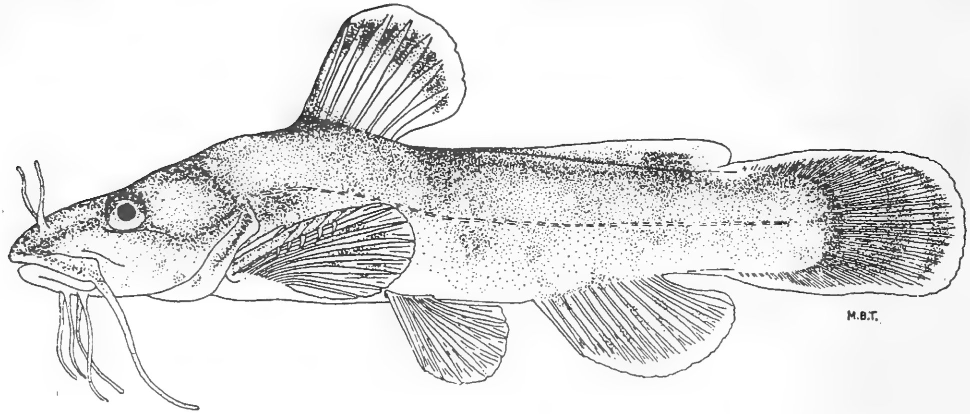

FIGURE 1. Drawing of the Northern Madtom, *Noturus stigmosus*, from Trautman (1981) by permission.

north from tributaries of the Mississippi River in Mississippi and Tennessee and throughout much of the Ohio River Basin in Kentucky, Indiana, the fringe of eastern Illinois, Ohio, and extreme western Pennsylvania. It is also present in the western Lake Erie drainage in Ohio, Indiana and Michigan, but absent from the Lake Michigan drainage basin (Taylor 1969; Rhode 1980).

Denoncourt et al. (1975) suggested that the Northern Madtom might be expected to occur in the Ohio River drainages of west Virginia (ie., Monongahela, Little Kanawha, lower and upper Kanawha, Guyandotte and Big Sandy Rivers). Subsequently, Stauffer et al. (1982) reported the presence of *Noturus stigmosus* in the Kanawha, Big Sandy, Licking, Kentucky, and Green drainages.

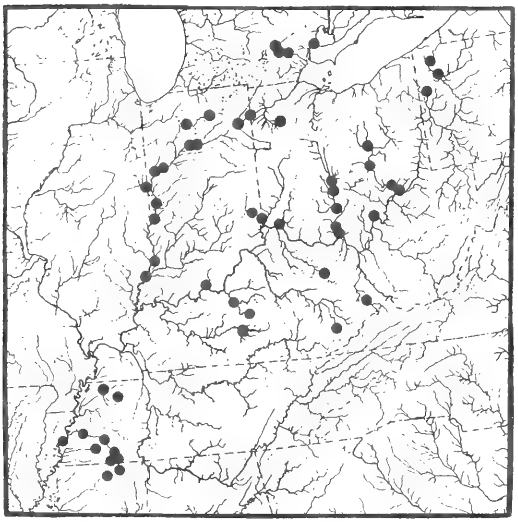

FIGURE 2. North American distribution of the Northern Madtom, *Noturus stigmosus* [from Rhode (1980)]. Lakes at top of map are Michigan (on the left) and Erie (on the right).

Never very common, the Northern Madtom occurs sporadically throughout its native range and is extremely rare in the fringe areas. For instance, in Illinois at the extreme western periphery of its range it is found only in the Vermillion River. It has also been collected near the Illinois border in the Wabash River, Indiana (Smith 1979). Similarly, its distribution is extremely restricted in the northwestern part of Pennsylvania (Cooper 1983).

The zoogeography of members of the genus *Noturus* is discussed comprehensively by Taylor (1969). The centre of their origin probably lies in the upland region of the east central United States. This general area was probably a refuge for several northern species during Pleistocene glaciation. At the end of the Wisconsin glacial period, the Northern Madtom may have used the Wabash River-Maumee Outlet to reach the lakes and streams in the Lake Erie Basin, but its absence from Lake Ontario, Lake Huron and Lake Michigan argue against this hypothesis. Alternatively, it may have been one of the species widely distributed in rivers and streams tributary to the Ohio River from where it simply migrated through minor drainage ways (Underhill 1986).

Canada

A single specimen of *Noturus stigmosus* has been reported from Canada (Figures 3, 4). It was taken from a trawl in Lake St. Clair, Ontario, near the origin of the Detroit River, 25 July 1963, by H. VanMeter [Ohio State University Museum; OSUM 14324 (Trautman 1981)]. The identity was verified by T. M. Cavender, Curator of Fishes, OSUM and by E. J. Crossman, Curator, Department of Ichthyology and Herpetology, Royal Ontario Museum (ROM) [E. J. Crossman; personal communication].

Northern Madtoms have been reported from the Detroit River in the United States [29 Oct 1903,

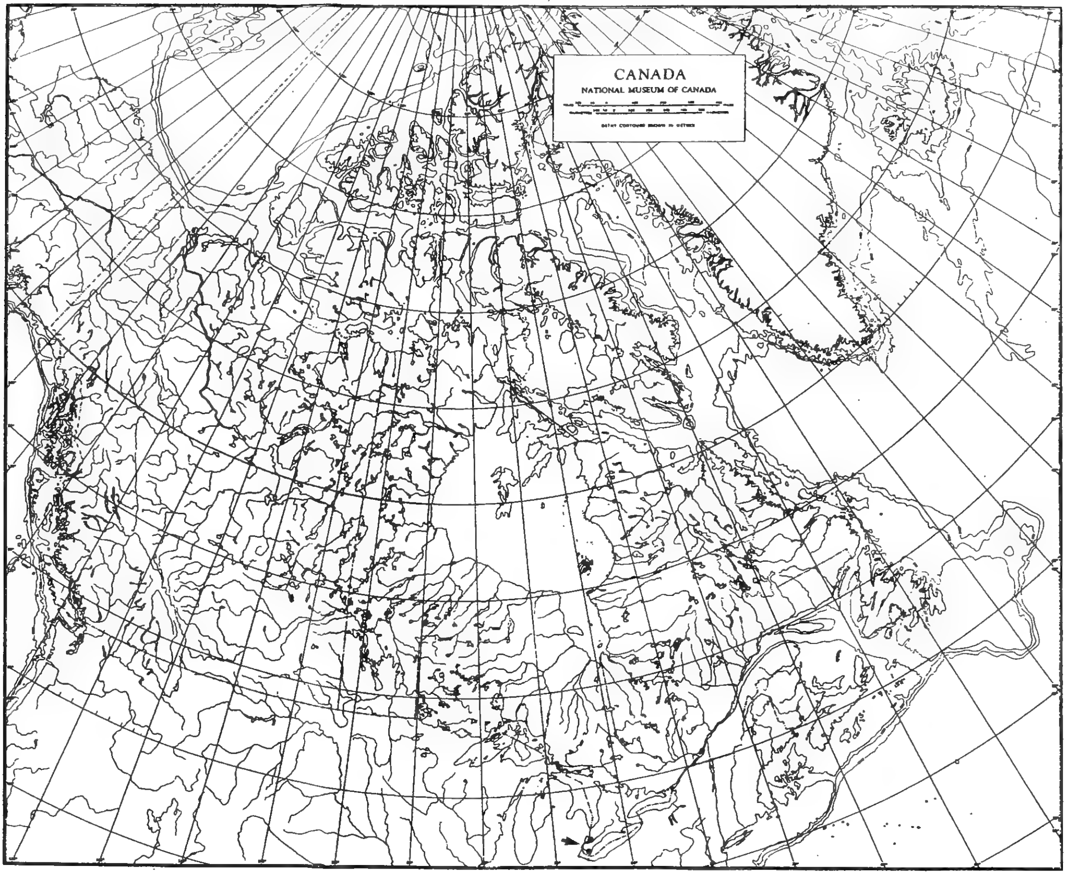

FIGURE 3. Canadian distribution of the Northern Madtom, *Noturus stigmosus.*

junction of Lake St. Clair and Detroit River, Wayne County (University of Michigan Museum of Zoology; UMMZ 132009)]. They are also frequently reported from the Huron River, Michigan. The Huron River flows into the Detroit River at its mouth in Lake Erie (Taylor 1969).

Based on collection records, the Detroit River, Lake St. Clair area is the northern limit of the distribution of *Noturus stigmosus.* Evidently the species has not been able to disperse further into Canadian waters, due to thermal or ecological barriers that have not yet been identified. It is also possible that small populations of Northern Madtoms have gone undetected (see Population Sizes and Trends). In recent times, the ecological degradation of the area may also be a barrier to further dispersal. In a study of potential invasion of the Great Lakes by various fish species during a period of climactic warming, the Northern Madtom was considered unlikely to invade based on a composite of ecological requirements (Mandrak 1989).

Protection

No specific protection exists in Canada other than that generally afforded by the habitat sections of the federal Fisheries Act.

Since 1988 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has suggested assigning a vulnerable (Ontario) status designation (Campbell 1988, 1989, 1990).

In the United States, it was listed as rare in Michigan (Miller 1972), of special concern in Kentucky, Mississippi, Tennessee and West Virginia, and legally protected in Michigan and Ohio (Johnson 1987).

Population Size and Trend

There is no evidence of a reproducing population of *Noturus stigmosus* in Canada. The only specimen that has been captured in Canadian waters was collected near the United States border, at the northern fringe of its range. However, little trawling had previously been done in the Detroit River area. In large streams, few people seine at night when Northern

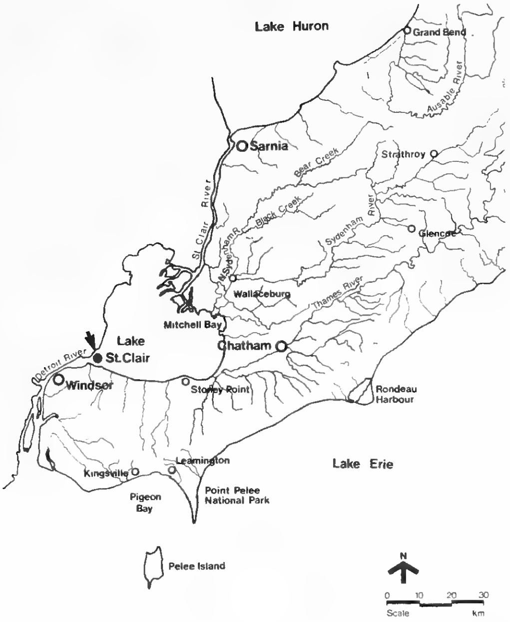

FIGURE 4. Location of capture of the Northern Madtom, *Noturus stigmosus*, in southwestern Ontario.

Madtom are active and more likely to be captured. Also, determining population levels of madtoms is complicated by their naturally secretive and nocturnal habits and their extremely disjunct distributions. Madtoms are infrequently captured except by intensive survey work using specialized sampling procedures such as piscicides, electrofishing or night seining (Taylor 1969; Bowen 1980).

Madtom populations are noted for wild fluctuations and varying spawning success from year to year (Trautman 1981; Bauer et al. 1983), complicating the assessment of their numbers and status. Therefore, it is not surprising that only one Northern Madtom has been caught to date and possibly premature to conclude that a viable population does not exist. The presence of the Margined Madtom, *Noturus insignis*, in Canada, was not recognized until the 1970s (Rubec and Coad 1974).

Small viable populations of Brindled Madtom, *Noturus miurus* are present in southwestern Ontario, but numbers are extremely low (McAllister et al. 1985). It is very similar in colour and meristic characters to the Northern Madtom and there is a possibility that collections of Brindled Madtom in Canada contain specimens of Northern Madtom (Scott and Crossman 1973). However, in a cursory look at collections of *Noturus miurus* in the Canadian Museum of Nature (NMC), none appeared to be *Noturus stigmosus* (D. E. McAllister, Canadian Museum of Nature, Ottawa, Ontario; personal communication).

In the United States, the few specimens of *Noturus stigmosus* that have been collected suggest a lack of congregation of individuals particularly as they are found scattered over considerable distances in a stream (Taylor 1969). In the fringe areas of its range in Illinois, Pennsylvania and Michigan, the Northern Madtom is rare or extremely rare (Cooper 1983; Smith 1979; Miller 1972).

The Northern Madtom has only been recognized as a distinct species since 1969, however Taylor (1969) demonstrated that many specimens of *Noturus stigmosus* were originally misidentified as other *Noturus* species. Collection records from Ohio indicate that Northern Madtom were never very abundant as even early collections contained very few specimens. Most populations in Ohio are even declining from those low numbers. Attempts have failed to take Northern Madtom in the turbid Maumee River system. Although it apparently still inhabits the Huron River of southeastern Michigan (Lake Erie tributary), none have been captured in the Great Lakes drainage of Ohio since 1950. Northern Madtom have been collected in only the following few localities in Ohio: Walhonding River, Lower Scioto River, Big Darby Creek and the Little Miami River (Trautman 1981).

Low and declining populations of Northern Madtom in Ohio and Michigan suggest that the species is disappearing from the northern part of its range and therefore it is unlikely to continue to be found in Canada. Either the species was never indigenous to Canada; its one reported capture a stray or accidental introduction or it existed in extremely low numbers and is now probably extirpated.

Habitat

It is surprising that *Noturus stigmosus* has been found in the Detroit River, Lake St. Clair area. This area has been identified as one of the most polluted water bodies in the Great Lakes region (Great Lakes Water Quality Board 1985) and Northern Madtom presumably have a low tolerance for heavily polluted water or high levels of siltation (Taylor 1969; Rhode 1980).

The Northern Madtom typically inhabits small and sometimes large rivers with sand, sandy mud, gravel or small pebble substrate. It is normally found in areas with little cover although it is sometimes found near fallen logs or debris. Northern Madtoms exhibit a preference for riffle areas or areas with moderate to swift current. Although somewhat tolerant of turbidity, they avoid extremely silty situations (Taylor 1969; Rohde 1980; Trautman 1981).

There is evidence for a north-south variation in size of streams and amount of current preferred by the Northern Madtom. In the southern part of its range, it occupies small rivers and creeks with moderate current. Further north in Illinois it is found in medium to large rivers with strong current, and finally in the northern areas in the Ohio Valley, Michigan and Pennsylvania it is typically collected in large streams with strong current and rocky riffles (Taylor 1969, Smith 1979).

Trautman (1981) suggests there is little competition between Northern Madtom and Brindled Madtom in streams they co-occupy because of different preferred habitat. Brindled Madtom live in pools below sluggish riffles in lowland streams with some current and in lakes over a soft bottom (Taylor 1969). Collections of Brindled Madtom from southwestern Ontario in the 1970s were from shallow lake environments and sluggish streams (McAllister et al. 1985). In contrast, in their discussion of the habitat of Brindled Madtom in Canada, Scott and Crossman (1973) described it as atypical of the species. Specimens were taken from fast-flowing streams with gravel bottoms, habitat more commonly characteristic of Northern Madtom.

The single location in Canada where Northern Madtom has been collected is not consistent with its habitat profile. In the Lake St. Clair location of capture, the specimen was taken in a trawl which suggests it was collected in deep lake water, habitat not associated with either Northern Madtom or Brindled Madtom.

General Biology

Reproductive Capability

Nothing is known about the reproductive capability of Northern Madtom in Canada. Taylor (1969) gives details of spawning in Michigan, where Northern Madtom spawn a little earlier than Brindled Madtom. Egg masses were found in gravel under stones or in open mouthed cans. Therefore, it is likely that any small cavity serves as a nest. Egg masses were found to contain from 61 to 141 eggs. Species of *Noturus* lay comparatively few eggs probably as a result of small body and large egg size.

Breeding Northern Madtom males have distinctive broadening and flattening of the head, swelling of lips, cheeks, back of head and predorsal region, and a general diffusion of body pigments. As with other madtom species, males guard fertilized eggs and developing young probably remain with them until the yolk sac is absorbed. All are probably solitary nightime spawners.

Time of spawning probably occurs in middle or late summer, in the north for madtom species. Egg masses were collected in middle and late July in Michigan.

In Ohio, young-of-the-year measured 25 to 58 mm (1.0 to 2.3 inches) in October; 36 to 64 mm (1.4 to 2.5 inches) at one year; and adults were usually 56 to 97 mm (2.2 to 3.8 inches). The largest specimen was 130 mm (5.2 inches) long (Trautman 1981).

Behaviour/Adaptability

Little is known about this rare, secretive fish but its food habits are presumably similar to other related *Noturus* species. No stomach contents have been examined but small insects and invertebrates are probably included in its diet (Cooper 1983) and feeding likely takes place at night.

There are no reported parasites for the Northern Madtom but it could be comparatively free of parasites as is the Brindled Madtom (Hoffman 1967). The degree of its tolerance to human disturbance is unknown.

Limiting Factors

It is difficult to speculate what factors are limiting the distribution of Northern Madtom in Canada, based on the single specimen captured. Apparently the distribution is primarily limited by temperature at the far northern fringe of its North American range where it is naturally rare. Low population numbers and sporadic populations suggest that the species has very specific ecological requirements and it is probably intolerant of habitat degradation.

Special Significance of the Species

Madtoms, genus *Noturus*, are small, secretive fish about which little is known. Many species such as the Northern Madtom have only recently been recognized as distinct species and there exists a fair amount of confusion with identification. The only species in Canada with which *Noturus stigmosus* could be confused is the Brindled Madtom, *Noturus miurus*. Brindled Madtom populations are in jeopardy and the species has been assigned a vulnerable status in Canada (Campbell 1988).

Noturus stigmosus is of interest because, like other madtoms, it is one of a few freshwater species that can inflict a painful (but not dangerous) wound from the pectoral spines and associated poison gland (Taylor 1969).

Northern Madtom are of no direct economic importance. However, all species should be valued with regard for the protection of the biodiversity of native ecosystems.

Evaluation

Southwestern Ontario is at the extreme northern fringe of the range of Northern Madtom and this species is naturally rare throughout its North American range. The single capture record provides inconclusive evidence that an indigenous population ever existed in Canada or if it has now been extirpated.

At present there is insufficient scientific evidence for an evaluation of the status of *Noturus stigmosus* in Canada. The possibility that the species has been extirpated or that a remnant population still exists cannot be completely discounted and therefore the status of the Northern Madtom should be re-examined if any further specimens are reported from Canada.

Acknowledgments

Financial support for this report was provided by Fisheries and Oceans Canada. Sincere thanks to R. R. Campbell, Canadian Wildlife Service, for support during preparation of the manuscript. The assistance of Erling Holm, Royal Ontario Museum; D. E. McAllister and Sylvie Laframboise, Canadian Museum of Nature; George E. Gale and Gareth A. Goodchild, Ontario Ministry of Natural Resources; in providing access to records and reports is gratefully acknowledged. Comments and suggestions provided by Nick Mandrak, Department of Zoology, University of Toronto as well as for those received through the COSEWIC Fish and Marine Mammals Subcommittee are greatly appreciated.

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Accepted 15 August 1993

Status of the Tessellated Darter, *Etheostoma olmstedi*, in Canada*

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Goodchild, Cheryl D. 1993. Status of the Tessellated Darter, *Etheostoma olmstedi*, in Canada. Canadian Field-Naturalist 107(4): 423–430.

The Tessellated Darter, *Etheostoma olmstedi* (Percidae), is a small darter which occurs in the St. Lawrence River, Ottawa River, Lake Ontario and their tributaries, in Canada. It is closely related to the Johnny Darter, *Etheostoma nigrum*, and separation between the two species, which exhibit considerable variation, is often difficult. Although in the United States there is very little overlap in the ranges of the two species, Canadian populations of Tessellated Darters often occur sympatrically with Johnny Darters. Tessellated Darters may occur more extensively than current data suggest since they have only recently been recognized in Canada. The Tessellated Darter is tolerant of a wide range of environmental conditions, is widespread in the United States, and is not at risk in Canada.

Le dard tesselé, *Etheostoma olmstedi* (Percidae), est un petit dard dont l'aire canadienne comprend le fleuve Saint-Laurent, la rivière des Outaouais, le lac Ontario et leurs tributaires. La distinction entre le dard tesselé et l'espèce apparentée, *Etheostoma nigrum*, le raseux-de-terre, n'est pas très nette et les deux espèces présentent des variations considérables. Les populations de ces deux espècessont largement sympatriques au Canada et surtout allopatriques aux États-Unis. Les dards tesselés peuvent avoir une aire de répartition plus étendue que ne le suggèrent les données car la reconnaissance de l'espèce au Canada est récente. Le dard tesselé tolère une gamme étendue de conditions ambiantes, et les populations canadiennes ne semblent pas menacées. L'espèce est largement répandue aux États-Unis.

Key Words: Tessellated Darter, *Etheostoma olmstedi*, dard tesselé, Percidae, rare and endangered fishes.

The Tessellated Darter, *Etheostoma olmstedi* Storer 1842 (Percidae: Etheostomatinae), is one of several species of darters which occur in Canada (Figure 1). It is very closely related to the Johnny Darter, *Etheostoma nigrum*. Both Tessellated Darters and Johnny Darters exhibit a highly polymorphic nature and a great number of similarities, resulting in a considerable amount of controversy regarding their taxonomic status.

Tessellated Darters and Johnny Darters are now generally considered to be separate species, based on samples examined from the United States (Stone 1947; Cole 1965, 1967, 1971). They are recognized as distinct species by the American Fisheries Society (AFS) [Robins et al. 1991].

Studies of variation in Canada using morphological and genetic data also have provided evidence to support the conclusion that *Etheostoma olmstedi* warrants specific status (McAllister et al. 1972; Chapleau and Pageau 1985). Specimens showing characteristics of both species (intermediates) were designated as interspecific hybrids not subspecific intergrades. Habitat selection may provide an isolating mechanism between the two forms enabling them to maintain discrete gene pools characteristic of two species. The actual degree of habitat overlap was determined by a study of Tessellated Darter and Johnny Darter in Quebec. Both species and a few hybrids were captured at only 24% of the stations (Chapleau and Pageau 1985). Gilbert (1961) has suggested that the tendency of two forms to occupy different habitats is more characteristic of species than subspecies.

Scott and Crossman (1973), however, felt that more thorough studies of meristic and morphometric characters were required to ascertain taxonomic status. The greatest difficulty in differentiating between the Tessellated Darter and the Johnny Darter is found in areas where their ranges overlap. Prince (1979) analyzed sympatrically occurring specimens from Virginia using electrophoresis and concluded that the Tessellated Darter should be considered a sub-species, *E. nigrum olmstedi*. Further study may yet confirm that the Tessellated Darter is a subspecies (E. Holm and N. Mandrak, Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto; personal communication).

Tessellated Darters can be reliably identified except for some isolated populations from eastern and central Quebec (Chapleau and Pageau 1985). Many of the specimens in Royal Ontario Museum (ROM) collections from Quebec, currently identified as *Etheostoma nigrum*, if re-examined might prove to be *Etheostoma olmstedi* or *E. nigrum olmstedi* (E. Holm; personal communication).

Tessellated Darters and Johnny Darters are both pale and sandy coloured with small X¯ or W¯ shaped

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*Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

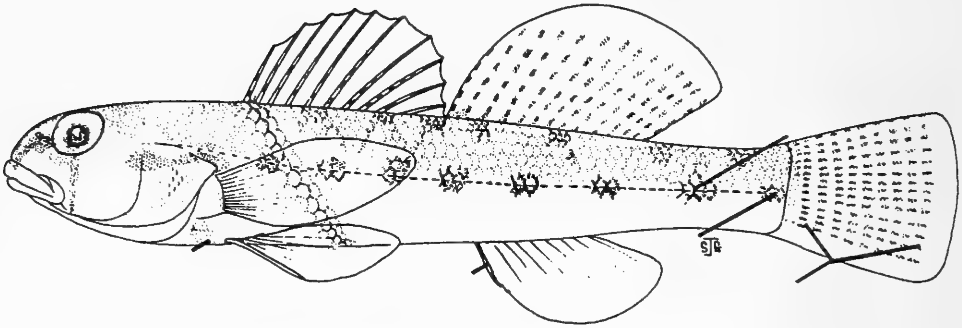

FIGURE 1. Drawing of the Tessellated Darter, *Etheostoma olmstedi*. (Courtesy D. E. McAllister, Canadian Museum of Nature).

markings on back and upper sides and both have only a single anal spine (McAllister and Coad 1974; Smith 1985). Richardson (1938) first mentioned morphological differences with respect to squamation of cheek and operculum in Canadian populations of Tessellated Darters and suggested that these should not be considered valuable diagnostic characters.

In Canada, the following characteristics are most useful in discriminating between the two species: Tessellated Darters have a scaled breast, 5 to 8 fine bars on the caudal fin, 9 to 11 X- and W-lateral marks on the side of body, infraorbital canal usually complete with 8 pores, preoperculomandibular canal with usually 10 or 11 pores, 12 to 15 soft dorsal rays, and a higher number of pectoral rays. By comparison, Johnny Darters have a scaleless breast, 3 to 4 bars on caudal fin, 6 or 7 X- and W-lateral marks, infraorbital canal usually interrupted with 4 plus 2 pores, preoperculomandibular canal usually has 9 pores, usually 10 to 12 soft dorsal rays (Scott and Crossman 1973; McAllister and Coad 1974; Smith 1985). The snout of the Tessellated Darter is described as subconical and slightly inclined whereas that of the Johnny Darter is rounded before the eyes and almost vertical at the mouth. Snout profile may not be a reliable identifying character. Kott and Humphreys (1978) found clinal variation in snout profiles of *Etheostoma nigrum*. *Etheostoma nigrum* from Lake Superior and northwestern Canada possess a subconical snout as present in *Etheostoma olmstedi*.

Distribution

North America

Etheostoma olmstedi is confined to Atlantic drainages of North America. The range of the Tessellated Darter extends from western Lake Ontario to the St. Lawrence drainage in southern Quebec, south through Lake Champlain and the Connecticut River and coastal streams from Massachussetts, Rhode Island, Connecticut, New York State (including Long Island), and Pennsylvania. South of the Susquehanna River it is known only from below the Fall Line[1] except in several drainages in Virginia, North and South Carolina (Cole 1967). Continuous distribution extends south to the Altamaha River in Georgia. There is also a disjunct population in the lower Oklawaha River of the St. Johns River system, Florida (Lee and McAllister 1980; Page 1983; Smith 1985).

Most of the range of the Tessellated Darter is discrete from the range of the Johnny Darter (Figures 2 and 3). In Pennsylvania, allopatry between the two species is particularly distinct; Johnny Darter only occurs in the western third of the state whereas the Tessellated Darter occurs only in the eastern part of the state (Cooper 1983). The two species are allopatric throughout much of New York State. There is a characteristic division of the distributions of the two species which occurs at the approximate longitude of the Gennesse River. Tessellated Darters do occur sympatrically in tributaries to Lake Ontario and the St. Lawrence River drainage of northern New York State as well as in parts of Virginia and North Carolina.

Canada

Defining the limits of *Etheostoma olmstedi* distribution in Canada is complicated because it has often been confused with *Etheostoma nigrum*. The range of the Tessellated Darter includes the St. Lawrence River, the Ottawa River, Lake Ontario and their trib-

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[1] The Fall Line is the line joining waterfalls on a number of approximately parallel rivers. In the eastern United States, it refers to the line running along a sharp increase of slope between the Atlantic Coastal Plain and the Appalachian Mountains.

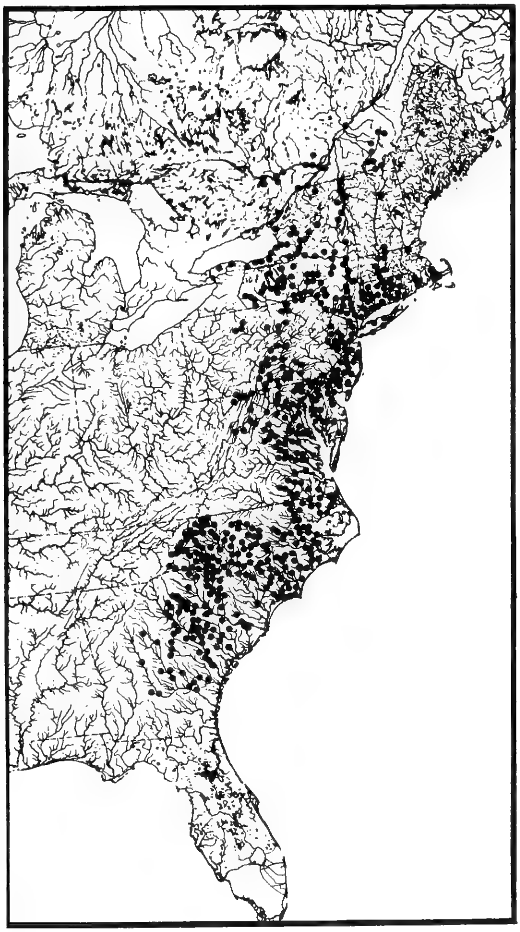

FIGURE 2. North American distribution of the Tessellated Darter, *Etheostoma olmstedi*, from Lee and McAllister (1980).

utaries (Figure 4). In Quebec and in the Lake Ontario region the ranges of the Tessellated Darter and Johnny Darter are largely sympatric but ecologically distinct.

From the St. Lawrence River, the Tessellated Darter has been reported as far northeast as Quebec City at St. Foy, Quebec (Lee and McAllister 1980) and recently just downstream from Quebec City, near the Boyer River, Bellechasse, Quebec [ROM 41917]. It has been collected extensively and evidently is well established in many of the tributaries to the St. Lawrence River in both Quebec and Ontario.

The Tessellated Darter extends upstream in the Ottawa River to Little Bay [Canadian Museum of Nature, Ottawa (NMC), NMC 80-0910]. Additionally, it is found in other larger rivers of the area such as the Mississippi and Rideau. McAllister and Coad (1974) suggest that it is usually replaced in smaller rivers of this area by the Johnny Darter. However, the Tessellated Darter has also been collected in several smaller streams tributary to the Ottawa River such as the Little Carp River, Cody Creek, Brassils Creek, and Dales Creek [NMC 68-2104, 68-0310, 58-0315; ROM 11154].

Until recently, *Etheostoma olmstedi* was not well known from the Canadian tributaries to Lake Ontario. Collections by the Ontario Ministry of Natural Resources (OMNR) and the ROM in the 1970s and 1980s can be summarized as follows: the Bay of Quinte and Prince Edward County, west to Salem Creek and Smithville Creek in Northumberland County, west to Bowmanville, Frenchman's Bay and the Toronto Harbour [ROM 04881, OMNRS64, ROM 35110, AOCMNR86, ROM 36533, AOCMNR86, AOCMNR87].

Furthermore, *E. olmstedi* has been collected west of Lake Ontario, in Forty Mile Creek, tributary to the south shore of Lake Ontario [ROM 37338 and 38037] and at the mouth of the Niagara River [ROM 38035]. Mandrak (1990) suggests that these scattered records from western Lake Ontario might be attributed to problems of identification and confusion with *Etheostoma nigrum*. However, recent discoveries of *Etheostoma olmstedi* throughout the Lake Ontario drainage are not surprising due to proximity to well established populations in both the St. Lawrence River and in southern tributaries to Lake Ontario in New York State.

Radforth (1944) considered the Tessellated Darter and the Johnny Darter to be subspecies and thought that they probably diverged when isolated during a glacial period; Tessellated Darter in the Atlantic coastal plain and Johnny Darter in the Mississippi Valley. Intergrades theoretically occur in areas where their ranges overlapped as they dispersed during the retreat of the glaciers.

The probable glacial refugia for Tessellated Darters and other coastal plain fishes were located on the exposed continental shelf in the area of southern Virginia or North Carolina. After the last glacial recession, between 14 500 years ago (ya) to 3500 ya when the Atlantic Ocean reached its present sea level, *Etheostoma olmstedi* and other species with low salinity tolerances dispersed through freshwater drainage connections and/or low salinity bridges. During the period when tilting of the continental shelf provided northward drainage of stream channels, it probably had access as far as the Delaware River. From there it may have gained access to the Hudson and Connecticut Rivers (Schmidt 1986).

The postglacial dispersal of the Tessellated Darter into Canada from its Atlantic coastal refugium may have occurred through the Champlain Valley and Mohawk glacial outlets

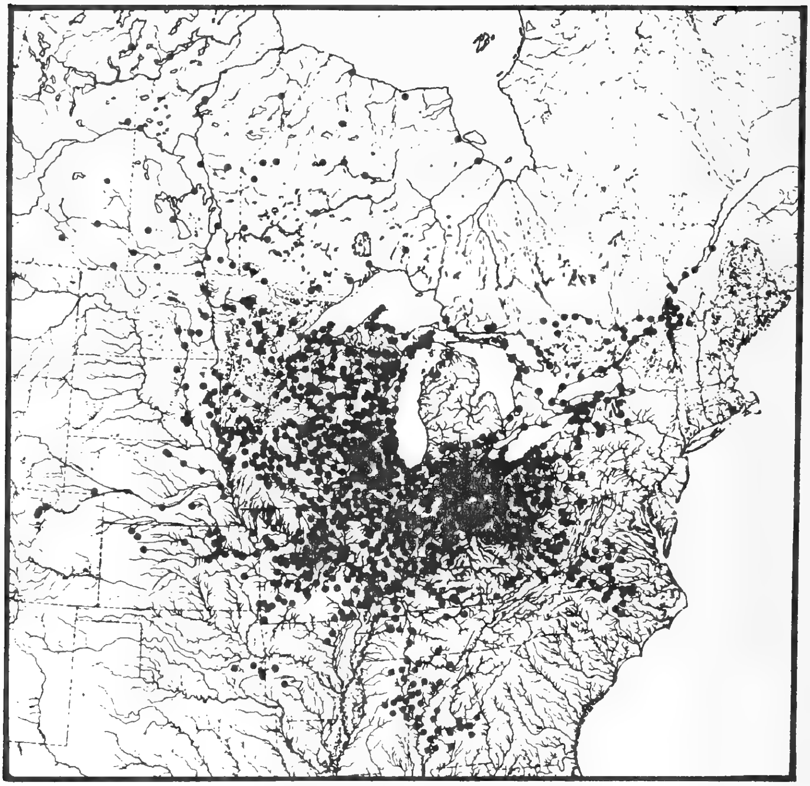

FIGURE 3. North American distribution of the Johnny Darter, *Etheostoma nigrum*, from Bruner (1980).

(Mandrak 1990). Its presence in Lake Champlain, the St. Lawrence and Ottawa River drainages suggest colonization after the separation of Lake Erie and Lake Ontario by Niagara Falls (12 500 ya) due to its absence from the Lake Erie basin (Underhill 1986; Mandrak 1990).

Protection

Etheostoma olmstedi receives no specific protection in Canada other than that generally afforded by the habitat sections of the federal Fisheries Act. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) suggested assigning a vulnerable status designation for *Etheostoma olmstedi* in Ontario pending a status review (Campbell 1988).

Etheostoma olmstedi and its close relative *Etheostoma nigrum* are not considered to be in jeopardy in North America (Miller 1972; Williams et al. 1989). However, the Southern Tessellated Darter, *Etheostoma olmstedi maculaticeps*, is protected in Florida (Johnson 1987).

Population Sizes and Trends

The Tessellated Darter is considered to be the most abundant darter in Atlantic Coast streams of the eastern United States (Cole 1967; Cooper 1983). For example, *Etheostoma olmstedi* averaged 25% of the total larval fish drift from 1978-1982, in the Susquehanna River (Gale and Mohr 1978).

Tsai (1972) noted a distinct seasonal population change. Population density rose sharply after arrival of the 0-year class, which gradually replaced I and II-year fish that died off during summer and fall. When the 0-year class was extremely small, and older year classes also reduced, the entire population almost disappeared in October.

Although studies have not been specifically conducted to assess populations in Canada, inferences based on collection records indicate no evidence of decline. Population trends are unknown because few specimens of *Etheostoma olmstedi* were collected and/or identified before 1970. Increased survey efforts coupled with improved recognition of the Tessellated Darter as a distinct species have resulted in greater numbers of specimens being collected in recent years. Tessellated Darter populations are well established in Canada.

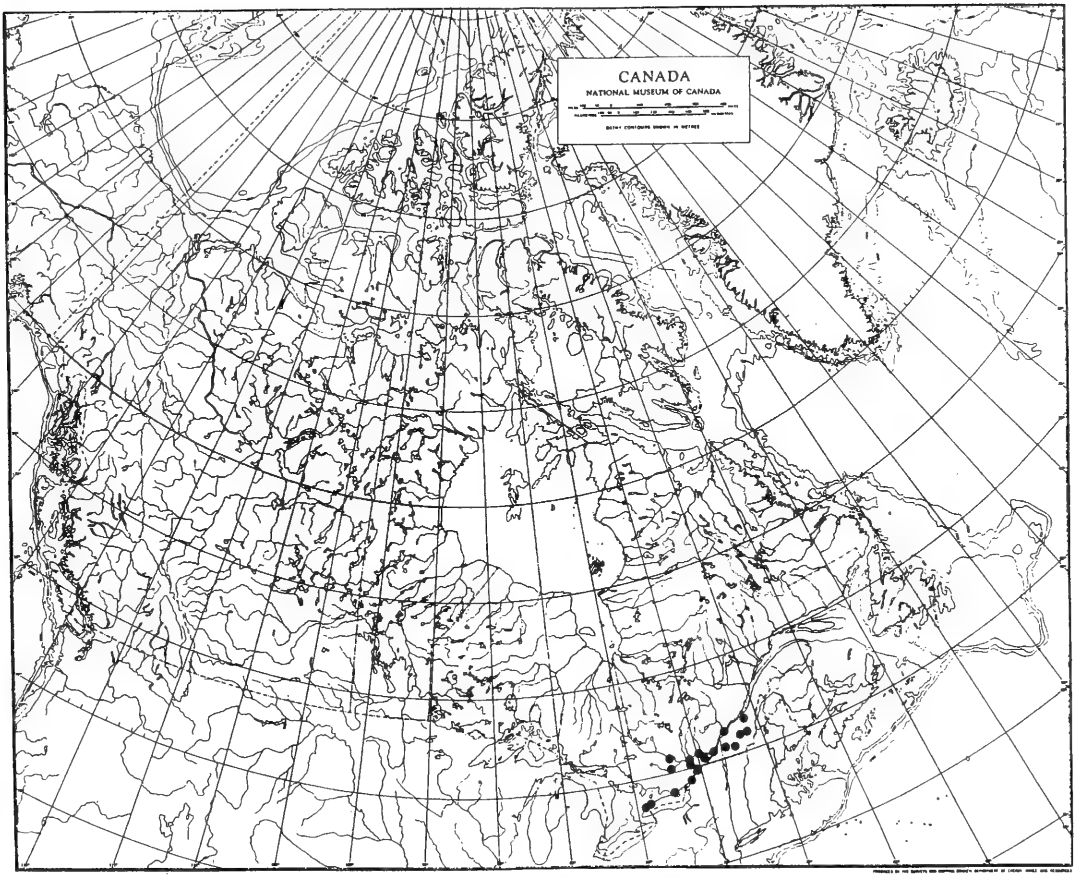

FIGURE 4. Canadian distribution of the Tessellated Darter, *Etheostoma olmstedi*.

Habitat

Tessellated Darters are tolerant of a wide range of habitat characteristics. Although commonly associated with pools of streams and low gradient rivers, they are also found in larger rivers and lakes (Lee and McAllister 1980; Chapleau and Pageau 1985). The Tessellated Darter occurs in both flowing and standing waters but it shows a preference for quieter areas with slow current or still water and avoids strong riffles (Smith 1985). The Tessellated Darter favours shallow areas with sand, mud or rubble substrate. It is occasionally found in brackish waters as well (Lee and McAllister 1980; Page 1983).

Physical conditions of streams occupied by study populations of Tessellated Darter in Maryland are as follows: width 6 to 15 m (20-50 feet), depth 13 cm (5 inches) in riffles to nearly a meter (3 feet) in pools (Tsai 1972). McAllister et al. (1972) located the Tessellated Darter in larger rivers (over 30 m wide) in the Ottawa area, in particular the Mississippi, Rideau, and Ottawa rivers. By contrast, the Johnny Darter is usually established in smaller streams (less than 15 m), although it also is found in the Ottawa River.

General Biology

Reproductive Capability

Studies designed to investigate the life history of the Tessellated Darter have not been conducted in Canada. The following information is gathered from published studies in the United States.

The Tessellated Darter spawns in late spring. The exact time is dependent upon a combination of suitable temperature and optimal photoperiod. Spawning has been reported from April to June throughout its range with yearly fluctuations due to varying water temperature (Raney and Lachner 1943; Lee and McAllister 1980; Page 1983). Tsai (1972) studied two isolated populations of Tessellated Darters in the Patuxent River, Maryland. He found spawning took place in May to late June at water temperatures of 12.5 to 14.5°C in cold reservoir tailwaters below the 110′ high Rocky Gorge Dam and in May to early June at water temperatures of 15.0 to 18.5°C in warmer sewage polluted water.

Tessellated Darters usually spawn during the day, but may occasionally spawn at night (Gale and Deutsch 1985). Spawning takes place in moderate current in water 30 to 61 cm deep, over marl, sand, gravel or stone. Males select and guard a small territory where they excavate nests. Eggs are laid on the underside of objects, usually stones, while both males and females are inverted. Females abandon the nest while males remain to guard and aerate the eggs. Usually only one male will nest under a single stone but Raney and Lachner (1943) observed as many as three using the same stone when nesting sites were scarce. Under crowded conditions the eggs also were laid on tops and sides of rocks. Subordinate males may guard eggs that have been fertilized by other conspecific males (Constantz 1979).

Tessellated Darters are fractional spawners and lay from 2 to 8 clutches, producing 97 to 1435 (mean = 158) eggs per pair (Gale and Deutsch 1985). Clutches range in size from 19 to 324 eggs (mean = 158). Nests containing nearly 2000 eggs were found in water ranging in depth from a few centimetres to riffles over 2 m near the channel. Large nests resulted from males spawning with different females over an extended period. One female was observed engaging in 50 spawning acts during a 2-hour period (Atz 1940). There is some indication that *Etheostoma olmstedi* spawns several times during a season unlike *Etheostoma nigrum* which spawns only once a season (Speare 1965).

Eggs are demersal and range in size from 1.5 to 1.6 mm in diameter. They are laid in a single layer 2 to 8 cm wide (Lee and McAllister 1980). Eggs hatched in 97 hours at 25 to 26°C (Gale and Deutsch 1985). Larval length at hatch is 5.1 mm or smaller. Eggs and larvae are depicted by Hardy (1978) and larval development is outlined by Rhode (1974).

Raney and Lachner (1943) determined that sex ratio varied geographically in the Tessellated Darter. It ranged from 1 (male):0.17 (females) in Oneida Lake, New York State to 1:2.9 in the Otter River, Massachusetts. In a study of the Tessellated Darter in Maryland, females consistently outnumbered males (Tsai 1972).

Maximum recorded adult size for the Tessellated Darters is 88 mm Standard Length (SL) for a four-year-old male (Raney and Lachner 1943). Usually size ranges between 44 to 62 mm Total Length (TL), although Tessellated Darter males are larger than females. For example, in the Susquehanna River, males ranged in size from 53 to 74 mm TL and females were 48 to 67 mm TL (Gale and Deutsch 1985). The following average size age classes (year in Roman numerals) were determined: for males I-34.9 mm, II-51.2 mm, III-58.0 mm; for females I-32.8 mm, II-43.4 mm, III-48.6 mm. In both sexes more than 60% of total growth takes place in the first year from the middle of June to the middle of October (Tsai 1972).

Sexual maturity is reached when Tessellated Darters attain the size of 40 mm TL (Lee and McAllister 1980). Faster growing individuals of both sexes can mature and breed at one year of age, and all are mature and breed by two years of age. Life expectancy is normally three years (maximum four), but relatively few live beyond one or two years (Raney and Lachner 1943). The following age composition was calculated from two differing habitats in Maryland: 93.0% I-year old, 6.6% II-year old, 0.4 % III-year old, in cold tailwaters; 82.3% I-year old, 17.3% II-year old, 0.4% III-year old, in sewage polluted water (Tsai 1972).

Species Movement

Young Tessellated Darters reportedly remain near the nest until reaching about 30 mm TL (Layzer and Reed 1978). Gale and Mohr (1978) observed large numbers of Tessellated Darter larvae drifting near the surface at night, in Pennsylvania. Movements of adult Tessellated Darters have not been recorded.

Behaviour/Adaptability

The diet of the Tessellated Darter consists mainly of zooplankton and midge larvae, with some algae and other small aquatic insects (Cooper 1983), although there appears to be a gradual shift to larger insects as the fish gets bigger (Smith 1985). Feeding occurs most frequently during daylight hours (Layzer and Reed 1978).

The Tessellated Darter is tolerant of low oxygen levels (Cooper 1983) and are able to thrive in moderately polluted water. The growth rate of Tessellated Darter in sewage polluted streams was faster than in cold tailwaters. Fecundity in populations from mildly polluted water was also greater presumably because of larger size and body weight attained (Tsai 1972).

Blacknose Dace, *Rhinichthys atratulus,* and Bluntnose Minnows, *Pimephales notatus,* are commonly associated with Tessellated Darters in warm water streams (Cooper 1983). In cold tailwater streams the dominant fishes associated with Tessellated Darters are White Suckers, *Catostomus commersoni,* and Pumpkinseed, *Lepomis gibbosus* (Tsai 1972).

Limiting Factors

Tsai (1972) determined that high levels of sewage pollution reduced growth rate of Tessellated Darters, although lower levels of sewage pollution enhanced fecundity and growth. Population density was substantially lower in polluted water and he observed the almost complete decimation of the population due to the serious reduction in numbers of all age groups. Any catastrophic event would have the potential to severely reduce or eliminate populations since the vast majority of Tessellated Darters only live to one or two years.

Predation by larger game species may play a substantial role in limiting the size of Tessellated Darter populations. Large population size and wide distribution make the Tessellated Darter quite valuable as forage for game species (Cooper 1983); in particular for young Walleye, *Stizostedion vitreum*, in lakes and for Smallmouth Bass, *Micropterus dolomieu*, in streams (Raney and Lachner 1942, 1943). Predation by game species may drastically reduce the numbers of larger darters under some conditions (Raney and Lachner 1943).

Special Significance of the Species

Etheostoma olmstedi is of no direct economic value due to its small size but is ecologically valuable as forage for many fish species such as Walleye and Smallmouth Bass.

Evaluation

Etheostoma olmstedi is able to tolerate a wide range of environmental conditions. In the United States, Tessellated Darters are considered to be among the most abundant of darter species. Populations are not in jeopardy, with the exception of the small disjunct population of the Southern Tessellated Darter, *E. o. maculaticeps*, in Florida.

Although throughout most of North America, Tessellated Darters and Johnny Darters are allopatric, within the range of the Tessellated Darter in Canada, both "species" often occur sympatrically. Actual collections of *Etheostoma olmstedi* from Canada, may be more extensive than indicated by the data since many specimens may be misidentified as *Etheostoma nigrum*, particularly in older collections from the St. Lawrence River system. Consequently, the apparent expansion of the range of Tessellated Darter in Canada is likely due to increased survey efforts combined with better recognition of the species. Population numbers derived from collection records are low but populations appear to be stable and secure. Therefore the Tessellated Darter does not require COSEWIC designation and protection at this time, however its status should be re-examined at regular intervals.

Acknowledgments

Funding was provided by the Department of Fisheries and Oceans Canada. Sincere thanks to R. R. Campbell, for support during preparation of the manuscript.

The assistance of Erling Holm, Royal Ontario Museum; D. E. McAllister and S. Laframboise, Canadian Museum of Nature; G. E. Gale and G. A. Goodchild, Ontario Ministry of Natural Resources; in providing access to records and reports was invaluable. D. E. McAllister granted permission to use the drawing of *Etheostoma olmstedi* from the book *Fishes of Canada's National Capital Region*.

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Accepted 15 August 1993

Status of the Channel Darter, *Percina copelandi*, in Canada*

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Goodchild, Cheryl D. 1994. Status of the Channel Darter, *Percina copelandi*, in Canada. Canadian Field-Naturalist 107(4): 431–439.

The Channel Darter is an indigenous species known from Lake Erie, the Detroit River and tributaries to the St. Lawrence River. Recently, it was collected from the Ottawa River, and tributaries to eastern Lake Ontario. Although the known distribution of the Channel Darter in Canada has expanded, the few individuals collected may indicate exceptionally small populations. In the United States, Channel Darter populations are declining and the species has been extirpated from many locations.

Le dard gris est un poisson indigène qui se retrouve dans le lac Érié, dans la rivière Détroit, et dans les tributaires du fleuve Saint-Laurent. Il a récemment été découvert dans la rivière des Outaouais et dans les affluents de la partie orientale du lac Ontario. Bien que la répartition canadienne connue du dard gris s'est etundue, le nombre relativement peu élevé d'individus collectionnés peut indiqué des populations exceptionnellement petites. Aux Etats-Unis, les populations de dard gris sont en déclin et l'espèce est disparue en maints endroits.

Key Words: Channel Darter, *Percina copelandi*, dard gris, Percidae, darters, rare and endangered fishes.

The Channel Darter, *Percina copelandi* (Jordan, 1877), is a small percid (subfamily Etheostomatinae), which has a disjunct distribution in central North America. *Percina copelandi* is polytypic and may include several species or subspecies (Kuehne and Barbour 1983). In particular, the Pearl River and Pascagoula River populations of Mississippi probably represent undescribed species (Gilbert and Burgess 1980). Populations from the Black Warrior, Cahaba and Coosa rivers of Alabama are isolated and likely also distinct. Specimens from Kansas also have variable characters and may represent another distinct form (Cross 1967).

Percina copelandi has probably always been rare in Canada. Very few individuals have been collected in southern Ontario despite intensive aquatic habitat inventory surveys [G.A. Goodchild, Aquatic Ecosystems Branch, Ontario Ministry of Natural Resources (OMNR), Peterborough, Ontario; personal communication]. This suggests that the Channel Darter probably occurs in very low numbers in the northern extent of its range and makes it a species of interest to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Description

The Channel Darter (Figure 1) resembles the more common Johnny Darter, *Etheostoma nigrum*, and the Tessellated Darter, *Etheostoma olmstedi*; but both have only one anal spine while the Channel Darter has two. The Channel Darter hybridizes with the Logperch, *Percina caprodes* (Trautman 1981). It is also possible to confuse *Percina copelandi* with *Percina shumardi*, the River Darter, in Canada. Adults, however, can be distinguished by spiny dorsal fin pigmentation. *Percina copelandi* is dark at the base and side of the dorsal fin unlike *Percina shumardi* which has a small anterior black spot and a large posterior black spot. Characters most useful in identifying the Channel Darter are: scales around caudal peduncle 18 or fewer; anal rays 7 to 10 usually 8 or 9; anal fin of adult male not elongated (Page 1983). *Percina copelandi* differs from other members of the genus by lacking a frenum or rarely having a narrow one (Kuehne and Barbour 1983).

The overall coloration of the Channel Darter is light sand or olive, with brown speckles on the back. Cross-shaped markings are usually scattered over the dorsal surface, while a dusky bar or spot may be present beneath the eye and extend forward onto the snout. The fins are clear or only lightly speckled and the ventral half of the body is whitish. The breeding male is dusky, and may develop intense darkening of the fins and body with an almost black head. Male Channel Darters may exhibit breeding tubercles (Kuehne and Barbour 1983).

Distribution

North America

Percina copelandi has a wide but discontinuous and extremely disjunct distribution in central North America west of the Appalachian Mountains

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* Report accepted by COSEWIC, threatened status approved 15 April 1993.

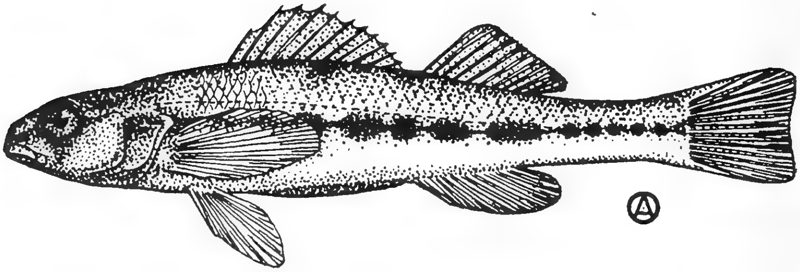

FIGURE 1. The Channel Darter, *Percina copelandi*, (41 mm; Ohio; ROM 6975). Drawing by A. Odum, from Scott and Crossman (1973) by permission.

(Figure 2). It occurs in the upper Mississippi River system in the Tennessee River drainage; to the northeast it is found throughout most of the Ohio River drainage, the Great Lakes basin (Lakes Huron, Erie, Ontario), and the St. Lawrence River drainage of Ontario, Quebec, New York and Vermont. A disjunct population occurs to the southwest in the Red, Ouachita, and Arkansas sys-

FIGURE 2. North American distribution of the Channel Darter, *Percina copelandi*, adapted from Gilbert and Burgess (1980).

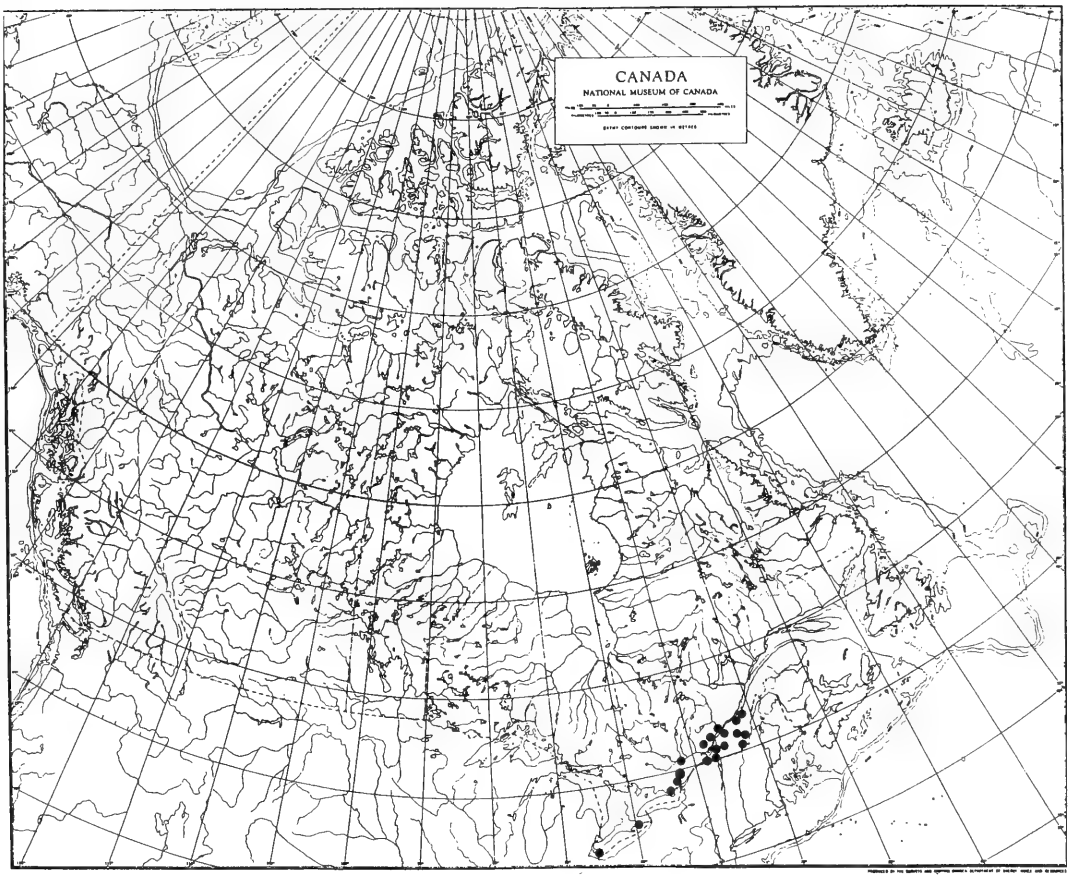

FIGURE 3. Canadian distribution of the Channel Darter, *Percina copelandi*.

tems of the Mississippi drainage, in Louisiana, Oklahoma, Arkasas, Kansas, and Missouri. Other isolated populations may represent undescribed species or sub-species such as those in the Mobile Bay basin, Alabama, and in Mississippi (Gilbert and Burgess 1980; Kuehne and Barbour 1983).

The Channel Darter may have had a more widely ranging preglacial distribution. Its native distribution in the United States is considered to include the lower and central Mississippi basin (Stauffer et al. 1982). Surprisingly, the Channel Darter is apparently absent from the main stem of the Mississippi River. The Mississippi River however was the most probable corridor through which the Channel Darter dispersed into most of its current range.

Percina copelandi is reported from the entire eastern margin of the lower peninsula of Michigan including Lake Huron (Hubbs and Lagler 1967). As such, it may represent one of the early migrants that utilized eastern connectives from the Wabash River to reach lakes and streams in the Erie basin. Alternatively, it may bave been widely distributed in rivers and streams tributary to the Ohio River and simply moved through minor drainageways (Underhill 1986).

In Missouri, populations are widely separated from the main range of the species to the northeast. These populations may date from a southwest movement of the species during one of the glacial advances of the Pleistocene Ice Age (Pflieger 1975). Fossil darters tentatively assigned to the extant species *Percina copelandi* have been found in a Pleistocene lake deposit in eastern South Dakota (Cavender 1986), further evidence of a wider preglacial distribution.

Canada

The Channel Darter is uncommon in Canada. But several extremely disjunct populations are established throughout the lower Great Lakes basin (Figure 3), from the Detroit River through Lake Erie, Lake Ontario tributaries and in tributaries of the St. Lawrence River.

Although reported from the United States along the entire eastern margin of the lower peninsula of Michigan (including Lake Huron) [Hubbs and Lagler 1967], there has been only one reported capture of the Channel Darter in the Detroit River area of Canada. In 1940, it was collected one mile south of Amherstburg, Essex County (Radforth 1944).

The first reported collections of Channel Darter along the north shores of Lake Erie were from Port Dover in the early 1940s [Royal Ontario Museum, Toronto; ROM 17924, 17970, 17971, 18292]. In the early 1950s, small collections were also taken at Port Burwell, Erieau, and Point Pelee from sand and gravel beaches (Scott 1955). Recent collections from Pelee Island in 1984, indicate that the species probably still occurs in this area [ROM 44024, 45578].

Other disjunct populations of the Channel Darter are found hundreds of kilometres to the east in Ontario. Two specimens of *Percina copelandi* were collected in 1948 from an unnamed creek near Moira Lake, Hastings County, Lake Ontario drainage [ROM 18471]. Subsequently, several additional collections of Channel Darters were obtained in Hastings County by the Ontario Ministry of Natural Resources (OMNR), in the Trent River [OMNRS64]; and the Skootamatta River [ROM 30556 and OMNRS64]. Collections of Channel Darter from Hastings County are approximately 50 km inland from the Bay of Quinte area of Lake Ontario.

A single specimen of *Percina copelandi* has also been collected in the Ottawa River near Quyon (McAllister and Coad 1974). Collections made at the reported Quyon site a year or two later, however, did not find additional specimens (D. E. McAllister, Canada Museum of Nature, Ottawa, Ontario; personal communication).

In the province of Quebec, many disjunct populations of *Percina copelandi* occur in tributaries to the St. Lawrence River. Early records of the Channel Darter in Quebec, were from the Lachine Rapids, Rivière Châteauguay, l'Anse-au-Sable, as well as from Rivières Nicolet and St François which flow into Lac Saint Pierre (Cuerrier et al. 1946). Mongeau et al. (1974) provide a distribution map for southern Quebec which indicates the presence of *Percina copelandi* in both north and south flowing tributaries to Lac Saint Pierre. These include Rivière Bayonne and Rivière du Chicot which flow south into Lac Saint Pierre and Rivière Noir and Rivière Yamaska which flow north into Lac Saint Pierre (Service d'Aménagement et d'Exploitation de la Faune 1979). Three additional specimens were collected in Rivière Yamaska in 1969 [ROM 27183] and many more have been collected by the Service de l'Aménagement et de l'Exploitation de la Faune in the Yamaska drainage basin (Mongeau 1979).

Information contained in provincial reports, collection records, and distribution maps recently provided to me indicate a far greater number of specimens of *Percina copelandi* have been collected in Quebec over a wider-ranging area than was previously assumed (Guy Tencia, Québec Ministère du Loisir, de la Chasse et de la Pêche, Charlesbourg, Québec and Michel Huot, Ministère du Loisir, de la Chasse et de la Pêche, Québec, Québec; personal communications).

Before 1945, collections of Channel Darter had been taken from tributaries to the St. Lawrence River from southwest of Montreal as far east as Quebec city. Collections have been reported from tributaries along the south shore of the St. Lawrence River from the Trout River, south west of Huntingdon and from Rivière aux Ormes and the Gentilly River in the Trois Rivières vicinity. Specimens have also been collected east of Quebec from Rivière du Sud and from locations in the most southeastern corner of the province of Quebec; Nigger River near Ayer's Cliff; Salmon Brook; and in a stream entering Lac Aylmer less than 60 km from the United States border (Wynne-Edwards 1945).

Since the early 1960s, the known range of *Percina copelandi* has been extended considerably eastward in Quebec. In 1964, specimens of *Percina copelandi* were collected in the Bécancour River at Bécancour (Paquet 1965). A small number of specimens were collected in 1971 from Rivière Henri and Rivière du Chêne, still farther north east approximately half the distance from Bécancour to Quebec city (G. Tencia; personal communication). Surprisingly large numbers of specimens have been collected in the St. Lawrence drainage substantially farther east than Quebec City, in the Montmagny area. Paquet (1965) reports collections of *Percina copelandi* taken from several stations along Rivière du Sud in 1964. In August 1980, a small number of specimens of Channel Darter were also collected from Rivière Bras St. Nicolas which flows into Rivière du Sud (G. Tencia; personal communication).

Since the mid 1970s, Channel Darters have been collected from several rivers in the vicinity of Montreal: from Rivière Chateauguay, Rivière aux Outaides-Est, Rivière aux Anglais, and Rivière à la Truite (south east of the city); Rivière Noire and Rivière Richelieu (east of the city), and on the north side of the St. Lawrence from Rivière L'Assomtion and Rivière Ouareau north east of Montréal (Service d'Aménagement et d'Exploitation de la Faune 1979).

Recent collections taken from the southeast corner of the province of Quebec near the United States border, further enhance our knowledge of the distribution of Channel Darter. In 1977, collections were made in Rivière Au Bluets, Frontenac County, 3 km west of Courcelles [NMC 77-0752] and in a tributary of Rivière au Salmon, Compton County, 5 km north of Gould [NMC 77-0829].

The extensive but disjunct distribution of the Channel Darter in Canada suggests the species may have been even more extensive in the past. *Percina copelandi* probably survived glaciation in a Mississippian refugium, utilizing the Fort Wayne outlet to gain access to southern Ontario (Mandrak 1990). Bailey and Smith (1981) suggest that it may have used glacial Lake Maumee (which existed in the Erie and lower Huron basins), as a refuge and access route for dispersal into the Lake Ontario watershed. Its occurrence in the Lake Huron basin and the St. Lawrence lowland indicates early migration (Underhill 1986).

Protection

No specific protection exists in Canada for the Channel Darter, although the fish habitat sections of the federal *Fisheries Act* do provide general protection. In the United States, *Percina copelandi* is listed as rare in Kentucky and West Virginia by Miller (1972). It is also designated as "of special concern" in Kentucky and Quebec, and protected in Michigan and Ohio (Johnson 1987).

Population Sizes and Trends

No population studies have been done for the Channel Darter in North America. However, evidence from its changing distribution and fewer numbers collected supports the conclusion that the Channel Darter has undergone considerable reduction throughout its range.

In the northern tributaries to the Ohio River in Indiana, Ohio, and Pennsylvania, Channel Darter populations are substantially reduced (Trautman 1981). None had been collected in the Ohio River, from 1978 until recently when adult and larval specimens were collected in both the upper and middle reaches of the Ohio River (Reash 1991). The species may have some ability to re-populate areas when water quality improves.

The Channel Darter is apparently absent above the confluence of the Ohio River in the northwestern Mississippi River drainage. No specimens have been collected from the Maumee River, Ohio, since 1922. Small populations once present in the Muskingum River, Ohio, are probably extirpated because none have been collected in this location in more than 40 years (Hocutt et al. 1986). Also, it is likely extirpated from the Little Miami River (Burr and Page 1986). Hocutt et al. (1986) suggest that *Percina copelandi* probably once occupied Illinois but have been extirpated. Populations around Bass Island, Lake Erie, are also declining. Channel Darters were taken annually in considerable numbers before 1954, but none have been collected since 1972 (Trautman 1981). In Pennsylvania, besides localized populations in the Allegheny River and in Lake Erie, Channel Darters are considered rare (Cooper 1983).

In Mississippi, Channel Darters are extremely rare, bordering on extirpation. In Missouri, they occur only in the Spring River and its large tributaries of the southwestern Ozarks (Pflieger 1975). They are also rare throughout the lower Tennessee River system and probably have been extirpated from the system in Kentucky (Gilbert and Burgess 1980).

Similarly, low numbers are also evident in the disjunct southwest populations of Channel Darter. It is not abundant anywhere in Kansas where it inhabits the larger tributaries of the Arkansas River (Cross 1967). It is, however, widespread in the Arkansas and Red River drainages of Oklahoma and Arkansas (Cross et al. 1986).

Percina copelandi has probably always been rare in Canada, based on collection records. Very few individuals have been collected in southern Ontario despite intensive aquatic habitat inventory surveys in the 1970s and early 1980s (G. A. Goodchild; personal communication). This suggests that the Channel Darter probably occurs in very low numbers in the northern extent of its range. Collection data from the province of Quebec, recently provided to me, indicates that the species is apparently more widespread there then would be expected based on its scarcity elsewhere in North America.

Due to the apparent difficulty in collecting Channel Darters, assumptions regarding the status of populations of Channel Darter should be viewed cautiously. More intensive surveys occasionally reveal the presence of Channel Darter in new locations. For instance, the Channel Darter is included on the checklist of the fishes of West Virginia (Denoncourt et al. 1975). Also, it was recently added to the faunal list from the Little Kanawtha River, West Virginia, indicating populations may be more extensive than previously believed (Hocutt et al. 1986). Similarly, recent collections expanding the range of Channel Darter in Ontario, and Quebec may indicate that populations are increasing or that its distribution is expanding. Alternatively, these collections may merely reflect increased survey efforts.

Based on the scant numbers of individuals captured, populations of the Channel Darter are extremely limited throughout North America. This is particularly true of populations in Canada.

Habitat

The Channel Darter is a benthic species found most commonly over sand and gravel shoals of larger rivers or beaches where the associated current is slow (Smith 1985; Scott and Crossman 1973). In rivers, the Channel Darter inhabits deeper pools or sluggish riffles with sufficient current to create a silt-free gravel substrate (Pflieger 1975). Although frequently associated with larger river systems, they may inhabit smaller channels and tributaries (Branson 1967). They are seldom found in moderate or fast flowing riffles except during spawning when there is a notable migration to these areas.

Characteristic habitat of Channel Darters from streams in Ontario, as summarized from OMNR field collection records, is rock, sand and rubble bottom in water over a metre deep. Actual current rates are not recorded, however the presence of aquatic vegetation at these sites indicates slow to sluggish flow. Trautman (1981) suggests that Channel Darters occupy water over a metre in depth during daytime, but very shallow areas are favoured at night.

In Canada, Channel Darters are also found in lakes over wave-washed sand and gravel beaches. This is the typical habitat associated with collections of Channel Darters taken along the north shore of Lake Erie.

General Biology

Reproductive Capability

Spawning occurs in spring or early summer. In Kansas, many specimens obtained in late April or early May exhibited breeding coloration and females were distended by eggs. By June, specimens lack spawning colours and females are spent (Cross 1967). In early June, 1929, a 7 mm larval specimen was collected from Lake Erie, Ontario, indicating spawning had taken place in May (Fish 1932). Greeley (1929) reported ripe males in riffle areas in mid-June. In Michigan, spawning occurred in July at water temperatures of approximately 21°C (Winn 1953). Water temperature probably determines time of spawning.

Channel Darters presumably undergo a short migration to the spawning grounds (Cooper 1983). They may move upstream where scattered rubble affords spawning sites (Kuehne and Barbour 1986). Adults seek streams with moderate to fast current to spawn, probably accounting for the scanty numbers taken in lake tows during the breeding season (Fish 1932).

Winn (1953) provides the most comprehensive discussion of the breeding habits of the Channel Darter. The spawning site described is inside a bend of the Cheboygan River below a Power Dam and Pulp Mill, approximately 1.5 km (1 mile) above its mouth in Lake Huron. At the spawning site the river is 35 m (100 feet) wide, 35 to 175 cm (1.5 to 5 feet) deep, and characterized by a swift current. The Channel Darter may prefer water less than 175 cm (5 feet) deep or may be avoiding competition for spawning sites with *Etheostoma nigrum* which were common in deeper pools.

Fairly rapid current is evidently a requirement for successful spawning of Channel Darters. Breeding activity ceased when flow temporarily slowed in the river. This suggests there is a minimum threshold for water movement below which spawning is inhibited. Breeding adults placed in aquaria with simulated natural conditions but with a slow current, also failed to spawn (Winn 1953).

Males establish territories slightly less than one metre in diameter centred about a large rock in the current. Territories are actively defended against conspecific males but not from males of *Percina caprodes*. Spawning is communal with many territories in a small area. Females move through the territories successively spawning with many males. During an individual spawning act a male will direct a ripe female to an area of gravel behind a rock where the female partly buries herself in gravel.

There is no parental care of eggs. Approximately 4 to 10 eggs are deposited during each spawning act. Total number of eggs deposited by a single female has not been determined but egg counts from one- to two-year-old females range from 350 to more than 700 (Page 1983).

Eggs are approximately 1.4 mm in diameter, but there is wide variation in size. The eggs are slightly adhesive, demersal and oddly-shaped. They are partially transparent with an orange oil globule. Fish (1932) provides a detailed description of the morphology of a 6.1 mm TL larval specimen.

Sexual dimorphism and the striking breeding colours are described by Winn (1953). Males apparently grow to a larger size than females. Young-of-the-year were reportedly 20 to 38 mm in length by October and the largest specimen reported from Ohio was 64 mm long (Trautman 1981). The largest specimen indicated by Scott and Crossman (1973) was 61 mm TL, and the range in size of specimens collected in Canadian waters is 34 to 61 mm TL.

Species Movement

Due to its scarcity and small size, the Channel Darter has not been extensively studied and, therefore, little is known about its movements. There is a brief migration to spawning grounds in the spring or early summer (Cooper 1983). Since there is no parental care of eggs and young, adults probably remain in the spawning area for a very short time.

Seasonal movements were observed by Branson (1967), in Oklahoma. The Channel Darter was found to overwinter in quiet, leaf and debris filled backwaters, which it departed for the main channel during April and May.

Behaviour/Adaptability

Percina copelandi is frequently found in association with the Logperch, *Percina caprodes* and the Mimic Shiner, *Notropis volucellus* (Cooper 1983).

The Channel Darter is a benthic feeder. Evidently, there is little difference in the diet of young and adults. Turner (1921) analyzed stomach contents of the Channel Darter from the Bass Islands regions of Lake Erie. He found that the species primarily fed upon mayfly and midge larvae but also ingested large amounts of algae and detritus. Winn (1953) also found that the diet was principally composed of benthos, chiefly chironomid and trichopteran larvae. On the other hand, in Kentucky, the predominant diet consisted of microcrustacea (copepods and cladocerans) with chironomids being second in importance in both volume and frequency (Cross 1967).

The incidence of parasitism of the Channel Darter in western Lake Erie may be increasing. Only 8 out of 34 specimens examined by Bangham and Hunter (1939) contained parasites (23%). However, 25 were infected when Bangham (1972) later examined the parasites of 33 specimens (76%). Parasitized individuals of Channel Darter contained trematodes, cestodes and nematodes (Bangham and Hunter 1939; Hoffman 1967; Margolis and Arthur 1979).

Limiting Factors

The communal spawning behaviour of female *Percina copelandi* may limit the number of eggs deposited. Females were observed depositing less than 10 eggs during each spawning act. To lay all her eggs, a female must spawn repeatedly with many males and this opportunity may not always exist. During periods when stream flow fluctuates below the minimum required for spawning, the Channel Darter terminates spawning activity, resulting in fewer eggs being deposited. If periods of optimum temperature were also brief then there would likely be very low spawning success, resulting in decreased year class strength.

Also, critical to spawning success is access to areas with moderate to rapid flow. During the breeding season, Channel Darters probably make short migrations from the sand and gravel shoals with slow current with which they are normally associated, to areas with more rapid current (Cooper 1983). Therefore, any barriers preventing movement to preferred breeding habitat would limit reproduction. Competition for spawning territory from other darters such as *Percina caprodes* and *Etheostoma nigrum* also may play a role in limiting Channel Darter populations.

Trautman (1981) suggests that populations probably once existed on the extensive sand and gravel bars in the Ohio River before impoundments and the resultant increase in siltation and turbidity. As a benthic feeder, heavy siltation may affect both its ability to feed and the availability of desired larval prey. Since the Channel Darter probably dispersed through the Mississippi River, its absence from the main stem is noteworthy. Human intervention in the Mississippi River has caused such drastic environmental changes and resulting habitat alteration and degradation that it may have been rendered unsuitable for Channel Darters.

In southwestern Ontario, extensive sedimentation has occurred due to poor agricultural practices and urban land use (Francis et al. 1979). This has caused a loss of optimal habitat for *Percina copelandi* which may have extremely detrimental effects on populations already very low in numbers.

Channel Darters are associated with moderate current over sandy substrate, however, the conditions required to create such habitats may occur only at intervals. This may result in variation in reproductive success and changes in abundance from year to year. For instance, in the Tennessee River drainage, where stream conditions fluctuate, it is often difficult to demonstrate the presence of Channel Darter during some years due to low population density (Starnes et al. 1977).

Increasing susceptibility to parasitism (Bangham 1972) may also be an indicator of the relative poor health of existing populations and may contribute to the species' inability compete.

Special Significance of the Species

Percina copelandi is one of several small darter species that occur in Canada. There is little interest in this species by either the public or fisheries managers. Its role in our aquatic environment is not well understood, a direct result of its scarcity and small size. Although the Channel Darter is of no direct economic importance, all indigenous species should be protected to conserve the biodiversity of aquatic ecosystems.

Evaluation

The Channel Darter occurs in very low numbers throughout its range and particularly in the north. In southern Ontario, fewer than 100 specimens have been collected, although higher numbers have been captured in the province of Quebec. Recent collections expanding the known range of the Channel Darter in Ontario and Quebec likely result from increased survey efforts and are probably not indicative of increasing populations.

Populations of Channel Darters in the United States are also undergoing considerable reduction in numbers and are being extirpated from many locations where they were formerly well established. The biology of the Channel Darter is not well understood and the reasons for its rarity have not yet been established but populations evidently have limited potential for stabilization.

This indigenous species' continued existence in Canada, is tentative. The Channel Darter should be considered a threatened species in Canada.

Acknowledgments

This status report was funded by the Department of Fisheries and Oceans Canada and World Wildlife Fund (Canada). Sincere thanks to R. R. Campbell, Canadian Wildlife Service, for support during its preparation.

The assistance of Erling Holm, Royal Ontario Museum; Don E. McAllister and Sylvie Laframboise, Canadian Museum of Nature; George E. Gale and Gareth A. Goodchild, Ontario Ministry of Natural Resources in providing access to records and reports is gratefully acknowledged.

Nick Mandrak, Ph.D. Candidate, University of Toronto, provided valuable insight into the zoogeography of the species as well as editorial assistance. Guy Tencia, Ministère du Loisir, de la Chasse et de la Pêche, Charlesbourg, Québec, supplied collection data for the province of Quebec, as did Michel Huot, Ministère du Loisir, de la Chasse et de la Pêche, Québec, Québec. Comments from several reviewers enhanced the text.

W. B. Scott, Huntsman Marine Laboratory and E .J. Crossman, Royal Ontario Museum kindly granted permission to use the drawing of the Channel Darter, *Percina copelandi*, illustrated by Anker Odum, from the book *Freshwater Fishes of Canada*, Bulletin 184, Fisheries Research Board of Canada, 1973.

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Accepted 2 March 1994

Status of the Ghost Shiner, *Notropis buchanani*, in Canada*

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Holm, E., and J. Houston. 1993. Status of the Ghost Shiner, *Notropis buchanani*, in Canada. Canadian Field-Naturalist 107(4): 440–445.

The Ghost Shiner, *Notropis buchanani*, is a small minnow only recently discovered in Canada. Little is known of this fish which is restricted to southwestern Ontario where it is apparently common in quiet areas of large turbid rivers. Canadian populations of the Ghost Shiner are considerably isolated; they are the only known populations from the Laurentian Great Lakes watershed. The species should be considered rare, but not at risk in Canada.

Le Méné fantôme, *Notropis buchanani*, est un petit méné qui n'a été découvert que récemment au Canada. On connaît peu de chose de cette espèce qui est limitée à la partie sud-ouest de l'Ontario; elle est apparemment commune dans les tronçons calmes des grands cours d'eau trouble. Les populations canadiennes de cette espèce sont isolées à un très haut point. Ce sont les seules populations connues vivant dans le bassin hydrographique des Grands Lacs du Boudier Laurentien. Il faudrait considérer que cette espèce est rare, mais qu'elle n'est pas menacée au Canada.

Key Words: Ghost Shiner, *Notropis buchanani*, méné fantome, Cyprinidae, southwestern Ontario.

The Ghost Shiner, *Notropis buchanani* Meek 1896, is a small minnow which is closely related to, and resembles, the Mimic Shiner, *Notropis volucellus*. Adults (Figure 1) are usually 33 to 58 mm total length (TL) in Ontario, but are known to reach 64 mm TL in Ohio (Trautman 1981). This little known fish has only recently been recorded from Canada (Holm and Coker 1981) where the extent of the known range is confined to southwestern Ontario.

It is not known whether *Notropis buchanani* is native to Ontario or has been introduced sometime prior to 1972, the earliest record of capture. The Ghost Shiner displays a disjunct North American distribution (see inset, Figure 2); nearest populations in the United States occur only in the Mississippi and other Gulf of Mexico drainages.

Given the limited distribution of the species in Canada and its apparent rarity, *Notropis buchanani* was considered to be of interest to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This presentation serves to document the extent of available information on the species.

Description

Notropis buchanani (Figure 1) has a compressed body with very little pigment; this pallid colouration accounting for the vernacular name. Unlike *Notropis volucellus*, it lacks infraorbital canals and has only two or three small infraorbital bones (Reno 1966). It has a relatively deep body (depth into standard length [SL] 3.7–5.5), highly elevated anterior lateral line scales (exposed scale width into exposed scale height 2.8–4.5), and a long caudal peduncle (its length 3.7–4.5 in SL).

Although reported to have a narrower caudal peduncle than *Notropis volucellus* (Trautman 1981; Page and Burr 1991) a sample of specimens of *Notropis buchanani* from Ontario, Ohio, and Iowa had significantly deeper caudal peduncles than a sample of *Notropis volucellus*. The ratio of caudal peduncle into standard length was compared between a sample of 26 *Notropis buchanani*, distinguished primarily by absence of infraorbital canal, and a sample of 26 *Notropis volucellus*, identified by presence of infraorbital canal. Caudal peduncle depth over standard length ranged from 0.09–0.10 (mean = 0.95, standard deviation = 0.0038) in *Notropis volucellus* and 0.09–0.13 (mean = 0.107, standard deviation = 0.0078) in *Notropis buchanani*. Although there is a considerable overlap in the ratios between species, the average caudal peduncle depth of the Ghost Shiner is significantly greater ($p < 0.0001$). No significant difference was found in caudal peduncle depth between the sexes of either *Notropis volucellus* ($t = 0.73$, $p < 0.47$) or *Notropis buchanani* ($t = 0.36$, $p < 0.72$). Six of the 26 specimens from each species were from the United States; the Ghost Shiner had a significantly deeper caudal peduncle than the Mimic Shiner in these specimens as well.

In life, the Ghost Shiner is silvery or translucent with very little pigment. In preserved adult specimens, the scales on the entire length of the back are outlined with melanophores. On several anterior lateral line scales, there is often a large melanophore on

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*Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

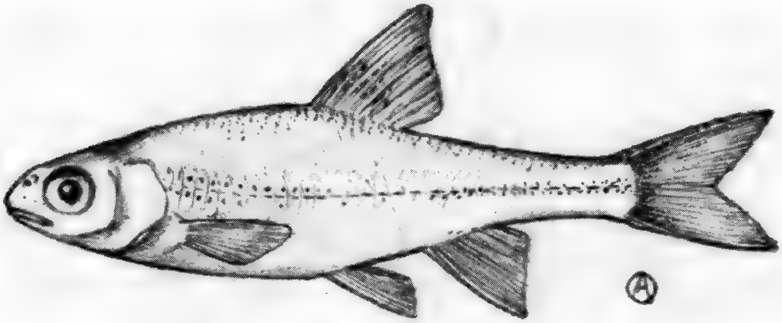

FIGURE 1. Ghost Shiner, *Notropis buchanani*, from Thames River (Royal Ontario Museum 36439), 45 mm TL. Drawn by Anker Odum.

each side of the lateral line and, posteriorly, a line of melanophores along the midlateral surface extending to the caudal base. Ventrally, melanophores occur along each side of the anal base and a row of melanophores is present on the lower surface of the caudal peduncle. At the base of the caudal fin, there is often a lightly pigmented bar. The first two outer rays of both the upper and lower caudal lobe are clear but the rest of the caudal is usually speckled with numerous melanophores. Breeding males become densely tuberculate on the top of the head, nape, and snout. The tubercles may also be evident on rays two to seven of the pectoral fins. Its tubercles are larger and greater in number on the top of the head than in *Notropis volucellus* but, unlike that species, it lacks tubercles below the eyes and on the underside of the head (Cross 1967).

Taxonomic Considerations

The taxonomy of *Notropis buchanani* Meek and related species has been very confused. Originally described in 1896, it was later regarded as a synonym of *Notropis blennius* (Girard) and then of *Notropis deliciosus* (Girard) [= *Notropis stramineus* (Cope)]. Hubbs and Greene (1928) reduced *buchanani* to subspecific level, representing southern populations of *Notropis volucellus* (Cope) which is currently considered by some to be a complex of more than one species (Smith 1979; Trautman 1981). Taylor (*in* Bailey 1951) noted that *Notropis buchanani* lacked an infraorbital canal and it was subsequently returned to full species status.

Distribution

The Ghost Shiner occurs in the Mississippi River drainage and Gulf of Mexico drainages west of the Mississippi (Figure 2, inset). It occurs in Gulf of Mexico drainages as far south as the lower Rio Grande in Mexico and Texas and, in the Mississippi drainage, from central Louisiana and Mississippi north to Minnesota and Wisconsin in the upper Mississippi and east to Pennsylvania in the Ohio River drainage (Gilbert 1980; Cooper 1985). There is a conspicuous absence in the Ozark Mountains in upper Arkansas and lower Missouri and in the Ouachita Mountains in southwest Arkansas. It appears more closely restricted to large rivers in northern and eastern parts of its range where its occurrence is often sporadic and localized, but it is common in most suitable habitat of the western Mississippi system (Gilbert 1980).

In Canada, *Notropis buchanani* is known primarily from clay plains of southwestern Ontario in streams tributary to lakes Huron and St. Clair (Figure 2, Royal Ontario Museum records). Holm and Coker (1981) first documented its occurrence from 1979 and 1980 collections in the lower Thames River. Additional field work in southwestern Ontario by the Royal Ontario Museum (ROM), the Canadian Museum of Nature (CMN) [formerly National Museum of Natural Science], and the Ontario Ministry of Natural Resources (OMNR) uncovered many additional records from sites in the Lake St. Clair and Lake Huron drainages. An additional five records from the Sydenham River drainage, including a 1972 record from Mollys Creek, were discovered at the Canadian Museum of Nature in 1990 during an examination of collections identified as *Notropis volucellus*. Field work in the Thames and Sydenham rivers in 1991 continued to increase the known range of the Ghost Shiner farther up the Thames and Sydenham rivers. *Notropis buchanani* has been collected from the Lake Huron drainage from the mouth of the Bayfield River and in the lower Ausable River. It has been captured in two tributaries to the St. Clair River, Clay and Bowens creeks near their mouths. It is found in the Lake St. Clair drainage from the drainages of the Sydenham River, Little Bear Creek, Maxwell Creek, and Thames River. The western-most record is from a

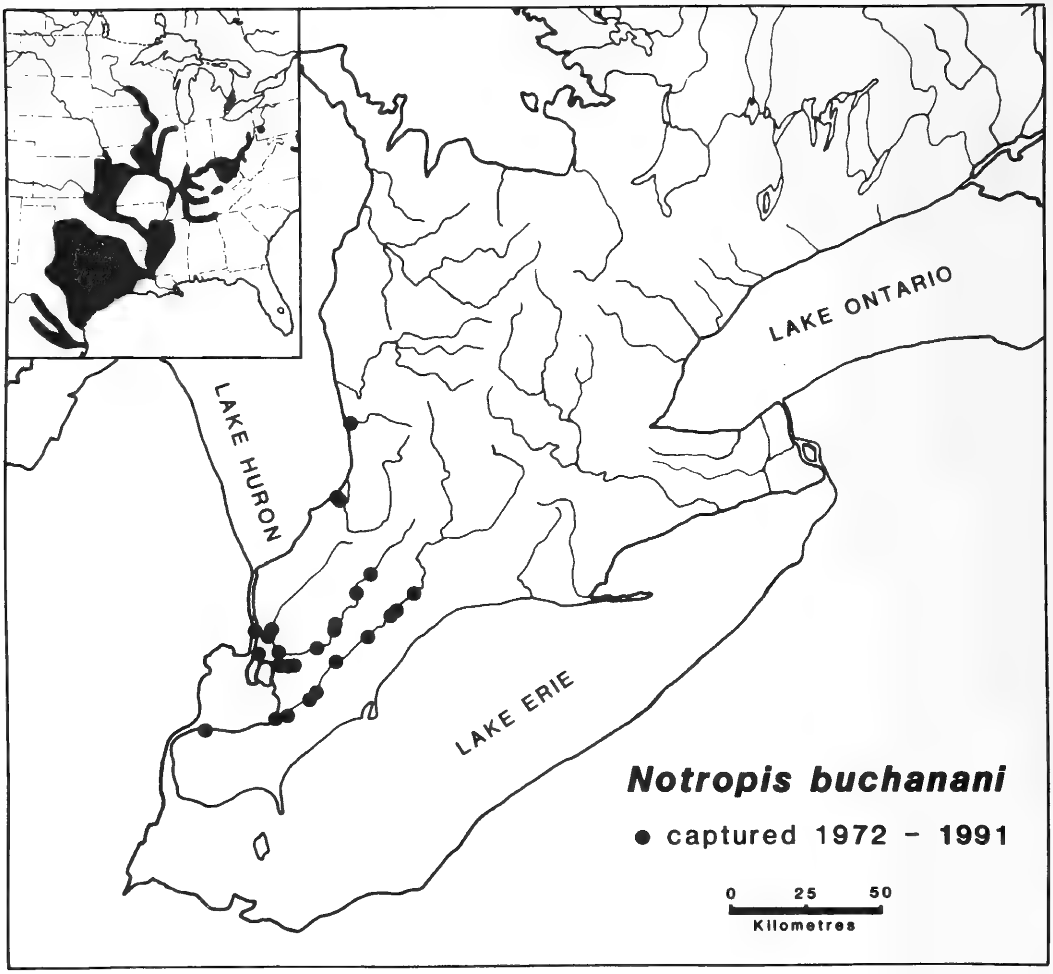

FIGURE 2. Distribution of the Ghost Shiner, *Notropis buchanani* in Canada based on Royual Ontario Museum records. Inset: North American distribution of the Ghost Shiner, based on a range map provided by C. R. Gilbert (personal communication).

site at the mouth of Duck Creek, a creek draining into the southwest end of Lake St. Clair.

All distribution records obtained from the OMNR Fish Species Distribution Data System and CMN were checked; only valid records were plotted and listed in ROM. All specimens have been identified by E. Holm, G. Coker, or R. M. Bailey.

Van Meter and Trautman (1970) listed *Notropis buchanani* from Talbot Creek, a tributary of Lake Erie in Ontario and stated it may occur in other tributaries of Ontario. However, they based their record on Hubbs and Lagler (1964) who considered the Talbot Creek specimens "an aberrant form, wrongly called *Notropis volucellus buchanani* Meek". Hubbs and Brown (1929) indicated that these specimens were too large for typical *N. buchanani* and approached the colour pattern of typical *N. volucellus*. The specimens (25-61 mm TL) from Talbot Creek (UMMZ 60495, UMMZ 56798) were examined. An obvious infraorbital canal is present and these are, therefore, not *Notropis buchanani*. Despite intensive sampling at many suitable habitats in the drainage by OMNR, ROM, and CMN, there are no valid records from the Lake Erie drainage.

Canadian populations of the Ghost Shiner are 240 km north of the nearest record in the Ohio River drainage, a distribution gap which is greater than all other species native to Ontario. This gap and the species' late discovery may suggest that Ontario populations arose from one or more recent introductions. It is unlikely that the small delicate Ghost Shiner was imported intentionally from the United States for bait, but it is possible that specimens may have been included in bait buckets inadvertently and subsequently released.

It is also possible that *Notropis buchanani* is native having dispersed into Ontario thousands of years ago. Underhill (1986) suggested that *Notropis buchanani* could have either utilized the eastern connectives from the Wabash River to reach the lakes and streams of the Erie basin 10 000 to 12 000 years ago, or simply moved through minor passageways from preglacial rivers and streams tributary to the Ohio River. Its distribution is similar to other species such as the Gravel Chub, *Erimystax x-punctata* (now considered extirpated in Canada), and the Silver Chub, *Macrhybopsis storeriana* both of which are considered native to Ontario and had (have) disjunct northern distributions with absences in adjacent Great Lakes drainages.

Early collectors failed to note the species in many parts of the U.S. range, perhaps due to its small size (Cross 1967), its subspecific status (Trautman 1981), and lack of intensive sampling in its prime habitat (Cooper 1985). Inability to differentiate the species from the Mimic Shiner may also have been a factor. Based on University of Michigan Museum of Zoology (UMMZ) and ROM records, only six sites have been sampled in Ontario within the present range of *Notropis buchanani* prior to 1972. These collections, including a collection of 110 *Notropis volucellus* captured in the Thames River "at Muncey" in 1923 (UMMZ 60438), were re-examined for possible misidentifications. *Notropis buchanani* was not found. A total of 35 Ghost Shiners were captured at four sites near the Muncey Indian Reserve in 1991. Available evidence, therefore, indicates that it has only recently become established at least in the Thames River at the Muncey Indian Reserve.

Protection

There are no specific protection measures in place for the species in Canada. The habitat sections of the Fisheries Act afford general habitat protection.

In the United States, *Notropis buchanani* is considered to have declined in Ohio to the extent that it is given Protected status there (Johnson 1987). Recently discovered in Pennsylvania, the Ghost Shiner has been classified as endangered pending more intensive sampling in that state (Cooper 1985).

Population Sizes and Trends

In the United States, there is some suggestion of decline in the populations in the upper Mississippi drainage. Smith (1979) indicated that *Notropis buchanani* was once more widespread in the upper Mississippi, although could not account for its decline in the northeast. Once known from many sites in the upper Mississippi River in Wisconsin, the Ghost Shiner is now regarded as extirpated in that state (Becker 1983). Recent records are known from the upper Ohio River in Ohio. Trautman (1981) documented a 1966 record of *Notropis buchanani* from the Muskingum River and four records in the Ohio River taken between the years 1968 and 1970. These records confirmed its continued presence in the Muskingum River in 1966 and extended its range farther upstream in the Ohio River.

In Ontario, the Ghost Shiner has been collected from 49 sites between 1972 to 1991 from several river systems. It was frequently caught in substantial numbers and comprised a significant proportion of the catch except in the Bayfield River, in Duck Creek, and at the sites farthest upstream in the Sydenham and Thames rivers. At nine sites it was the most abundant species in the seine hauls. Individuals of *Notropis buchanani* average 12 percent of the total catch in 42 collections for which complete species data is available. This high relative abundance may, however, reflect bias in the sampling technique. Small mid-water schooling species such as the Ghost Shiner are probably more susceptible to a seine than species which are larger and faster or more secretive.

The Ghost Shiner has been collected from four sites in the North Sydenham drainage from Wallaceburg upstream for a distance of 23 km to Bear Creek above Wilkesport, and from ten sites in the Sydenham drainage from Wallaceburg upstream for a distance of 95 km to Melwood Conservation Area, 11 km southwest of Strathroy. It has been collected from Chenail Ecarté, a channel draining into the northeast end of Lake St. Clair; two tributaries of Chenail Ecarté, Little Bear Creek where it was collected from four sites, and Maxwell Creek where it has been collected from three sites. It has been collected from 19 sites in the Thames River and its tributaries from the mouth of the Thames upstream for a distance of 106 km to the Muncey Indian Reserve, about 30 km southwest of London. Distribution records indicate that the Ghost Shiner is undergoing a range expansion.

Habitat

In the United States, *Notropis buchanani* has been recorded from large rivers or creeks usually near their confluence with a large river where they are found in quiet pools, eddies or backwaters away from current. In Kansas, it has been found in the main channel during periods of drought when the flow was slight (Cross 1967). In Arkansas, it can be common in reservoirs as well as in large warm sluggish streams or rivers (Robison and Buchanan 1988). Bottoms frequently consist of silt, clay, sand, and detritus (Smith 1979; Burr and Warren 1986; Becker 1983) or of clean sand, and gravel (Trautman 1981; Cooper 1983). The Ghost Shiner is found in moderately clear water in Missouri, Ohio, and Pennsylvania (Pflieger 1975; Trautman 1981; Cooper 1985) but in moderate to high turbidities in

Kentucky, Arkansas, Illinois and Kansas (Burr and Warren 1986; Retzer et al. 1983; Robison and Buchanan 1988; Smith 1979; and Cross 1967). Retzer et al. (1983) recorded no submerged aquatic vegetation whereas Trautman (1981) noted some submerged aquatics such as pondweed.

In Ontario, *Notropis buchanani* is found principally in the main channels of large rivers or in creeks near their confluence with large rivers having bottoms of silt and clay, frequently with sand, and occasionally with gravel or detritus. Stream width recorded for 13 sites was 13 to 45 m. Of 33 sites 91% had a component of silt, 73% of clay, 48% of sand, and 39% of gravel and 15% of detritus. Aquatic vegetation was present at 55% of 31 sites. Of those sites that had vegetation, 67% had submerged, 33% emergent, and 17% floating aquatic vegetation. Current varied from none to moderate but was most frequently none to slow (45% of 29 sites-none; 33% none to slow; and 22% moderate). Water clarity was estimated at 18 sites and ranged from 0.2 to 0.5 m with an average of 0.3 m. At other sites the water was described most frequently as muddy or turbid and at some sites as cloudy. In Ontario, the water where the Ghost Shiner occurs has never been described as clear.

Biology

Very little is known concerning the biology or ecology of the species. Spawning is reported to be from May to August in Kansas (Cross 1967), from June to August in Wisconsin (Becker 1983), and from late April to early July in Missouri. It takes place over sluggish riffles composed of sand and gravel (Pflieger 1975). In Ontario, collections indicate that *Notropis buchanani* spawns in the latter half of June. Females were found full of mature eggs and males were tuberculate on 12 June 1980 in the Thames River at a water temperature of 19°C. Pflieger (1975) noted that most spawning adults are in their second summer and individuals are not believed to live past their third summer of life.

Young of the year from Ohio were reported to be 20 to 38 mm TL by October and 28 to 58 mm TL by around 1 year. Adults are reported to average 33 to 64 mm (Trautman 1981). In Ontario, mature males reach a maximum of at least 43 mm TL, and mature females up to 58 mm TL have been found.

Diet has not been investigated, but in the Neosho River in Kansas, the Ghost Shiner has been observed to dart out from large stones for bits of food borne downstream by the current (Cross 1967).

Limiting Factors

Notropis buchanani appears to be limited to large sluggish rivers or large creeks near their confluence with a large river. Turbidity or siltation does not limit the distribution of the Ghost Shiner as it apparently thrives in areas of high turbidity and silty bottoms. Requirements for successful spawning, temperature tolerances, and effects of predators or competitors are unknown.

Special Significance of the Species

The value of the fish as a bait or forage species is unknown, but its localized abundance in certain sections of some streams could indicate an importance as a prey species. *Notropis buchanani* has been used in histological and osteological studies of development of the infraorbital canal and infraorbital ossicle (Reno 1966).

Evaluation

The Ghost Shiner has a limited range in southwestern Ontario where it is on the fringe of its northeastern distribution. There is no evidence to indicate that *Notropis buchanani* is indigenous to the fauna of Ontario. It may have been introduced but lack of early sampling in its current range makes it difficult to make a positive conclusion. Its range may be expanding and it should be looked for in suitable habitats where it has not yet been found. Viable populations exist in several river systems flowing into lakes Huron and St. Clair. At present Ontario populations of *Notropis buchanani* do not appear to be threatened, but the steadily increasing bait fish harvest in southwestern Ontario could have serious effects on the limited number of Ontario populations if they were allowed to be over-harvested.

Acknowledgments

Financial support for preparation of the document was made possible through World Wildlife Fund (Canada), the Royal Ontario Museum, and the Department of Fisheries and Oceans. Margaret Rouse and William Ramshaw assisted with field work. Douglas Nelson, University of Michigan, Museum of Zoology arranged the loan of specimens. The manuscript was improved by comments from E. J. Crossman, W. B. Scott, and two anonymous reviewers.

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Accepted 15 August 1993

Status of the Striped Shiner, *Luxilus chrysocephalus*, in Canada*

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Goodchild, Cheryl D. 1993. Status of the Striped Shiner, *Luxilus chrysocephalus*, in Canada. Canadian Field-Naturalist 107(4): 446–454.

The Striped Shiner, *Luxilus chrysocephalus*, is closely related to the Common Shiner, *Luxilus cornutus,* and former lack of differentiation between the two species has contributed to confusion over the status of Canadian populations. Populations of Striped Shiner in southwestern Ontario are contiguous with those in the United States. Striped Shiner populations in the United States are dwindling but data are insufficient to establish trends in Canada. Actual numbers are low and populations appear to be limited by water condition and inter-specific competition. The species should be considered as vulnerable in Canada.

Le méné rayé, *Luxilus chrysocephalus*, etroitement apparenté au méné à nageoires rouges, *Luxilus cornutus*. Autefois les deux espèces n'étaient pas différenciées. Il existe donc une certaine confusion quant à la situation des populations canadiennes. Dans le sud-ouest de l'Ontario, les populations de méné rayé sont contiguës à celles des État-Unis. Aux États-Unis, ces populations déclinent, mais les données sont insuffisantes pour qu'on puisse repérer les tendances démographiques au Canada. L'effectif réel est bas, et les populations semblent limitées à cause de la perturbation du milieu naturel et la compétition avec les espèces apparentées. Le méné rayé devrait être considérer comme une espèce vulnérable.

Key Words: *Luxilis (= Notropis) chrysocephalus*, Striped Shiner, méné rayé, Cyprinidae, cyprinids, minnows, rare and endangered fishes.

The Striped Shiner, *Luxilus chrysocephalus* Rafinesque 1820, Cyprinidae, has an extremely interesting and complex relationship with the Common Shiner, *Luxilus cornutus*, that does not readily conform to any simple taxonomic definition (Figure 1). Considered by many to be slightly-differentiated species of recent origin, the evolution of these two forms may be at an early stage. Because the two species are inextricably linked, there has been intense controversy over attempts to define whether they are separate species or subspecies. They were regarded as subspecies before being elevated to the species level by Gilbert (1964). Several subsequent studies, however, disagree with Gilbert (Miller 1968; Resh et al. 1971; Menzel 1976), but his findings are supported by others (Buth 1979; Dowling and Moore 1984; Dowling and Moore 1985; Dowling et al. 1992).

Despite a considerable degree of hybridization, Striped and Common shiners are, at least in part, reproductively isolated at all localities indicating that they have diverged beyond the subspecific level and should be considered separate species (Dowling and Moore 1984). The glacial history of Ohio suggests that both forms occupied unglaciated portions of the Mississippi River drainage. Taxonomic divergence in the complex may be little greater than that which could have occurred in post-Wisconsin time (Starnes and Etnier 1986). However, Gilbert (1961) promotes the contradictory view that Striped Shiners and Common Shiners were probably isolated from the Pliocene and that a post-Wisconsin invasion of the Great Lakes represents the first remixing of the two species since the ancestral stock was separated.

Phylogenetic relationships determined from analysis of mitochondrial DNA are also consistent with continued recognition of *Luxilus chrysocephalus* as a distinct species (Dowling et al. 1992). Ability to distinguish between these Striped and Common shiners in a collection varies from population to population. Sometimes they hybridize or intergrade so completely that differentiation is extremely difficult (Trautman 1981; Cooper 1983). Yet, in other areas they are so distinctive that they can be readily separated in the field (Becker 1983; Smith 1985). Often, identification can be based primarily on behavioral differences during collection. *Luxilus chrysocephalus* captured in seine nets from the Niagara River exhibited more energetic, vigorous and excitable behaviour than that normally associated with *Luxilus cornutus*. (E. Holm, Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto, Ontario; personal communication).

Both the Striped Shiner and the Common Shiner have deep moderately compressed bodies, normally nine anal rays (extremes 8 to 10), 2,4-4,2 pharyngeal teeth, complete lateral line with 36 to 40 scales, rounded snout, deep deciduous scales, and dark brown peritoneum.

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* Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

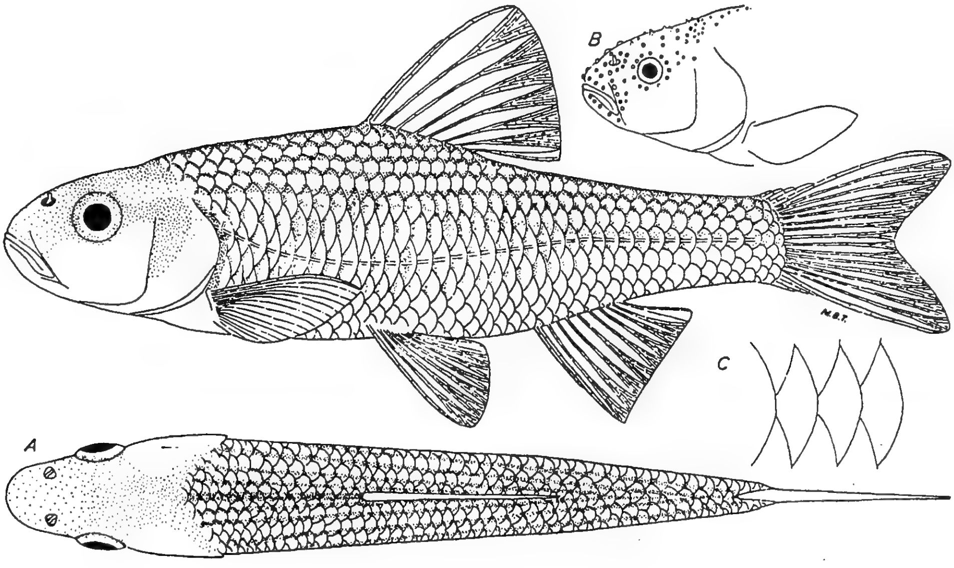

Figure 1. Drawing of the Striped Shiner, *Luxilus chrysocephalus*, from Trautman (1981) *Fishes of Ohio*; by permission.

The relative size and arrangement of the scales of the dorsal part of the body can be used to differentiate between Striped and Common shiners. Striped Shiner scales are large with dark outlines. Pigment in the dorsal scales usually form a distinct chevron-shaped pattern. Additionally, the dusky pigment on the chin and gular region is usually darker and more distinct on the Striped Shiner, although this character is extremely variable especially in areas of sympatry (Trautman 1981).

Adult Striped Shiners are bluish-green dorsally, with bluish-silvery sides and silvery or milk-white on the underside. Breeding males take on a bluish cast of the head and body, have pink sides and red outer margins on the fins (Trautman 1981). In breeding males, tubercles are found on the top of the head, snout, lower jaw, scales of back and leading edge of dorsal fin (Becker 1983). Breeding females lack tubercles and are less brilliantly coloured (Trautman 1981).

Distribution

North America

Luxilus chrysocephalus occurs in central North American freshwater drainages from the southern half of the Great Lakes basin, west of the Appalachian Mountains and south through the Mississippi River basin to the Mobile Bay drainage. Its overall distribution (excluding related forms *Luxilus cornutus* and *Luxilus isolepis*) includes tributaries to Lakes Michigan, Huron, Erie and Ontario, south through Ohio, Mississippi and Tennessee river drainages, west into Red and Arkansas river drainages, and north through Missouri and Illinois drainages (Gilbert 1980; Smith-Vaniz 1968; Smith 1985).

Luxilus chrysocephalus is sympatric with *Luxilus cornutus* throughout much of its range (Figures 2 and 3). Allopatry in Missouri and eastern Illinois, as well as in much of West Virginia, Ohio, and Indiana may be the result of competition (Gilbert 1961).

Canada

In Canada, the Striped Shiner occurs only in southern Ontario but is most abundant in southwestern Ontario (Figures 4 and 5). Populations of Striped Shiners in southwestern Ontario are contiguous with those in the United States.

The Striped Shiner has been collected from as far north as Penetang Harbour (Georgian Bay) on Lake Huron (ROM 43357 and ROM E). Another specimen also has been found near Owen Sound, southern Georgian Bay (ROM 43334). It is reported from many streams and rivers tributary to Lake Huron, such as Boundary Creek, and the Maitland, Bayfield and Ausable rivers.

Striped Shiners also have been reported from the St. Clair River and the Detroit River. They are common in the Lake St. Clair drainage basin, particularly in the Thames River, as well as the Sydenham River, Black and Nairn creeks. Striped Shiners are frequently collected in the Grand River system (Conestogo River and Nith River), tributary to Lake Erie. It is also documented in the Niagara River and

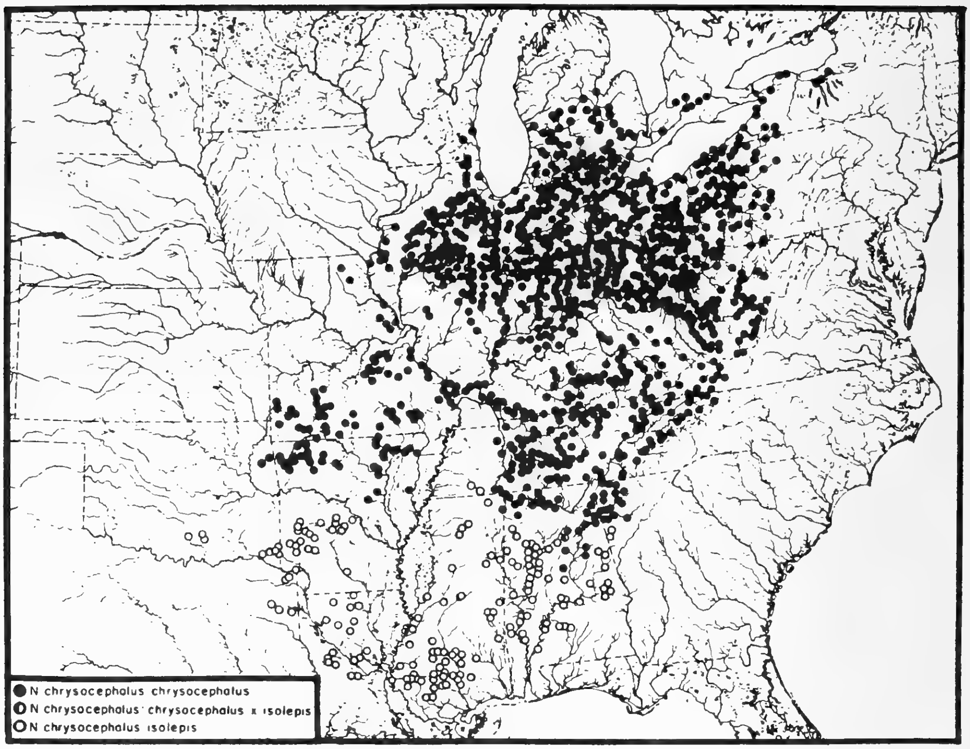

Figure 2. North American distribution of the Striped Shiner, *Luxilus chrysocephalus,* from Gilbert (1980).

its tributary streams such as Frenchman's, Ussher's, Miller, and Black Creeks.

Although commonly found in tributaries to Lake Ontario in New York State (Smith 1985), the Striped Shiner was not known from tributaries to the northeastern shore of Lake Ontario until recently. Disjunct populations of Striped Shiners are apparently established in eastern Ontario tributaries to Lake Ontario.

A single specimen was collected in the Pigeon River, near Omemee in 1988 (ROM 55213). The Pigeon River flows into the Trent River, tributary to Lake Ontario. This location is over 100 km east of continuous Striped Shiner distribution in Ontario. Its occurrence there may be the result of an accidental introduction of baitfish (E. Holm; personal communication). Many minnow species taken from southwestern Ontario are commercially sold, and large cyprinids such as Striped Shiner are a favoured bait [G.A. Goodchild, Ontario Ministry of Natural Resources (OMNR); personal communication].

Another disjunct population representing a significant extension of the range of Striped Shiner occurs approximately 150 km northeast of the Pigeon River location. Striped Shiners were first collected from Buckshot Lake, Ottawa River drainage in 1969 (OMNRL66) and were again found at this location in 1979 (ROM 38517, identification verified by E. Holm). Accidental release of baitfish also may explain its presence in Buckshot Lake. Introduction of other southwestern Ontario species are documented in the area (Goodchild and Tilt 1976).

Determining if the limits of Striped Shiner distribution have changed is complicated by the fact that the species previously was not recognized as distinct from the Common Shiner. Distinctions between the two species are not always clear cut (Scott and Crossman 1973). Some older museum collections from Ontario currently identified as *Luxilus cornutus* may in fact contain *Luxilus chrysocephalus* (E. Holm; personal communication). Thus, the majority of reference collections containing Striped Shiners are recent (since the 1970s), a result of intensified survey efforts and recognition of *Luxilus chrysocephalus* as a distinct species and are not necessarily indicative of increasing populations.

The Striped Shiner probably dispersed into southern Ontario from the Mississippian refugium through the Chicago and Grand Valley glacial outlets, and as a result of postglacial stream capture in the vicinity of the Fort Wayne outlet (Mandrak 1990).

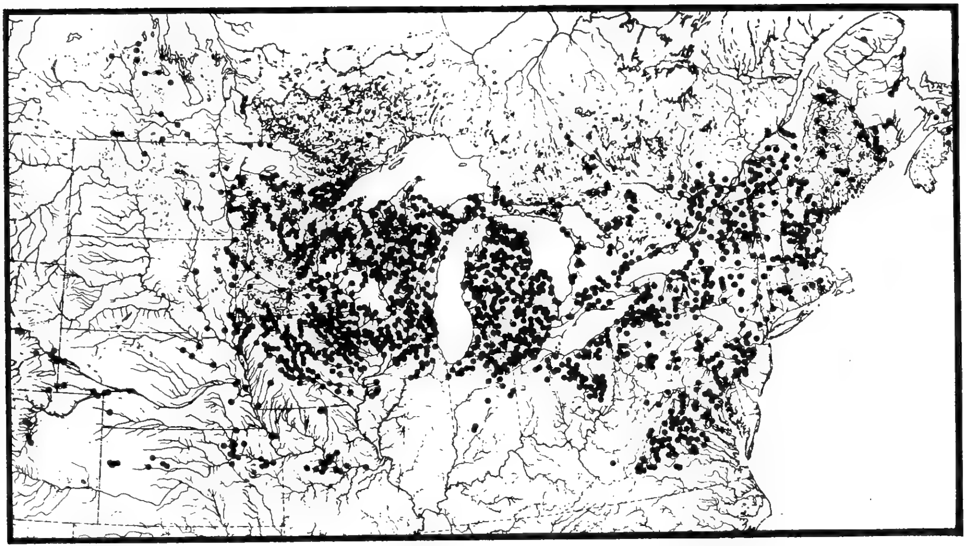

Figure 3. North American distribution of the Common Shiner, *Luxilus cornutus,* from Gilbert (1980).

Protection

No specific protection for *Luxilus chrysocephalus* exists in Canada although the federal Fisheries Act does provide general habitat protection.

Luxilus chrysocephalus is not considered to be in jeopardy in the United States (Miller 1972); however, Johnson (1987) does list this species as "of special concern" in Kansas and "protected" in Wisconsin (Johnson 1987). It has been given "endangered" status by the State of Wisconsin (Becker 1983).

Population Size and Trend

Although Striped Shiners in southwestern Ontario have been studied to determine taxonomic status, actual population estimates are lacking. Most *Luxilus chrysocephalus* specimens have been collected and identified in the past two decades, predominately due to increased survey efforts and better recognition of the Striped Shiner as a distinct species.

In many regions of the United States, however, Striped Shiner populations are declining. In Wisconsin, the range of the Striped Shiner has been shrinking over the past century and is now very constricted. Presently, it is found in only the Milwaukee River and the lower portions of two tributaries, Cedar Creek and Pigeon Creek (Becker 1983).

In Missouri, the Striped Shiner is less widespread than a century ago. It is decreasing in several systems including tributaries of the Upper Mississippi River. None the less, it remains abundant in the eastern and southern Ozarks (Pflieger 1975).

Although abundant in eastern and central Illinois the range of the Striped Shiner has shrunk. It formerly occurred over a wider area, particularly in the north and west (Smith 1979).

In Ohio, determination of current numbers is difficult because populations comprised entirely of Striped Shiners without visible evidence of intergradation with Common Shiners are present only in the southern third of the state. Preserved specimens and written records from before 1900 indicate that Striped Shiners were once very abundant (Trautman 1981).

Habitat

The Striped Shiner is typically found in clear, medium-sized streams with moderate to swift current over gravel or rubble substrate (Gilbert 1980). It is, however, associated with a variety of habitats from small streams with moderate gradients to larger streams with pools and riffles. There is little consensus regarding habitat preference.

Striped Shiners avoid extremely quiet water as well as areas with exceptionally strong riffles and swift current (Smith 1985). In Illinois, Striped Shiners frequent fast to moderately flowing brooks and large creeks and are sometimes present just below riffles in moderate current (Smith 1979). They evidently prefer deeper sections of streams with slight current in New York State (Smith 1985).

Although the Striped Shiner customarily inhabits weedless areas, in Wisconsin it is often found in dense aquatic vegetation in shallow, slightly turbid water at depths of 0.1 to 1.5 m (Becker 1983). It is not usually established in lakes, except in the north-

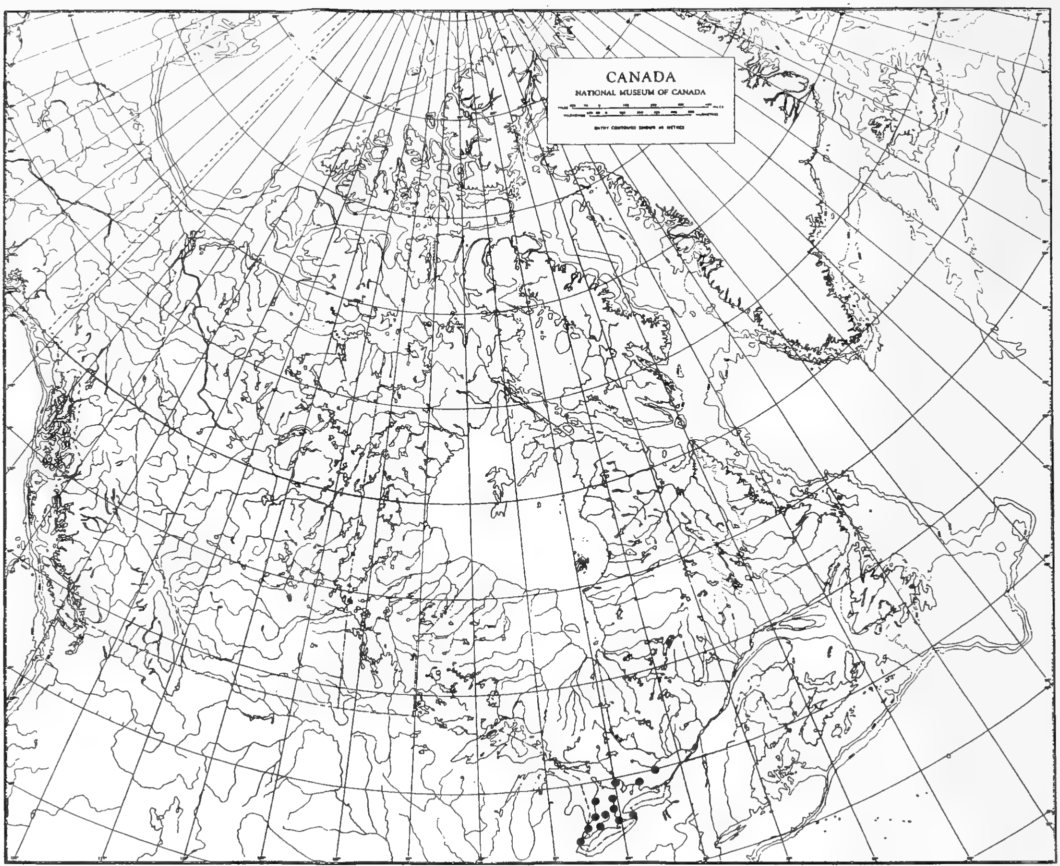

Figure 4. Canadian distribution of the Striped Shiner, *Luxilus chrysocephalus*.

ern part of its range where it may be found along shore areas (Smith 1985). It is common in lowland streams and weedy shoreline areas of Lake Ontario (Crossman and Van Meter 1979).

Based on distributional patterns of Striped Shiners and Common Shiners, Gilbert (1961, 1964) proposed that they occupy ecologically distinct habitat. He observed that in areas where they occur sympatrically, the Common Shiner tends to occupy headwaters and the Striped Shiner usually lives nearer the stream mouth, suggesting that the latter prefers warmer slower water. Radforth (1944) thought that the northern limit of distribution for the Striped Shiner bore some relationship to the 21°C (70°F) July isotherm. Common Shiner distributional limits roughly conformed to the 18°C (65°F) July isotherm, inferring that Common Shiners are able to tolerate colder mean temperatures or are capable of breeding at a lower minimum temperature.

Evidence of higher lethal temperature tolerance for Striped Shiner was presented by Hart (1952), but the study specimens were taken from different geographic areas (Striped Shiner from Kentucky, Common Shiner from Toronto). Kott et al. (1980), however, found no significant difference in thermal tolerance between syntopic populations of the two species in the Grand River, southwestern Ontario. Additionally, more recent collections have expanded the known range of the Striped Shiner beyond that which corresponds to these isothermal boundaries. Intensive sampling along the Grand River determined that both forms were well established and occur syntopically along its entire length (Mackay 1983).

General Biology

Reproductive Capability

Spawning habits of the Striped Shiner are extremely similar to those of the Common Shiner. Observations of Common Shiners spawning in New York state are documented by Raney (1940). Generally, spawning occurs over gravelly riffles in flowing water during daylight hours.

Spawning time may be related to water temperature but there is wide variation in the temperature

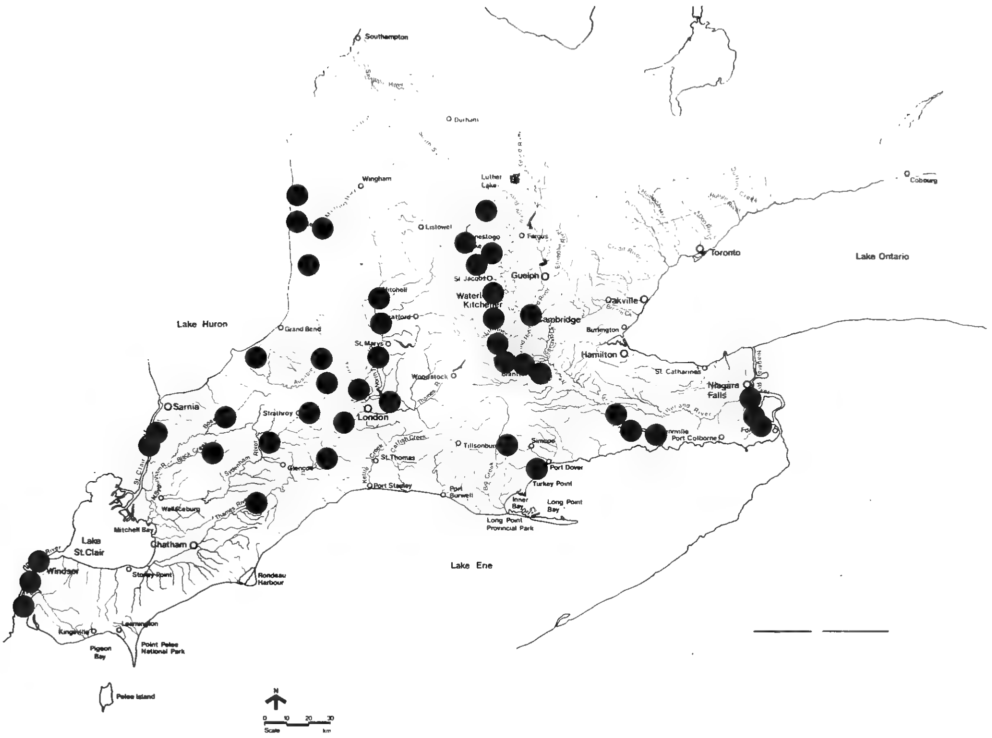

Figure 5. Distribution of the Striped Shiner, *Luxilus chrysocephalus*, in southwestern Ontario.

required to initiate spawning. Water temperatures of 15 to 18°C have been reported for Striped Shiners spawning during late April to June, in the United States (Smith 1979; Becker 1983), and between 15.6 to 18.3°C for Common Shiner (Raney 1940). Spawning adults, eggs and larvae were collected from Canadian tributaries to Lake Erie during mid-June indicating that spawning had occurred during June and the first half of July (Fish 1932).

The presence of two egg clutch sizes within maturing ovaries of Striped Shiners was discovered in a study of fecundity relationships in the Grand River, Ontario (Grant 1987). Although many species with protracted reproductive seasons have a number of clutches of ova, the Striped Shiner has a relatively short spawning period not normally associated with more than one clutch. Having two waves of eggs may provide an adaptive advantage ensuring a maximum number of eggs spawned during a fluctuating cold period.

The premise that Striped Shiners spawn at higher temperatures than Common Shiners is disputed as a result of examination of the condition of the ovaries of both species. Simultaneous ripening of the ovaries in both forms was observed in specimens from the Grand River, Ontario, demonstrating that they probably spawn concurrently (Grant 1987). Similarly in Michigan, no significant difference in the time of spawning was observed for these two species (Gilbert 1961).

During spawning male Striped Shiners establish small territories. Nuptial tubercles are used in fighting off other males and in defending the nest (Smith 1979). Larger individuals establish dominance, keeping away intruding fish, while mature females school closely around each male providing the opportunity to spawn with many different females. Males may excavate shallow nests in the gravel or they may occupy nests prepared by males of other cyprinid species such as the River Chub (*Nocomis micropogon*) or the Hornyhead Chub (*Nocomis biguttatus*)[Cooper 1983]. This results in a relatively high incidence of intra- and intergeneric hybridization. *Luxilus chrysocephalus* hybridizes or intergrades with *Luxilus cornutus* in an irregular fashion throughout areas of sympatry.

Hybridization of the Striped Shiner also has been documented with the following species: Central Stoneroller, *Campostoma anomalum*, Hornyhead Chub, *Nocomis biguttatus*, Rosyface Shiner, *Notropis rubellus*, Fallfish, *Semotilus corporalis*, Creek Chub, *Semotilus atromaculatus* (Breder and

Rosen 1960; Trautman 1981; Becker 1983); and reportedly with the Silver Shiner, *Notropis photogenis* (Stauffer et al. 1979). *Notropis chrysocephalus x Notropis rubellus* is one of the most common cyprinid crosses in the eastern United States (Gilbert 1961). Populations of *Notropis chrysocephalus* from Clark Creek, Mississippi, examined electrophoretically, showed no evidence of introgressive hybridization; species distinctions were apparently maintained (Grady and Cashner 1988).

Fewer than 50, demersal, orange eggs approximately 1.5 mm in diameter are broadcast during each spawning act (Smith 1979). There is no parental care of the eggs which become adhesive a couple of minutes after extrusion. Development of eggs and larvae up to 13.2 mm is described by Fish (1932).

The Striped Shiner commonly attains a length of up to 180 mm. The largest reported specimen was 236 mm long but specimens more than 200 mm are rare. Trautman (1981) provides the following age and growth data for Striped Shiner from Ohio: young of the year in October, 25 to 64 mm long; at 1 year, 38 to 89 mm; adults usually 76 to 180 mm. Specimens from the Milwaukee River, Wisconsin showed the following average growth; age class 0, 33.8 mm TL; age class I, 70.1 mm TL; age class II, 92.1 mm TL; age class III, 103.3 mm TL; age class IV, 119.0 mm TL (Becker 1983).

Age and growth data for *Luxilus chrysocephalus* from the Grand River, Ontario are as follows: at 1 year, 1.3 to 1.8 g; 2 years, 1.8 to 4.8 g; 3 years, 5.3 to 13.8 g; 4 years, 14.3 to 29.1 g; 5 years, 41.3 to 50.1 g. Growth of Striped Shiners and Common Shiners were compared and found to be virtually identical. (E. Kott, Department of Biology, Wilfrid Laurier University, Waterloo, Canada; personal communication [unpublished data]).

Striped Shiner survive for a maximum of four to five years. They form their first annulus at an average length of 43.5 mm (Marshall 1939). Annulus formation takes place during the breeding season in adults.

Species Movement

After the spawning season, Striped Shiner may move downstream to occupy larger, deeper waters with lower gradients especially during winter or periods of drought (Trautman 1981).

Behaviour/Adaptability

The Striped Shiner is omnivorous and usually a surface feeder although occasionally may be found seeking food at the bottom. Diet is assumed to be similar to the Common Shiner, consisting primarily of aquatic insects, larvae, algae and other plant material (Scott and Crossman 1979). Crustaceans are also reported to figure prominently in their diet (Cooper 1983).

A survey of parasites from western Lake Erie found that all 49 specimens examined were infected (Bangham 1972). Hoffman (1967) provides only the following list of parasites found in the closely related Common Shiner: protozoa, trematoda, cestoda, nematoda, acanthocephala, mollusca and crustacea.

Limiting Factors

Competition between Striped Shiners and Common Shiners may explain certain anomalies in their distribution. Their ranges are completely allopatric in Missouri and Western Illinois yet both species would be expected to occur there based on probable post glacial dispersal. Competition between the two species may also explain the gradual replacement of Common Shiner by Striped Shiner in parts of Ohio (Gilbert 1961). Species very similar morphologically and ecologically are believed to be unable to coexist indefinitely. Yet, morphologically similar Striped Shiner and Common Shiner do occur syntopically in many areas.

The occurrence of Common Shiners over a much larger area in Canada implies that at least in northern latitudes it has an unknown competitive advantage over Striped Shiner. Common Shiners of equal standard length were found to have significantly higher fecundity than Striped Shiners in syntopic populations from the Grand River (Grant 1987). Higher fecundity would hypothetically provide Common Shiner with a competitive edge over Striped Shiner.

Range contraction of the Striped Shiner in Illinois is attributed to siltation, turbidity, agricultural pollution and summer drying of streams (Smith 1979). Poor agricultural practices in southwestern Ontario also may have a negative impact on populations of Striped Shiner.

Dams or other barriers preventing upstream migration to spawning sites could also severely decrease spawning success, thus potentially limiting Striped Shiner populations which move into downstream areas during winter. Gilbert (1961) observed substantial decreases in Striped Shiner populations after dams were constructed at the mouths of streams tributary to the Huron River in Michigan. Common Shiners, which prefer to remain in headwaters, continued to be abundant. Thus, the prevalence of small dams throughout southwestern Ontario may be restricting Striped Shiner populations.

Large cyprinids such as the Striped Shiner are favoured bait for angling. Striped Shiners are used extensively for this purpose in the southern United States (Becker 1983). In Ontario, there is a considerable harvest of baitfish which could conceivably limit or depress small populations of Striped Shiners.

Special Significance of the Species

Formerly considered a subgenus of *Notropis*, *Luxilus* was raised to generic status by Mayden (1989). This action was subsequently supported by Coburn and Cavender (*in press*) and adopted by the

American Fisheries Society (AFS)[Robins et al. 1991]. *Luxilus chrysocephalus* and *Luxilus cornutus* are of particular interest to taxonomists because of their close relationship. The contention that they are valid species and not subspecies as formerly believed, is controversial. Lack of agreement on taxonomic rank has unfortunately resulted in confusion regarding the status of Striped Shiner populations.

The Striped Shiner is of minor economic importance as bait in Canada but fosters little public interest.

Evaluation

The current status of *Luxilus chrysocephalus* populations in Canada is difficult to determine. Canadian populations are contiguous with those in the United States, where there is evidence of decline throughout many regions. Any deleterious environmental conditions might be expected to have an impact on Striped Shiner populations at the northern limit of the species range, in Canada. However, widespread habitat deterioration is not forecast due to greater enforcement of the federal Fisheries Act and the accompanying "Policy for the Management of Fish Habitat" which has been adopted by the province of Ontario (G. Goodchild, personal communication).

Assumptions based on distributional patterns of the Striped Shiner compared to the Common Shiner imply that the Striped Shiner may be less tolerant of lower temperatures. This might have restricted populations of Striped Shiner from expanding northward. Scott and Crossman (1973) suggest that if the Striped Shiner is more tolerant of warmer, more turbid waters than the Common Shiner and is replacing it in areas where such conditions exist, then the Striped Shiner should extend its range in Ontario. The range of the Striped Shiner might therefore be expected to further expand during a warming trend in the climatic cycle. Improved management of habitats combined with a period of warmer temperature might constitute a refugium for the Striped Shiner ultimately resulting in augmented population numbers.

Recent evidence suggests, however, that although there appear to be morphological differences between the two species, they do not differ physiologically in response to upper lethal temperature and often occur syntopically in Ontario (Kott 1980; MacKay 1983). Perhaps the assumption that Striped Shiner are less tolerant of low temperatures is incorrect and other factors have limited the Striped Shiner from extending its range as far north as the Common Shiner.

Possible explanations for the recent observed changes in Striped Shiner distribution in Ontario have been suggested (E. Kott, Department of Biology, Wilfrid Laurier University, Waterloo, personal communication). The first is that it is a rather recent arrival in southwestern Ontario and as yet has not reached its physiological limits or there is some unknown physical barrier to its distribution. As a result it may be continuing to expand its range and this implies that the 21°C (70°F) isotherm does not adequately define the northern limit for the species.

The second possibility involves a genetic consideration. The Striped Shiner and the Common Shiner occur syntopically in southwestern Ontario. In these regions some hybrids were formed. Fertile hybrids, because of their low numbers, would most likely mate with an individual of one of the parent species. Through this mechanism a tolerance for colder temperature could possibly be transferred from the Common Shiner, through the hybrid, to the Striped Shiner. Some Striped Shiner populations would no longer be at their physiological limit and could extend northwards.

In fact, the apparent expansion of Striped Shiner populations in Canada may merely be indicative of increased survey efforts in combination with more definitive identification of the species. Although there is no ostensible decline in Canadian populations, their continued survival is unpredictable. Population numbers are low, populations in the United States have substantially declined, and many factors have been identified that have the potential to limit Striped Shiners. The species does not require COSEWIC designation and protection at this time, but its status should be re-examined at regular intervals.

Acknowledgments

This report was funded by the Department of Fisheries and Oceans Canada. Sincere thanks to R. R. Campbell, Canadian Wildlife Service, for support during preparation of the manuscript.

The assistance of Erling Holm, Royal Ontario Museum; Don E. McAllister and Sylvie Laframboise, Canadian Museum of Nature; George E. Gale and Gareth A. Goodchild, Ontario Ministry of Natural Resources; in providing access to records and reports is gratefully acknowledged.

Nick Mandrak, University of Toronto, provided editorial assistance. E. Kott, Department of Biology, Wilfrid Laurier University, provided unpublished data and insight regarding observed distributional changes.

I am grateful to P. McKee, Beak Consultants, for providing the southwestern Ontario "base" map. Lynne Bonenberger, Assistant Editor, Ohio State University Press graciously granted permission to use the drawing of the Striped Shiner from the book *Fishes of Ohio* by M. B. Trautman.

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Accepted 15 August 1993

Status of the Striped Dolphin, *Stenella coeruleoalba*, in Canada*

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Baird, Robin W., Pam J. Stacey, and Hal Whitehead. 1993. Status of the Striped Dolphin, *Stenella coeruleoalba*, in Canada. Canadian Field-Naturalist 107(4): 455–465.

The Striped Dolphin, *Stenella coeruleoalba*, is found in offshore waters throughout the world in warm-temperate and tropical seas. Large numbers are killed yearly in directed fisheries off Japan and they are also incidentally caught in fishing operations around the world. Published and previously unpublished records from Canadian waters include 11 from western and 17 from eastern Canada. The Striped Dolphin appears to be at the northern limits of its normal range in Canadian waters, and no serious threats to it exist here. No COSEWIC status designation is required.

Le présent rapport expose les caractéristiques biologiques du dauphin bleu (*Stenella coeruleoalba*), son statut mondial, et les mesures de gestion dont il fait l'objet et sa situation, particulièrement au Canada. L'espèce fréquente les eaux hauturières des mers chaudes tempérées et des mers tropicales du globe. De grands nombres sont tués chaque année dans le cadre d'une pêche sélective au large du Japon, et ils sont aussi capturés accidentellement au cours d'opérations de pêche dans toutes les mers du globe. Des données publiées et inédites pour les eaux canadiennnes font état de 11 observations dans les eaux du Pacifique et 17 observations dans les eaux de l'Atlantique. Les eaux canadiennes, où l'espèce n'est pas menacée, semblent représenter la limite septentrionale de l'aire de répartition courante du dauphin bleu. À ce titre, l'espèce ne requiert pas une intervention de la part du CSEMDC.

Key Words: Striped Dolphin, dauphin bleu, *Stenella coeruleoalba*, Canada, status, cetacean, North Pacific, North Atlantic.

This review summarizes the current state of knowledge of the Striped Dolphin, *Stenella coeruleoalba* (Meyen, 1833), with special reference to its status and management in Canadian waters. Striped Dolphins (Figure 1) reach maximum lengths of between 2.5 and 2.7 m; males are slightly larger than females (Leatherwood and Reeves 1983; Ross 1984). Leatherwood and Reeves (1983) and Ross (1984) summarize the physical description of Striped Dolphins. Striped Dolphins and Common Dolphins (*Delphinus delphis*) are superficially similar, and this may make it difficult to distinguish between them at sea. Detailed descriptions of the complex pigmentation pattern of the Striped Dolphin are given by Norris and Prescott (1961), Gihr and Pilleri (1969), Fraser (1974) and Ross (1984). Pigmentation patterns appear to be highly variable, though Fraser and Noble (1970) note that these variations do not appear to correlate with age, sex, or geographical distribution. Such variations have resulted in considerable taxonomic uncertainty. In his review of the taxonomic history of *Stenella coeruleoalba*, Hershkovitz (1966) lists 44 historical species designations. Common names attributed to this species include the Blue-white Dolphin, Long-beaked Dolphin, Gray's Dolphin, Gray's Long-snouted Porpoise, Streaker Porpoise, Meyen's Dolphin, and the Euphrosyne Dolphin.

Distribution

The Striped Dolphin is found in all warm-temperate and tropical waters and is the most widely distributed species of the genus *Stenella* (Wilson et al. 1987). In the eastern North Atlantic, the Striped Dolphin has been observed as far north as Britain and Denmark (Fraser 1974; Wilson et al. 1987). The species appears to become more common southward along coastal Europe (Brown 1975; Evans 1987; Collet and Duguy 1987; Duguy 1987, 1988), and is present in the Mediterranean (Morzer Bruyns 1974; Casinos and Vericad 1976; Duguy 1977; Di Natale 1983; Podesta and Notarbartolo-di-Sciara 1987). It has been recorded along the west coast of Africa, and its presence in the Indian Ocean is well documented (Ross 1984; Leatherwood et al. 1984; Alling 1986; Wilson et al. 1987).

In the Atlantic, van Bree (1973) reports a Striped Dolphin specimen that is thought to have originated from the waters of Greenland. The species has been recorded from Newfoundland, along the U.S. east coast (Mansfield 1967; Sergeant et al. 1970; Mercer 1973; Hain et al. 1985) to Florida, and in the Caribbean and the Gulf of Mexico (Odell and Chapman 1976; Perrin et al. 1981). There are also several records along the coast of South America from southern Brazil to northern Argentina (Brownell and Praderi 1976; Perrin et al. 1981; Wilson et al. 1987).

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* Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

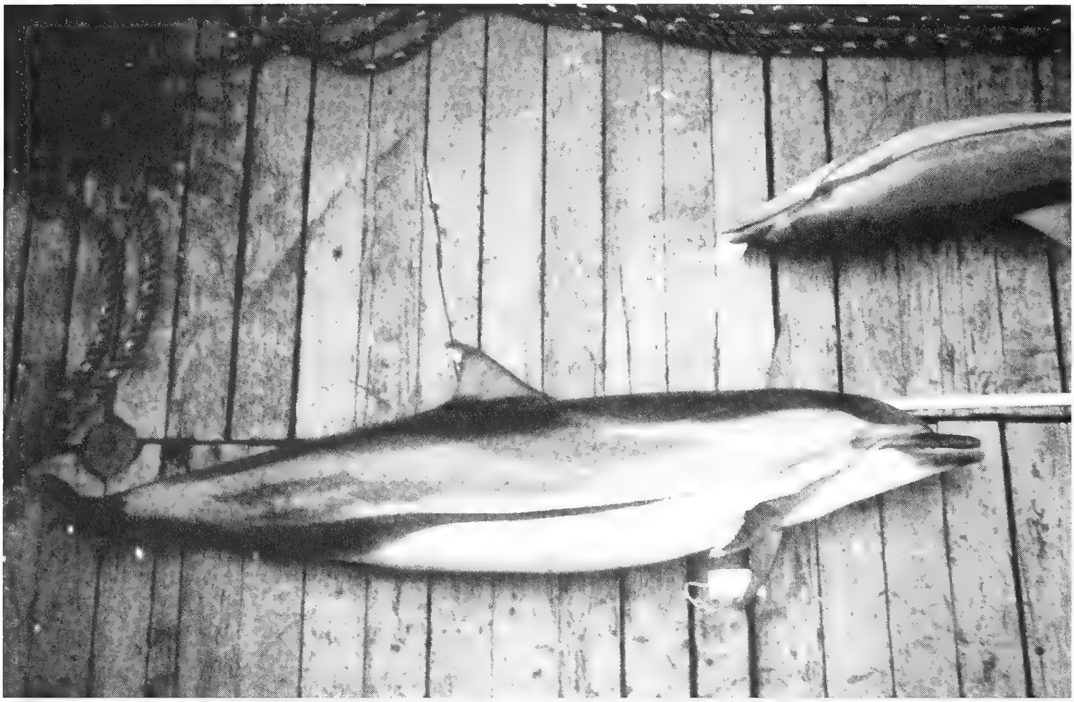

FIGURE 1. Striped Dolphin killed in a tuna purse-seine in the eastern tropical Pacific. Photo by O. Seth, courtesy National Marine Fisheries Service.

The Striped Dolphin is the most northerly distributed species of the genus *Stenella* in the North Pacific (Nishiwaki 1967). Watson (1981) notes that this species can be found as far north as the Bering Sea, but unfortunately presents no documentation. Considering this lack of documented records and the small number of records from northern parts of the North Pacific (Wilson et al. 1987), we believe it is unlikely they occur in the Bering Sea. In the eastern North Pacific, Striped Dolphins have been reported off the coast of North America from British Columbia to the equator, including the Gulf of California (Kellogg and Scheffer 1947; Cowan and Guiguet 1952; Sampson 1970; Hubbs et al. 1973; Wahl 1977; Aguayo-L. and Perdomo-V. 1985). Au et al. (1979) describe the distribution in the eastern tropical Pacific, which between the central Mexican and northern South American coast is known to reach to 153°W. Striped Dolphins are rarely seen in Hawaiian waters (Shallenberger 1981). There do not appear to be any records as far south as Peru (Perrin et al. 1983).

In the western North Pacific, Striped Dolphins are common off Japan (Nishiwaki 1967; Miyazaki et al. 1974). There are a few records north to the southern Sea of Okhotsk (Sleptsov 1961), and south through the South Pacific to New Zealand and Australia (Wilson et al. 1987).

Published records from within the Canadian 320 km (200 mi) extended economic zone (EEZ) are few (Cowan and Guiguet 1952; Mansfield 1967; Pike and MacAskie 1969; Sergeant et al. 1970; Mercer 1973; Wilson et al. 1987). Records are also found in unpublished reports by Hatler (1972), the Sea Education Association (1979) and Perkins et al. (1981). Jamieson and Heritage (1988) report an animal identified as *Stenella* sp. that was killed in an experimental fishery for Flying Squid (*Ommastrephes bartrami*) in offshore British Columbia waters. This animal was likely a Striped Dolphin, as other species in the genus *Stenella* found in the eastern North Pacific are typically more tropical (Leatherwood et al. 1988). A photograph of a dead Striped Dolphin on a wharf in Chester, Nova Scotia, from 1926, can be found in Reeves and Mitchell (1987), but there are no further details as to its origin. Katona et al. (1983) state that at least one record exists for Cape Breton Island, Nova Scotia, but this does not appear to match with any record compiled here. Mercer (1973) suggests that records from Quebec, and Halifax, Nova Scotia (Tomilin 1957; Miller and Kellogg 1955) are in error. Four unpublished records from the west coast, and eight unpublished records from the east coast, have also been compiled. In total, 11 records from the west coast,

TABLE 1. Records of the Striped Dolphin within the Canadian 320 km (200 mi) extended economic zone (V.I. = Vancouver Island). Specimens: UBC = University of British Columbia; BCPM = Royal British Columbia Museum, formerly BC Provincial Museum. See Figure 2 for locations.

Date	Location	Number	Type[A]	Source[B]	Temp[C]	Comments
Western Canada						
1948	Nootka Sound, V. I.	1	1	1	—	UBC 2886
18 March 1958	51°45′N, 133°45′W	5-10	2	2	—	
June 1960	Long Beach, V.I.	1	1	3	—	BCPM 6665
23 April 1961	Lawn Pt., Campbell River, V.I.	1	3	2	—	UBC 8011
23 April 1963	Kyuquot, V.I.	1	4	2	—	UBC 9236
05 March 1972	Wreck Bay, V.I.	1	1	4	—	UBC 9470
13 March 1972	Lovekin R., Long Beach, V.I.	1	1	4,5	—	BCPM 7525, male
1975	Victoria, V.I.	1	5	3	—	BCPM 8875[D]
— March 1975	Cadboro Bay, Victoria, V.I.	1	5	6	—	mandible only[D]
17 February 1983	Long Beach, V.I.	1	1	3	—	BCPM 11394, male
10 August 1987	≈ 48°44.3′N, 131°7′W	1	4	7	—	listed as *Stenella* sp., killed in squid drift net
Eastern Canada						
1926	Chester, Nova Scotia	1	6	8	—	photo of a dead animal on wharf
14 February 1964	W spit Sable Island	1	1	9	—	identification not positive
summer 1964	N. beach Sable Island	3	7	10	—	
12 January 1968	Sable Island	3	1	10	—	
1968/1969	St. Pierre Bank	1	4	11	—	caught in trawl, St. Pierre Museum
29 June 1971	47°16′N, 53°58′W	1	4	11	—	caught in salmon net
31 July 1979	41°40′N, 62°30′W	—	2	12	—	
03 August 1979	43°50′N, 58°10′W	—	2	12	—	
August 1981	44°00′N, 59°00′W	25	2	13	—	
23 July 1989	43°51.9′N, 58°55.9′W	15	2	14	15.6	w/*Lagenorhynchus acutus*
27 July 1989	43°33.1′N, 58°49.5′W	2	2	14	17.0	w/*Delphinus delphis*
04 August 1989	43°49.4′N, 58°54.6′W	20	2	14	18.6	
11 August 1989	43°48.9′N, 58°59.6′W	15	2	14	18.5	w/*L. acutus, D. delphis*
13 August 1989	43°50.4′N, 58°54.3′W	10	2	14	17.4	w/*L. acutus, D. delphis*
04 August 1990	43°50.8′N, 58°57.4′W	8	2	14	15.0	w/*D. delphis*
09 August 1990	43°50.8′N, 58°54.2′W	20	2	14	17.3	w/*Hyperoodon ampullatus*
10 August 1990	43°45.1′N, 58°57.2′W	15	2	14	19.1	w/*Globicephala melas*

[A] Type of Record: 1. Found dead on beach; 2. Sighting; 3. Skull collected, no details; 4. Caught in fishing gear, killed; 5. Skeletal parts found on beach; 6. Dead, no details; 7. Live stranded, died.

[B] Source of Record: 1. Cowan and Guiguet 1952; 2. Pike and MacAskie 1969; 3. Royal British Columbia Museum, formerly the British Columbia Provincial Museum; 4. Hatler 1972; 5. Wilson et al. 1987; 6. University of Victoria; 7. Jamieson and Heritage 1988; 8. Reeves and Mitchell 1987; 9. Mansfield 1967; 10. Sergeant et al. 1970; 11. Mercer 1973; 12. Sea Education Association 1979; 13. Perkins et al. 1981; 14. H. Whitehead, unpublished data.

[C] Sea surface temperature in degrees celsius.

[D] These two records from the Victoria area in 1975 may be from the same individual, as the first is represented only by a skull, and the second by a single mandible, of approximately similar sizes. Further details on these collections are unavailable.

and 17 from the east coast records are presented in Table 1, with locations shown in Figure 2. Most records are of strandings or opportunistic sightings from one research area.

Protection

International

There is no international trade known in Striped Dolphin products. If such trade were to exist, it would be regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As Striped Dolphins are listed under Appendix II of the Convention, international trade requires export permits from the country of origin. There is no international protection for Striped Dolphins from direct or incidental takes.

National

Canada: Until they were repealed in 1993, the Cetacean Protection Regulations of the Fisheries Act of Canada of 1867 protected all cetacean species from "hunting". "Hunting" was defubed as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner", and could only be undertaken under licence. Aboriginal "hunting", however, could be undertaken without licences. The Cetacean Protection Regulations were replaced with the Marine Mammal Regulations of the Fisheries Act in early 1993. These regulations appear to provide no more or no less protection by stating only that "no person should disturb a marine mammal except when… under the authority of these regulations." However, no provisions for regulation of incidental catches in fishing operations exist.

United States: All cetaceans are protected under the Marine Mammal Protection Act of 1972, as well as by the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of the Fisherman's Protective Act.

Population Size(s) and Trends

An estimated 2 300 000 Striped Dolphins are present in the eastern North Pacific (U.S. Department of Commerce 1987); the largest population estimate available for that area of any species of cetacean. Perrin (1975) notes that more than one stock may be present in the eastern tropical Pacific, with a distributional break between about 10° and 17°N latitude. Further research seems to support this population discontinuity, and Perrin et al. (1985) suggest that animals north and south of these latitudes be considered separate populations. Nishiwaki (1975) reported an estimate of 400 000 to 600 000 animals off Japan, while Kasuya and Miyazaki (1975; cited in Ellis 1989) note an estimate of between 130 000 and 180 000 for the same period and area. Kasuya (1985) concludes that the population off Japan has been declining since the mid-1940s. Forcada et al. (1990) note that the Striped and Common Dolphin are the most common small cetaceans in the offshore waters of the eastern North Atlantic.

Habitat

The Striped Dolphin's wide pelagic distribution in the eastern tropical Pacific is related to the distinctive oceanographic features of this region (Au et al. 1979). These authors note that all evidence points to a common preference among the pelagic dolphins, particularly the Striped and Common dolphins, for regimes of shallow thermocline, which is the major characteristic of the eastern tropical Pacific. Sightings off the northeast coast of the United States by CETAP (1982) were generally centred about the 1000 m depth contour. In a study in Japan, Miyazaki and Wada (1978) recorded Striped Dolphins in areas where sea surface temperatures ranged from 18.2 to 30.5°C. During research on Northern Bottlenose Whales (*Hyperoodon ampullatus*) off the Canadian east coast, Striped Dolphins were only recorded when water temperatures exceeded 15°C, during late July and August (Table 1), although field work in the area has been undertaken during June, July, August, October and February (Whitehead, unpublished data).

General Biology

Reproduction

Striped Dolphins usually produce a single calf; only one pair of twin fetuses was found in a sample of about 30 000 dolphins examined in Japan (Tobayama et al. 1970). Gestation is thought to be 12 months (Kasuya 1972). Average length at birth is about 100 cm (Kasuya 1972; Miyazaki 1977). According to Miyazaki et al. (1981), Striped Dolphins weigh about 12 kg at birth, and grow rapidly in their first two years of life. Weaning takes place at an average estimated length of 174 cm and average age of 15 months (Kasuya 1972). Estimated lengths at attainment of sexual maturity in different areas are 195-220 cm for males and 216 cm for females, with a mean age of 9 years for both sexes (range of 7-12 years for males; 5-13 years for females; Perrin and Reilly 1984). Asymptotic body weight is attained at an age of about 15 years, when males average 157.5 kg and females 135.9 kg (Miyazaki et al. 1981). The mean and minimum ages at maturity have declined in the population off Japan, likely due to exploitation (Kasuya 1985). Physical maturity is reached at 235 cm in the male, and 225 cm in the female (Miyazaki 1977). Estimates of ovulation rates of animals from the western North Pacific range from 3 to 12 times per year (Perrin and Reilly 1984). Calving interval estimates range from 1.4 years to 4.2 years. Kasuya (1985) notes that the reproductive cycle in animals off Japan has also likely shortened because of exploitation of that stock. Using counts of cemental growth layers, assuming the deposition of one growth layer group per year, Kasuya (1976) has found that animals may reach 50 years of age. From a sample of over 1000 individuals aged using this technique, Kasuya (1985) noted one individual of each sex reaching an age of 57 years. In the same study, although sex ratio between different schools varied from about 22% females to about 73% females, the mean sex ratio of 12 schools totalling over 3000 individuals was about 1:1.

Species Movement

Off the coasts of Japan, Nishiwaki (1967) noted northerly movements in May through July, and southerly movements in October through December. Compared to most other species of cetaceans studied by CETAP (1982) off the NE coast of the United States, no strong seasonal changes in distribution were evident for the Striped Dolphin. As noted above, northern movements into waters off the Canadian east coast generally appear to be related to the warming of surface waters, although records from mid-winter do exist (Table 1).

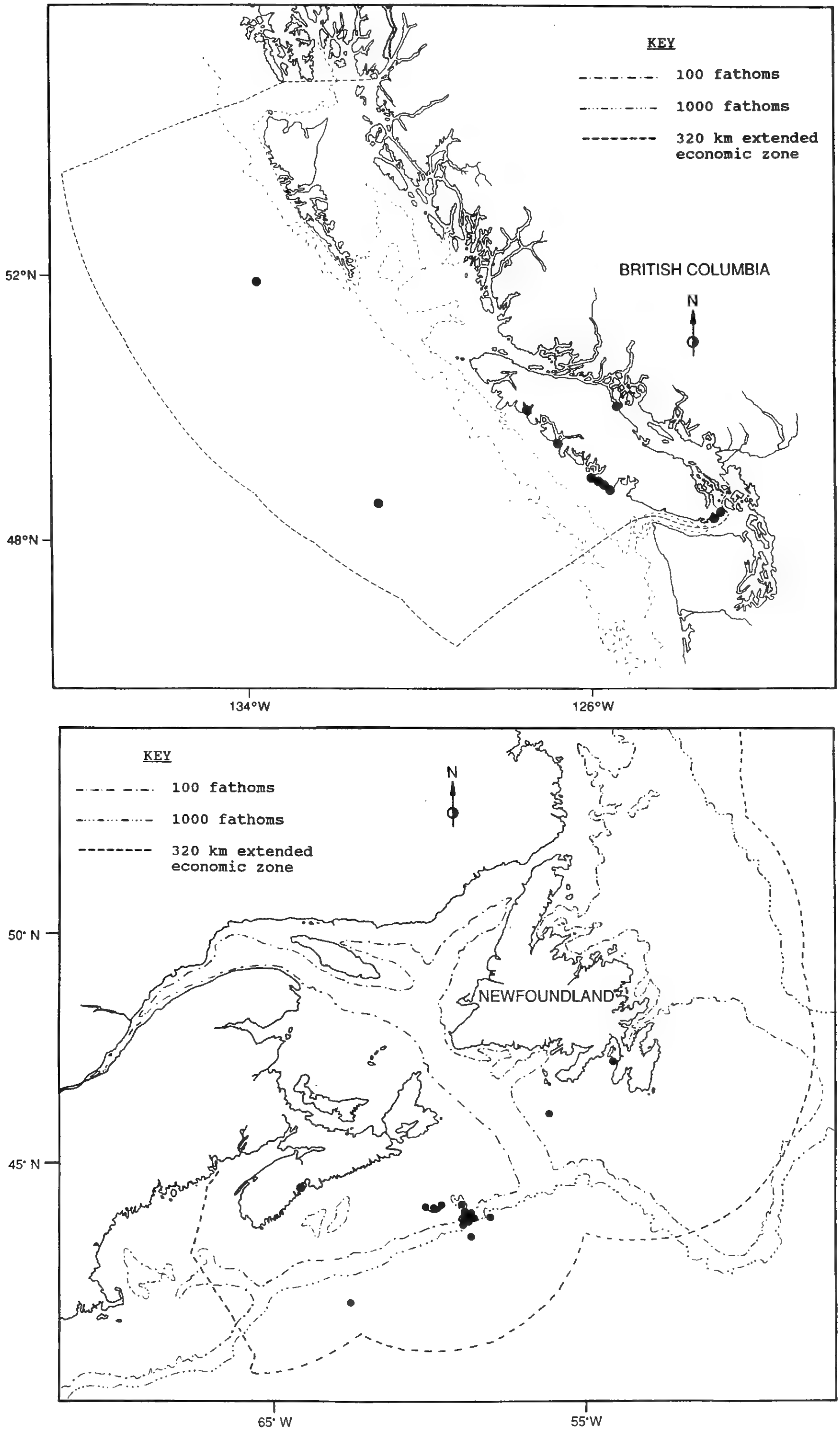

FIGURE 2. Locations of records from within the Canadian 320 km (200 mi) extended economic zone. Top: Pacific coast; bottom: Atlantic coast. See Table 1 for details of records.

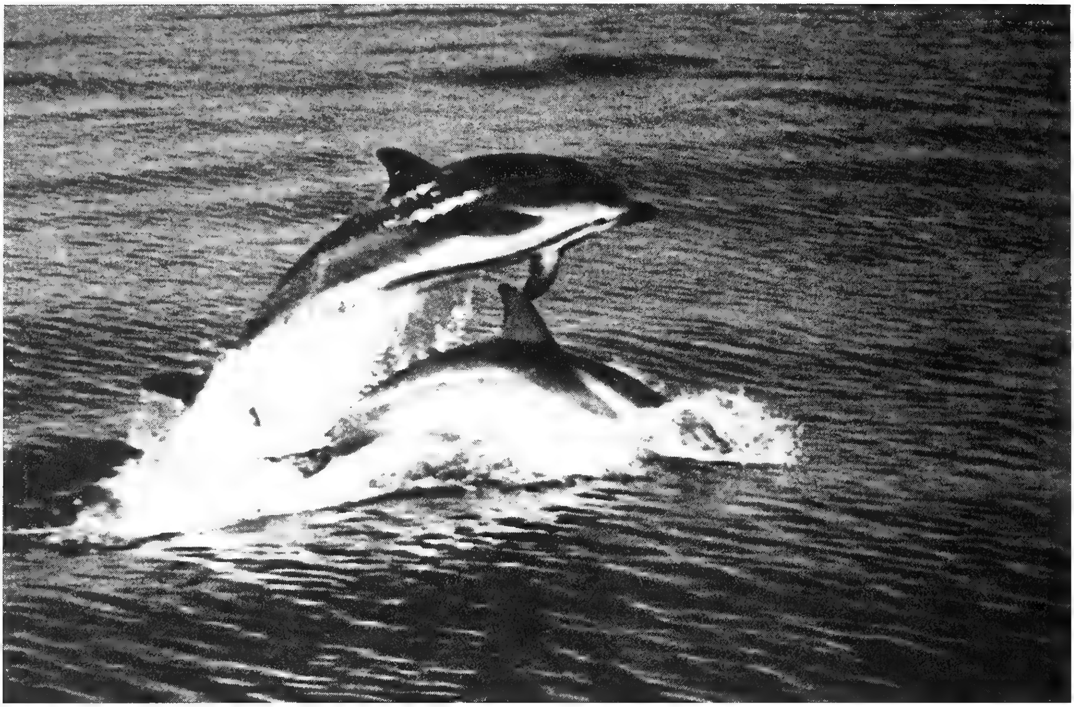

FIGURE 3. Striped Dolphins porpoising in the Mediterranean. Photo courtesy S. Leatherwood.

Behaviour

Groups of up to 3000 individuals have been reported off the coast of Japan (Nishiwaki 1975). Miyazaki and Nishiwaki (1978) examined 45 schools of Striped Dolphins off the coast of Japan between 1963 and 1973 and found that 85.8% of schools had fewer than 500 individuals; the range was 8 to 2136 individuals. They also described three different types of schools, juvenile, adult, and mixed, to which Striped Dolphins belonged at different times according to their age and reproductive condition. The average size of schools taken in the Japanese drive fisheries was 360 individuals (Nishiwaki 1975). From 114 sightings from the northeast coast of the United States, the mean estimated group size was 64.9, with a mode of 20, and a range from 1 to 500 individuals. In this area, Striped Dolphins were observed in the largest groups of all small cetacean species observed (CETAP 1982).

Food items recorded include fish, squid, and shrimp; myctophid fishes and the shrimp *Bentheogennema borealis* were dominant in the stomach contents of 27 individuals taken off the coast of Japan (Miyazaki et al. 1973). Feeding on anchovies and sardines in the Mediterranean has been suggested (Di Natale 1979).

Associations with seabirds, and at least nine other species of marine mammals, have been noted. These include Atlantic White-sided Dolphins (*Lagenorhynchus acutus*), Common Dolphins, Long-finned Pilot Whales (*Globicephala melas*), Risso's Dolphins (*Grampus griseus*), Bottlenose Dolphins (*Tursiops truncatus*), other species in the genus *Stenella*, Northern Bottlenose Whales, Sperm Whales (*Physeter macrocephalus*), and Minke Whales (*Balaenoptera acutorostrata*) (Table 1; CETAP 1982; Au and Pitman 1988). Au and Pitman (1988) note that associations with birds and other species of marine mammals occurred in seven and nine percent, respectively, of 139 schools observed in the eastern tropical Pacific.

Di Natale (1983) notes that Striped Dolphins have been recorded at swimming speeds up to 32 knots. Striped Dolphins are among the most acrobatic of dolphins (Figure 3), and have been reported to ride the bow waves of boats by many authors. However, Au and Perryman (1982) found that schools of *Stenella*, including the Striped Dolphin, exhibited an avoidance response to boats from as far away as six or more miles. It is possible that in certain areas, such as the eastern tropical Pacific where they have been pursued by tuna purse seine boats, they have learned to avoid vessels. In such areas this may result in a significant reduction in sighting probability by ship-board observers. Animals sighted off Nova Scotia in 1989 and 1990 came to the bow of

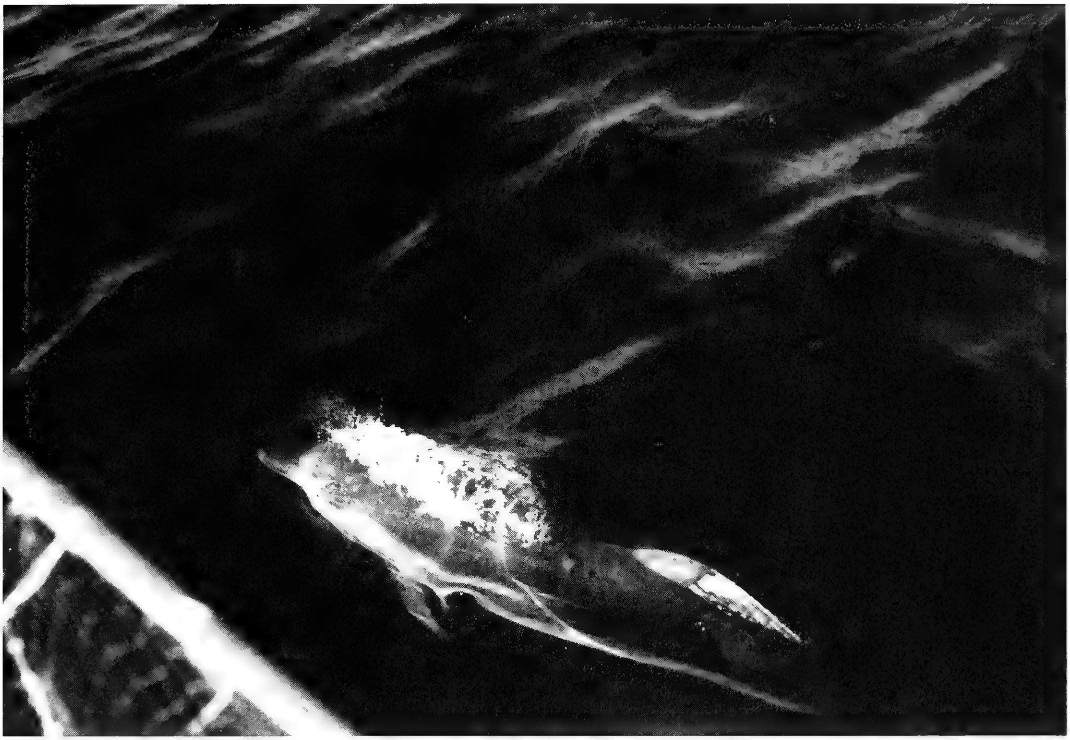

FIGURE 4. Striped Dolphin riding the bow wave on a research boat off Nova Scotia, 1989. Photo by H. Whitehead.

the research vessel (Figure 4) and did not appear to take avoidance action. Striped Dolphins have been maintained in captivity in Japan, but little appears to be known about their captive behaviour (Defran and Pryor 1980).

Limiting Factors

A shark attack on an ailing individual has been reported (Ross and Bass 1971). Predation by Killer Whales (*Orcinus orca*) has not been observed (Jefferson et al. 1991), but remains have been recovered from Killer Whale stomach contents (Nishiwaki and Handa 1958). Although predation by False Killer Whales (*Pseudorca crassidens*) has not been documented, it may occur in association with tuna purse seine operations in the eastern tropical Pacific, as has been reported for other species in the genus *Stenella* (Perryman and Foster 1980).

A variety of parasites have been reported from this species, including the nematodes *Halocercus lagenorhynchi*, *Halocerus delphini*, *Anisakis simplex, Anisakis typica;* the trematodes *Nasitrema* sp., *Pholetes gastrophilus*, *Campula rochebruni* and *Campula delphini*; the cestodes *Monorygma* spp., *Phyllobothrium delphini*, *Strobilocephalus triangularis* and *Tetrabothrius fosteri;* and the protozoan *Sarcocystis* sp. (Horning and Pilleri 1969; Ross and Bass 1971; Zam et al. 1971; Dailey and Brownell 1972; Dollfus 1974; Dailey and Stroud 1978; Dailey and Walker 1978; Viale 1981; Gales et al. 1985). Although presumably not detrimental to individuals, the external parasitic barnacle *Xenobalanus globicipitis*, as well as cyamids, have been recorded from this species (Pilleri 1970; Pilleri and Knuckey 1969; Ross 1984). The role of most parasites in mortality is generally unknown, although *Nasitrema* sp. has been implicated in the death of one individual off Florida (O'Shea et al. 1991). Infection by the yeast *Cryptococcus neoformas* has been implicated in the cause of death in an animal off Australia (Gales et al. 1985). Howard et al. (1983) note that pathogenic bacteria are probably responsible for most diseases and deaths in marine mammals. A morbillivirus has recently been implicated in the deaths of at least 400 Striped Dolphins in the Mediterranean (Domingo et al. 1990). O'Shea et al. (1991) note a pneumonia associated with the bacteria *Vibrio damsela* contributing to the death of a Striped Dolphin off Florida. Mass strandings have been reported for Striped Dolphins (Duguy 1987), but only infrequently (Sergeant 1982).

Striped Dolphins have been involved in the Yellowfin Tuna (*Thunnus albacares*) purse seine fishery in the eastern Tropical Pacific (Perrin 1975;

Wahlen et al. 1988), where hundreds have been killed yearly (e.g., Chivers et al. 1990; Hall and Boyer 1990). Small numbers have also been captured in tuna purse nets and swordfish driftnets in the Mediterranean (Di Natale 1983; Notarbartolo-di-Sciara 1990), and killed incidentally in gill nets off France (Duguy and Hussenot 1982). Jamieson and Heritage (1989) reported a single *Stenella* sp. taken in a Canadian experimental fishery for Flying Squid in British Columbia waters in 1987. The Striped Dolphin, along with other species of small cetaceans, have long been captured in Japan in both small type whaling and local fisheries (Ohsumi 1972). Up to 20 000 Striped Dolphins have been taken annually in drive fisheries off Japan (Nishiwaki 1975). Directed takes in Japanese coastal fisheries in recent years have been lower, ranging from 1225 to 2918 (IWC 1988, 1989, 1990, 1991), and the decline in catch may reflect a decrease in the population size, rather than a reduction in effort (Kasuya 1985). Aguayo-L. and Perdomo-V. (1985) report that Striped Dolphins may be taken for use as bait in a shark fishery in the Gulf of California.

The Striped Dolphin has been the subject of several detailed toxicological analyses (ie., Honda et al. 1982; Honda and Tatsukawa 1983; Honda et al. 1983; Honda et al. 1984a; Honda et al. 1984b; Tanabe et al. 1984). High levels of organochlorines have been detected in tissues taken from stranded and captured animals (Taruski et al. 1975; O'Shea et al. 1980). Significantly higher levels of mercury have been documented in Striped Dolphins compared with virtually all other species of cetaceans examined (Wagemann and Muir 1984). However, the role of contaminants in mortality is largely unknown.

Evaluation

This species appears to be only an uncommon visitor to Canadian waters. As such, it requires no COSEWIC status designation.

Acknowledgments

We thank the World Wildlife Fund (Canada) for financial assistance for the preparation of this report; Robert Campbell and COSEWIC for providing assistance and support; Kathy Lynch for providing information on records off the east coast; Neville Winchester (University of Victoria) and David Nagorsen (Royal British Columbia Museum) for access to specimens and information; Steve Leatherwood and Bill Perrin for providing photographs; and Randy Reeves and an anonymous reviewer for comments on the manuscript.

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Accepted 15 August 1993

Note added in proof:

An additional record of this species from western Canada, a single animal found dead on the west coast of Graham Island in 1990, has come to our attention. No other details as to precise date or location are available, but this record appears to represent the northern-most occurrence at this species in the eastern North Pacific. A photograph of this animal, apparently a male, is held in the files of the Marine Mammal Research Group (Stranded Whale and Dolphin Program of B.C. SWDP90–43).

Several additional records from eastern Canada have also come to our attention. In early November 1991, six Striped Dolphins were found dead ashore on a stretch of North beach, near Old Main, Sable Island, Two additional Striped Dolphins were found in an advanced state of decomposition about eight weeks later approximately 40 km from the six dolphins, on the north side of East Spit, Sable Island. These individuals may have come ashore during the same period as the six dophins. Measurements, samples for genetic analyses, teeth for aging , and photographs were collected for most animals. Our thanks to Zoe Lucas for providing this information.

Received 1 May 1994

Status of the Bottlenose Dolphin, *Tursiops truncatus*, with Special Reference to Canada*

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Baird, Robin W., Eric L. Walters, and Pam J. Stacey. 1993. Status of the Bottlenose Dolphin, *Tursiops truncatus*, with special reference to Canada. Canadian Field-Naturalist 107(4): 466–480.

The Bottlenose Dolphin, *Tursiops truncatus*, is distributed worldwide in warm temperate and tropical waters. This report reviews the general biology, worldwide status and management of this species, with special reference to its status in Canadian waters. More is known about the biology of the Bottlenose Dolphin than perhaps any other cetacean. No estimates of worldwide population size exist, although there are numerous estimates for specific regions. Two forms are recognized, coastal and offshore; they are distinguishable through a wide variety of characteristics. The species is not threatened, although the population in the Black Sea is currently considered at risk. In some areas, Bottlenose Dolphins are taken deliberately in drive fisheries, and they are caught incidentally in fishing operations worldwide. Levels of pollutants recorded in this species are among the highest recorded from any cetacean. The Bottlenose Dolphin is rare in Canadian waters, where it is at the northern limits of its range. Twenty-two records from eastern Canada, representing only 11 occurrences, are presented. Future records from the Canadian east coast may be less frequent, as an apparently natural die-off in the population off the north east coast of the U.S. in 1987-1988 may have resulted in a population reduction of over 50%. We know of no confirmed records from western Canada, although a stray animal from the inshore waters of Washington State has recently been recorded, and there are historical records from an Indian midden from the outer Washington coast. A single unconfirmed record from offshore British Columbia waters exists.

Le dauphin à gros nez, *Tursiops truncatus*, se rencontre dans les eaux tempérées et tropicales du monde entier. Le présent rapport traite de la biologie générale, de la situation et de la gestion de l'espèce, en insistant plus particulièrement sur sa situation dans les eaux canadiennes. La biologie du dauphin à gros nez est probablement mieux connue que celle de tout autre cétacé. Il n'existe pas d'estimations de la taille de la population mondiale, mais les estimations de la taille de populations vivant dans certaines régions bien définies sont nombreuses. On distingue deux formes de dauphin à gros nez, la forme côtière et la forme hauturière, lesquelles se différencient par de nombreuses caractéristiques. L'espèce n'est pas menacée, bien que la population de la mer Noire soit présentement considérée comme en danger. Dans certaines régions, les dauphins à gros nez sont capturés délibérément dans le cadre d'activités de pêche par rabattage; un petit nombre de dauphins sont également pris accidentellement par des pêcheurs un peu partout dans le monde. Les concentrations de polluants relevées dans les tissus de certains membres de cette espèce sont parmi les plus élevées enregistrées pour tous les cétacés. Le dauphin à gros nez est rare dans les eaux canadiennes, qui se situent à la limite nord de son aire de répartition. Vingt-deux mentions provenant de l'est du Canada, mais ne représentant que 11 spécimens, sont présentées. Le nombre de ces mentions pourrait encore diminuer dans l'avenir: une vague de morts apparement naturelles aurait en effet causé la disparition de plus de la moitié de la population qui vit au large de la côte nord-est des États-Unis en 1987 - 1988. Aucune mention n'a été confirmée dans l'ouest du Canada, bien qu'on ait récemment signalé la présence d'un spécimen dans les eaux côtières de l'État de Washington et que des restes de spécimens appartenant à l'espèce aient été découverts sur le site d'un tertre indien, sur la côte de l'État de Washington. Il existe une autre mention non confirmée concernant un spécimen aperçu dans les eaux situées au large de la Colombie-Britannique.

Key Words: Bottlenose Dolphin, douphin à gros nez, *Tursiops truncatus*, Canada, status.

For many species of cetaceans, the task of reviewing their biology or status is difficult, due to the small number of scattered references. Such is not the case for the Bottlenose Dolphin, *Tursiops truncatus* (Montagu, 1821), a species on which perhaps more has been published than any other cetacean (see, for example, the recent compilation edited by Leatherwood and Reeves 1990). We summarize here the current state of knowledge of the Bottlenose Dolphin (Figure 1), with special reference to its status and management in Canadian waters.

Considerable controversy has existed over the content of the genus *Tursiops*, with *Tursiops aduncus*, considered valid by some until recently (Ross 1977; Ross and Cockcroft 1990). Early designations of two or more species of *Tursiops* reflect the considerable variation in morphological and other characters of this species along geographic and ecologi-

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* Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

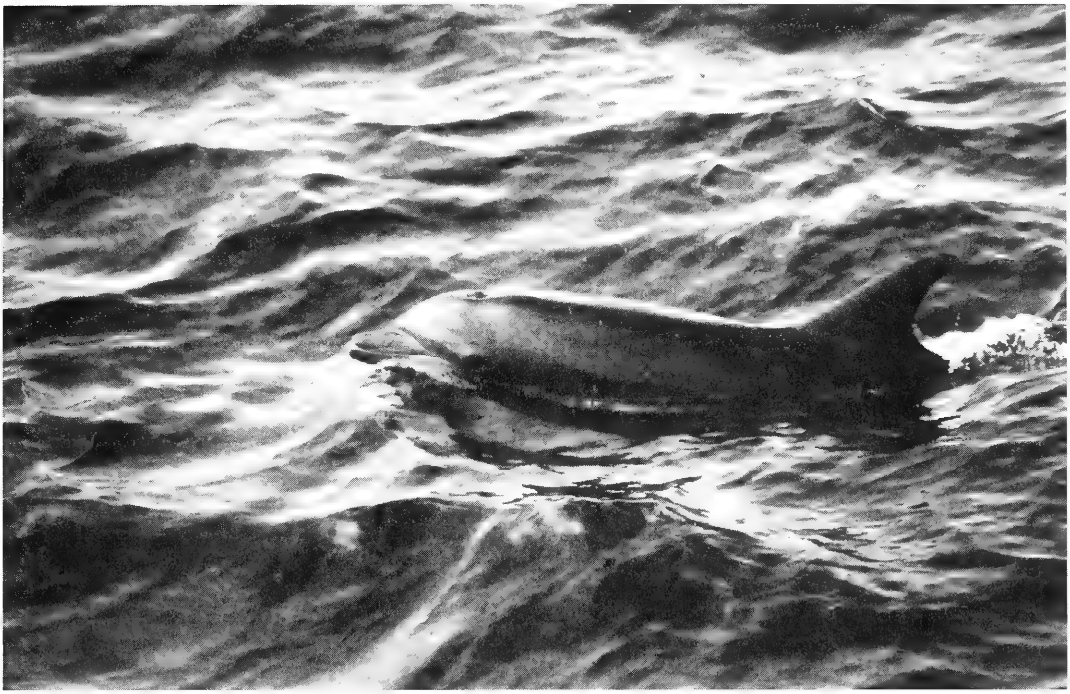

FIGURE 1. Bottlenose Dolphin photographed off Clipperton Island. Note the tall falcate dorsal fin and the well defined beak. Photo by R.L. Pitman, National Marine Fisheries Service.

cal lines. At least two forms of Bottlenose Dolphins do exist; a coastal form and an offshore form. These differ in morphology, blood chemistry, feeding habits and parasite loads (Walker 1981; Duffield et al. 1983; Hersh and Duffield 1990; Mead and Potter 1990). The following review derives information from both currently accepted forms and previous species designations, and the reader must recognize that the wide range in many characters reflects both intra- and inter-population variability.

Bottlenose Dolphins have been recorded at a maximum length of at least 3.9 m and weights up to 490 kg (Leatherwood and Reeves 1983; Mead and Potter 1990). Although some authors have reported that males are larger than females, Hersh et al. (1990) found no evidence for a difference in total body length in animals off the east coast of Florida. Body shape varies considerably between geographic locations, and even within a single group. Most individuals have a short (less than 16 cm), blunt-shaped rostrum and a robust head and trunk region (Leatherwood et al. 1982). The snout is clearly divided from the forehead by a sharp, well-defined line or crease (Leatherwood and Reeves 1983). The pectoral fins are of moderate length and taper to a point (Leatherwood et al. 1982). The tail flukes are deeply notched and have a smooth, concave rear margin (Leatherwood et al. 1982). The dorsal fin is tall and falcate, and is located at the midpoint of the body. The body is so robust in the anterior region however, that the dorsal fin often appears to be posterior to the midpoint (Leatherwood and Reeves 1983). As with other cetaceans, the presence of congenital and acquired markings on the dorsal fin, as well as general dorsal fin shape, allow for the long-term identification of some individuals (Würsig and Würsig 1977). This technique for identifying individuals in the wild has been used in a variety of studies on this species (e.g., Wells and Scott 1990).

General body colour varies, from charcoal to light grey and brown. Leatherwood and Reeves (1983) described the average appearance as follows: The body is marked with a nondescript cape, which begins at the apex of the melon and broadens from the blowhole to the dorsal fin, where it then narrows to a thin line. The flanks appear lighter than the cape, with the ventral surface even lighter still, ranging from light grey to pink. There is no clear division between the flanks and ventral surface based on skin pigmentation. Spots are found on some individuals, and subtle face and throat markings as well as an eye-to-flipper stripe are present but are barely discernible on most individuals. Colour variations include all black, all white, and cinnamon-coloured animals (Hain and Leatherwood 1982; Leatherwood and Reeves 1983). Individuals frequently have numerous scars and scratches on the body, caused by rubbing on inanimate objects, by other Bottlenose Dolphins, or through interspecific interactions (Lockyer and Morris 1985).

Distribution

Dolphins of the genus *Tursiops* are cosmopolitan, found throughout the world with the exception of higher latitudes (Leatherwood and Reeves 1983). They occur in the Indian Ocean from South Africa to Australia; in the eastern Atlantic from southern Norway to the tip of South Africa; in the Mediterranean and Black Seas; in the western Pacific from northern Japan to Australia; in the eastern South Pacific from the equator to Chile; and in the western South Atlantic from the equator to Patagonia, Argentina (Leatherwood and Reeves 1983).

Leatherwood and Reeves (1982) reported that the coastal form of the Bottlenose Dolphin in the eastern North Pacific regularly occurred as far north as southern California. At that time, the northern most records reported were two confirmed records at San Francisco (Orr 1963; Walker 1981). Surprisingly, the type specimen for *Tursiops gilli* was collected in Monterey Bay, which until recently was considered somewhat out of the regular range of the Bottlenose Dolphin. Subsequent to Leatherwood and Reeves' (1982) publication, coastal Bottlenose Dolphins expanded their range northward from southern to central California (Wells et al. 1990). More recently,

TABLE 1. Records of the Bottlenose Dolphin within the Canadian 320 km (200 mi) extended economic zone. Twenty-two records (listed as "positive" identifications by the observers) from the east coast are presented, but multiple records from single dates exist, likely indicating only 11 occurrences from the east coast. One unconfirmed record from the west coast is presented.

Date	Location	Number	Type[A]	Depth[B]	Temp[C]	Source[D]
East Coast						
15 September 1950	Petitcodiac River, NB	1	1	—	—	1
3 September 1968	Milford, NS 45°05’N, 63°25’W	1	2	—	—	2[E]
27 June 1969	NE edge Artimon Bank ≈ 45°10’N, 57°49’W	4	3	—	≈9	3
24 August 1969	43°50’N, 59°14’W	—	3	—	—	4
24 August 1969	43°53’N, 59°2’W	6	3	—	—	4
18 August 1978	42°5’N, 61°4’W	15	3	—	—	4
25 April 1979	41°19’N, 65°47’W	10	3	1100	9.4	4
25 April 1979	41°24’N, 65°53’W	40	3	390	9.9	4
9 August 1979	42°7’N, 66°18’W	10	3	60	18.9	4
18 August 1979	42°5’N, 61°4’W	17	3	—	—	4
30 May 1980	41°36’N, 66°2’W	2	3	50	11.2	4
30 May 1980	41°11’N, 66°14’W	9	3	600	15.5	4
30 May 1980	41°49’N, 66°33’W	1	3	40	9.1	4
26 June 1980	41°42’N, 66°18’W	20	3	45	—	4
25 August 1980	41°51’N, 65°47’W	12	3	75	17.5	4
25 August 1980	41°54’N, 66°0’W	25	3	50	18.0	4
25 August 1980	41°54’N, 66°0’W	26	3	50	18.0	4
25 August 1980	41°16’N, 65°56’W	4	3	800	24.5	4
25 August 1980	41°18’N, 66°1’W	3	3	700	25.0	4
25 August 1980	41°21’N, 66°4’W	39	3	100	24.0	4
25 August 1980	41°21’N, 66°5’W	60	3	100	24.0	4
25 August 1980	41°19’N, 66°22’W	15	3	50	24.0	4
21 January 1981	41°24’N, 65°56’W	20	3	300	10.0	4
West Coast						
13 September 1986	50°01.6’N, 133°11.5’W	1	4	—	—	5[F]

[A] Type of Record: 1. Killed; 2. Stranded, dead; 3. Sighting; 4. Caught in fishing gear, released alive.

[B] Depth in fathoms.

[C] Sea surface temperature in degrees celsius.

[D] Source of Record: 1. Sergeant and Fisher 1957; 2. Sergeant et al. 1970; 3. Beamish and Mitchell 1973; 4. Unpublished data collected through the CETAP program, University of Rhode Island, provided by R. Kenney; 5. Unpublished field notes of R. Burke, courtesy D. Heritage, Department of Fisheries and Oceans, Nanaimo.

[E] Identification not positive. This record is of a dead individual found washed up at the upstream limit of tidal penetration into the Shubenacadie River, Nova Scotia.

[F] Identification not positive.

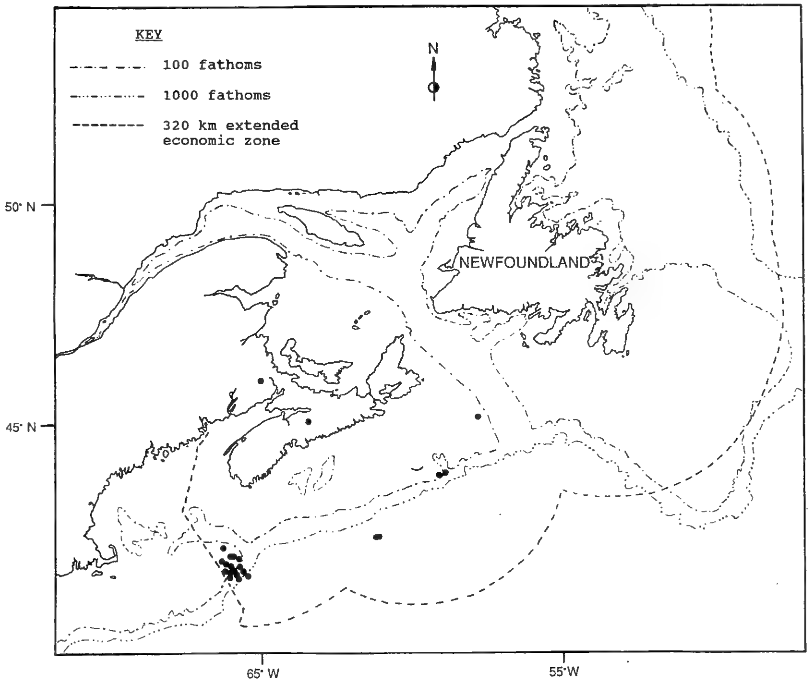

FIGURE 2. Locations of records of Bottlenose Dolphins off Canada's east coast (see Table 1 for details).

in March 1988, a single animal, apparently of the coastal form, was found dead in the inshore waters of Washington State (Osborne and Ransom 1988; Ferrero and Tsunoda 1989). This specimen was not the first record for Washington State however, as W. A. Walker (personal communication) has identified the remains of at least five Bottlenose Dolphins from an Indian midden near Willapa Bay, on the outer coast of southern Washington. Unfortunately the midden site was disturbed, and the age of the remains are unknown at this time. Based on skeletal characteristics, these specimens appear to be of the coastal form (W. A. Walker, personal communication). Nearby habitats are typical of areas that Bottlenose Dolphins frequent further to the south, and it is unlikely that these specimens came from a single stranding event, as mass strandings in this species are very infrequent (*see* Limiting Factors, below). Two possibilities account for such records north of the present day range; long-term expansions and contractions of the range, or short-term movements associated with warm-water events. Unfortunately, current information is insufficient to determine which of these explanations is most likely. The March 1988 stranding is to the northeast of the southernmost portion of Vancouver Island, British Columbia, and thus the animal likely moved through B.C. waters. However, we know of no other confirmed records of Bottlenose Dolphins from western Canada. Because of the limited research effort, information on the distribution of offshore Bottlenose Dolphins in the temperate eastern North Pacific is less detailed than for inshore populations. Walker (1981) indicated that offshore forms have been sighted only as far north as Point Conception, California (approximate latitude 34°31'N), although skeletal remains dredged from San Francisco Bay in 1980 were from an offshore individual. The Department of Commerce (1978) alleged that the Bottlenose Dolphin "infrequently occurs in offshore currents, perhaps as far north as southern Oregon", but at present there are no data to support this contention. One possible record exists from offshore British Columbia of an animal caught and released alive during experimental fishing for Flying Squid (*Ommastrephes bartrami*), over 150 nautical miles off the northern tip of Vancouver Island (details in Table 1). The Canadian Department of Fisheries and Oceans observer, R. Burke, recorded the animal as a probable Bottlenose Dolphin (D. Heritage, personal communication), but unfortunately, confirmation of the identity is not possible.

In the western North Atlantic, Leatherwood and Reeves (1982) noted that there is at least one reliable record from southern Greenland. In Canadian waters, Bottlenose Dolphins have been recorded almost as far north as Newfoundland, with records published by Beamish and Mitchell (1973) and Sergeant and Fisher (1957). Sergeant et al. (1970) also noted a possible record from Milford, Nova Scotia. Kenney (1990) discussed records from the western North Atlantic collected through the Cetacean and Turtle Assessment Program (CETAP) operated out of the University of Rhode Island. Published records noted above and previously unpublished details on records from Canadian waters obtained through the CETAP program (R. Kenney, University of Rhode Island), are presented in Table 1 (Figure 2). Only those CETAP records are included where the identifications were listed as positive. Not including Sergeant et al.'s (1970) possible record, there have been 11 occurrences, represented by 22 records, recorded from the Canadian east coast.

Protection

International

Regulation of international trade between members of the Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973 (CITES), and between non-members and Convention members, has been established by listing the Bottlenose Dolphin under Appendix II of the Convention (*see* Birnie 1982). International trade can take place, but this requires export permits from the country of origin. The International Convention for the Regulation of Whaling (1946) regulates the taking of whales in accordance with the current Schedule provisions. The International Whaling Commission (IWC) is responsible for whale management under this Convention, but whether the Commission's mandate covers small cetaceans is rather unclear, as members of the Commission are divided as to whether "whale" refers to all cetaceans, or only to some species (Klinowska 1987). In 1990, however, delegates to the IWC adopted a resolution requesting their Scientific Committee to assess the status of small cetaceans and the impacts of direct and incidental takes. For years the Small Cetaceans Subcommittee of the IWC Scientific Committee has reviewed the status of small cetaceans, although until now they have had little support in this task from the Scientific Committee or Commission as a whole. Regardless, Canada is not currently a member of the IWC, having withdrawn in 1982 (International Whaling Commission 1982).

National

Canada: Until they were repealed in 1993, the Cetacean Protection Regulations of the Fisheries Act of Canada of 1867 protected all cetacean species from "hunting". "Hunting was defined as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner", and could be only be undertaken under licence. Aboriginal "hunting", however, could be undertaken without licences. The Cetacean Protection Regulations were replaced with the Marine Mammal Regulations of the Fisheries Act in early 1993. These regulations appear to provide no more or no less protection, by stating only that "no person should disturb a marine mammal except when ... under the authority of these regulations." No provisions for regulation of incidental catches in fishing operations exist.

United States: All cetaceans are protected through the Marine Mammal Protection Act of 1972, as well as through the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of the Fisherman's Protective Act.

Population Size(s) and Trends

No estimates of worldwide population sizes exist. The U.S. Department of Commerce (1988) estimated a level between 14 000 and 23 000 for the western North Atlantic, although this is prior to the die-off which occurred in 1987-1988 (see Limiting Factors below), and the methodology from which the estimate was determined was not indicated. The U.S. Marine Mammal Commission (1990) noted that the Bottlenose Dolphin is the most common cetacean in the coastal waters of the southeast United States. Subsequent to the 1987-1988 die-off however, there has been a move for the National Marine Fisheries Service to designate this population as depleted (Marine Mammal Commission 1990). Kenney (1990) reported seasonal estimates for the continental shelf waters off the northeastern U.S. coast which varied from a minimum of 1500 to 2300 in the winter and 9700 to 12 800 during the summer. Numerous estimates exist for small areas along the southeast U.S. coast and the Gulf of Mexico (e.g., Leatherwood 1979; Barham et al. 1980; Irvine et al. 1981). Barham et al. (1980) presented a population estimate of 1319 for a region of the Texas coast, which, based on their density and population estimates, is an area of approximately 1750 km^2. Estimates provided by Odell and Reynolds (1980) for the west coast of Florida and the Florida panhandle totalled 787 ± 269 and 744 ± 527 (± 95% C.I.) individuals respectively. Holt and Powers (1980) estimated, for a portion of the eastern Tropical Pacific, 40 200 individuals.

No accurate estimates of population trends are available. There have been some reports of localized decreases in numbers, but documentation and comprehensive studies are for the most part lacking. Although the species is not considered threatened, the population of Bottlenose Dolphins in the Black Sea is currently considered at risk (Brownell et al. 1989). Kayes (1985) reviewed evidence indicating a decline in numbers of Bottlenose Dolphins in the North Sea. In 1942, Gunter suggested that the number of Bottlenose Dolphins along the Texas coast had declined in the preceding 40 years. Bottlenose

Dolphins were apparently absent from San Diego Bay for a period of about 10 years, reportedly due to high levels of pollution there, but subsequently reappeared as pollution levels decreased (Leatherwood and Reeves 1982).

Habitat

The Bottlenose Dolphin is found in a wide variety of habitats, both coastal and offshore. In the U.S., where most studies have been undertaken, the coastal form of the dolphin has been found to occur in rivers (Gunter 1942), coastal channels and waterways (Irvine and Wells 1972; Shane 1980; Scott et al. 1990), and enclosed protected bays and seagrass meadows (Scott et al. 1990). In Argentina, Bottlenose Dolphins observed from shore spend 92% of their time in water less than 10 m deep (Würsig and Würsig 1979). Studies by CETAP have documented the presence of the Bottlenose Dolphin off the northeast coast of the U.S., along the continental shelf, Georges Bank, and the shelf-break region (Kenney 1990). The offshore form of Bottlenose Dolphin inhabits the waters around offshore islands as well as the open ocean (Leatherwood and Reeves 1982; Figure 1). Sightings of Bottlenose Dolphins in mainly offshore areas in the eastern tropical Pacific are presented in Scott and Chivers (1990) and indicate a wide distribution in this area. Au and Perryman (1985) identified two different areas in the eastern tropical Pacific, defined by their water masses, that have specific dolphin communities. One area is characterized by Common Dolphins (*Delphinus delphis*), Striped Dolphins (*Stenella coeruleoalba*), and Short-finned Pilot Whales (*Globicephala macrorhynchus*), and the other by Spotted (*Stenella attenuata*) and Spinner (*Stenella longirostris*) dolphins, while Bottlenose Dolphins are found in both regions.

Kenney (1990) presented information on sea-surface temperatures from 607 sightings in the eastern North Atlantic, in the region from North Carolina to Nova Scotia. Sea-surface temperatures from sightings ranged from 1°C to 31.1°C, with a mean of 19.7°C, and a mode of 20°–22.5°C. Sightings in offshore waters were in cooler waters than those in nearshore areas. This is relevant to potential sightings in Canadian waters, indicating both that sightings should not be completely precluded by low water temperatures, and that sightings might be expected more frequently in offshore waters. Water temperatures from 15 of the records presented in Table 1 range from 9.1° to 25°C, with a mean temperature of 17.3°C.

General Biology

Reproduction

Estimates of sex ratios vary between areas, and between captive and wild populations. Collet (1984) found that females comprised 80% of captive-born calves. Kasuya (1985) showed that of about 500 Bottlenose Dolphins for which sex was determined in a Japanese drive fishery, 57.3% were females. Sergeant et al. (1973) noted a sex ratio of about 1:1 in a sample of 61 animals captured off Florida. Perrin and Reilly (1984) summarized other sex ratios reported from the Black Sea and the western North Atlantic, which range from about 47%–66% females.

Estimates of gestation range from 11.5–14 months (Perrin and Reilly 1984; Kasuya 1985). Schroeder (1990) found that births usually occur during the night, nearer dawn than dusk, and labour can last from 20 minutes to 2 hours. Length at birth has been recorded as being from 0.84 to 1.26 m (Harrison et al. 1969; Ross 1984). Suckling occurs both day and night, and in a captive animal was more frequently observed at night (Eastcott and Dickinson 1987). Suckling typically occurs two to four times an hour for less than a minute (Harrison 1969; Schroeder 1990). Calves are weaned at an average age of 18–20 months, although first solid food is taken between 4–11 months (Perrin and Reilly 1984); weaning is likely complete when a body length of 170–180 cm is reached (Barros and Odell 1990). The oldest nursing calf recorded by Perrin and Reilly (1984) was 38 months old. Echolocation and other feeding-related behaviour is believed to be learned during this prolonged period of nursing (Leatherwood and Reeves 1983). Bottlenose Dolphin calves are closely watched by adults during the first half-year, and "babysitting" has been observed, in which nearby adults remain with a calf as its mother forages. Offspring typically remain with their mothers for three to six years, although some associations last longer (Scott et al. 1990).

Estimates of sexual maturity are based both on examination of reproductive tracts from animals killed in fisheries, and from long-term observational studies of wild populations. The former estimates are dependent on the ability to determine age, using growth layer groups (GLGs) in the teeth. Hohn et al. (1989), using teeth pulled from known-aged individuals from a population off Florida, demonstrated that growth layer groups are deposited annually. Males reach sexual maturity between 9 and 20 years of age, with an average of 11 years (Perrin and Reilly 1984). Females apparently can attain sexual maturity at a younger age, with a range from 3.5 to 14 years of age, although the average age is 12 years (Perrin and Reilly 1984; Kasuya 1985). As noted above however, such estimates may be applicable only for some populations; Kasuya (1985) noted that in the animals off Japan, 50% of the females were sexually mature by 6.9 years of age, at a mean body length of about 2.86 m.

Once reproductively active, females bear a single calf, at an interval estimated to be from 1.3 to 2 years (Perrin and Reilly 1984; Ozharovskaya 1990). Based both on the observed presence of young calves and on hormone levels, calving is suggested to occur primarily from early spring to early fall, although calving year-round is known to occur (Harrison et al. 1969; Ozharovskaya 1990; Scott et al. 1990). In a captive male, Schroeder and Keller (1989) found that peak sperm production and density coincided with a fall peak in breeding activity. A promiscuous mating system has been suggested by Scott et al. (1990). Schroeder (1990) indicated that Bottlenose Dolphins are spontaneous ovulators, and captive animals have ovulated up to 7 times in a 13 month period. In their study around Sarasota, Florida, the oldest male examined was estimated at 34 years old, while the oldest female was estimated at 46 years old (Scott et al. 1990).

Species Movements

Bottlenose Dolphins may inhabit limited home ranges along overlapping segments of coast, although long-distance movements, up to 600 km, have been recorded by Wells et al. (1990), who also found that northward movements in the eastern North Pacific are linked either directly or indirectly (i.e., in response to movements of prey) to variations in water temperature. The offshore form appears less restricted in range and movements, being present in many productive areas, particularly in the tropics (Leatherwood and Reeves 1983). Burn et al. (1987) found that the distribution of dolphins off Florida appears to shift from the southwest coast north toward the Panhandle area during the fall. In the Gulf of Mexico they also found seasonal inshore/offshore changes in abundance. Seasonal movements by a proportion of the population off Texas have also been reported by Shane (1980), possibly due to changes in water temperature and food availability. Some Bottlenose Dolphins appear to be "resident" of particular areas such as the offshore islands of Clipperton and Galapagos (Leatherwood et al. 1982).

Behaviour

Scott and Chivers (1990), analyzing records from the eastern Tropical Pacific, recorded mean and median group sizes of offshore Bottlenose Dolphins of 57 and 10 individuals respectively. They also noted that herds of over 1000 individuals made up about 1% of the sightings (n = 5461) compiled from that area and suggested that some herds could contain as many as 10 000 individuals. Coastal Bottlenose Dolphins are normally found in groups of fewer than ten (Leatherwood and Reeves 1983). Barham et al. (1980) found a mean herd size of 6.95 for dolphins off the Gulf Coast of Texas, and noted that 9.3% of a typical herd consisted of calves.

Inshore Bottlenose Dolphins appear to be quite liberal in their feeding habits, taking a wide variety of fishes, crustaceans, and cephalopods (Barros and Odell 1990; Leatherwood et al. 1982). Walker (1981) noted that coastal animals from southern California feed primarily on fish and invertebrates inhabiting littoral and sub-littoral zones. Barros and Odell (1990) found that prey size ranged from about 5–30 cm. In many areas, Bottlenose Dolphins have adapted their feeding to take advantage of human activities, including ramming trawl nets to spill net contents, taking fish out of nets, eating fish discarded by fishermen or stirred up by nets and propeller washes, or catching fish attracted to idle vessels and fixed platforms (Leatherwood and Reeves 1983; Abel and Leatherwood 1985; see also Special Significance of the Species, below). Near the surface, Bottlenose Dolphins occasionally invert and feed upside-down, presumably to aid in echolocation by reducing noise from surface echoes (Leatherwood and Reeves 1983). Barros and Myrberg (1987) suggested that passive listening for "noisy" fish is an important cue in prey choice. Various types of cooperative hunting have been reported. Similar to the deliberate beach stranding behaviour reported for Killer Whales (*Orcinus orca*; Lopez and Lopez 1985; Guinet 1990), in some areas Bottlenose Dolphins chase and wash fish onto mudbanks, following them onto shore, and snapping up the stranded prey (Hoese 1971; Rigley 1983). Offshore Bottlenose Dolphins appear to feed primarily on epipelagic fish and cephalopods (Walker 1981).

Associations with at least 24 species of cetaceans have been recorded, including: Sperm Whale (*Physeter macrocephalus*), Risso's Dolphin (*Grampus griseus*), Short-finned Pilot Whale, Long-finned Pilot Whale (*Globicephala melas*), False Killer Whale (*Pseudorca crassidens*), Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), Atlantic White-sided Dolphin (*Lagenorhynchus acutus*), White-beaked Dolphin (*Lagenorhynchus albirostris*), Fraser's Dolphin (*Lagenodelphis hosei*), Melon-headed Whale (*Peponocephala electra*), Northern Right Whale Dolphin (*Lissodelphis borealis*), Rough-toothed Dolphin (*Steno bredanensis*), Common Dolphin, Indo-Pacific Humpbacked Dolphin (*Sousa chinensis*), Spotted Dolphins (*Stenella frontalis* and *Stenella attenuata*), Spinner Dolphin, Striped Dolphin, Southern Right Whale (*Eubalaena glacialis*), Fin Whale (*Balaenoptera physalus*), Minke Whale (*Balaenoptera acutorostrata*), and Sei Whale (*Balaenoptera borealis*) (Kraus and Gihr 1971; Leatherwood and Walker 1979; Würsig and Würsig 1979; Evans 1982; Martin 1986; Au and Pitman 1988; Corkeron 1990; Kenney 1990; Scott and Chivers 1990). Bottlenose Dolphins are often observed bow-riding or wake-riding on moving vessels (Figure 3), and will also ride ground swells and pressure waves of big whales such as Grey (*Eschrichtius robustus*) and Humpback (*Megaptera novaeangliae*) whales (Leatherwood

FIGURE 3. Bottlenose Dolphins playing in a vessel's stern wake, in the eastern Tropical Pacific. Photo by K. Sexton, National Marine Fisheries Service.

1974; Leatherwood et al. 1982; they can also frequently be found body surfing in nearshore areas – e.g., Caldwell and Fields 1959). Würsig and Würsig (1980) reported that although they recorded Bottlenose Dolphins within 0.5 km of Dusky Dolphins (*Lagenorhynchus obscurus*) on eight occasions, no interactions were observed, and each species was more abundant when the other was absent. Associations with seabirds and pinnipeds also occur (Würsig and Würsig 1979; Evans 1980; Martin 1986; Au and Pitman 1988). In captivity, Brown and Norris (1956) observed interspecific mating every day between male Bottlenose Dolphins and female Pacific White-sided Dolphins. Interspecific associations in captivity are not always so benign, however: they also noted a case where a male Bottlenose Dolphin killed a male Pacific White-sided Dolphin in captivity.

Limiting Factors

Throughout their range, Bottlenose Dolphins are strongly attracted by human activities (see e.g., Abel and Leatherwood 1985). They exhibit great behavioural flexibility (Shane 1990); their ability to adapt to human disturbance, in areas with high levels of fishing activity and boat traffic, may be responsible for frequent conflicts with humans. In some areas Bottlenose Dolphins have been shot as a nuisance to fishermen (Leatherwood and Reeves 1983; Reynolds 1985). Mortality by collisions with vessel propellers, particularly in confined areas, has been recorded (Reynolds 1985). A net fishery for Bottlenose Dolphins was operated periodically for over 100 years off the N.E. coast of the U.S., with catches in peak years of 2000 or more annually (Mead 1975). This fishery was discontinued in about 1929. In the Black Sea, a commercial fishery for oil and fishmeal depleted the Bottlenose Dolphin population severely by the mid-1960s, after which the Soviet Union terminated its harvest (Mitchell 1975; Leatherwood and Reeves 1983). Hunting by Turkey continues, however, and unknown numbers are taken annually (Leatherwood and Reeves 1983). A few are taken for food in Sri Lanka, West Africa, Venezuela, the West Indies, and other parts of the world (Leatherwood and Reeves 1983). Over a seven year period, from 1976 to 1982, over four thousand Bottlenose Dolphins were killed in drive fisheries off Japan, the largest number of the four species regularly taken (Kasuya 1985). Small numbers continue to be killed there, and in drive fisheries off the Faroe Islands (Bloch and Hoydal 1989; International Whaling Commission 1990, 1991). In Peru, up to several hundred Bottlenose Dolphins are killed annually for human consumption, in gillnets, purse seines and occasionally with beach seines and hand-thrown harpoons (Waerebeek et al. 1990). Small numbers are killed incidently in seine and gillnet fisheries worldwide (e.g., Harwood et al. 1984; Reynolds 1985; Chivers et al. 1990; Heyning et al. 1990; International Whaling Commission 1990, 1991; Notarbartolo-di-Sciara 1990). Animals are also killed in anti-shark nets off Australia and South Africa (Ross 1984; Cockcroft 1987; Australia 1990). Studies have been made to try to identify possible environmental and behavioural factors that may be contributing to this incidental catch, but no relationships have been found (Cockcroft 1987).

The United States has had a controlled live-capture fishery for the species in operation since 1938 (Leatherwood and Reeves 1983). Most animals have been taken off eastern Florida, in the Gulf of Mexico, and off southern California. Scattered live specimens have also been captured in recent years off Hawaii, South Africa, Japan, Mexico, the Philippines, Bahamas, and in the Mediterranean (Leatherwood and Reeves 1983). Leatherwood and Reeves (1982) noted that over 1500 were brought into captivity between 1938 and 1980.

There is a potential problem with humans feeding Bottlenose Dolphins in the wild. Commercial cruises operate out of several states in the U.S., including Florida, Georgia and South Carolina, taking people out to feed fish to wild dolphins. Young (1990) reported that fish handling techniques currently used could easily result in the transfer of pathogens to dolphins. As well, there are fears that allowing dolphins to rely on fish from feeding cruises could result in serious disruption of normal behaviour.

Large numbers of Bottlenose Dolphins off the east and Gulf of Mexico coasts of the U.S. have died in recent years. Geraci (1989) suggested that the primary cause of death for animals from the east coast stranding event was poisoning by brevetoxin, a neurotoxin produced by the dinoflagellate *Ptychodiscus brevis*. An estimated 50% or more of the coastal migratory stock between Florida and New Jersey died between June 1987 and May 1988 (Scott et al. 1988; Marine Mammal Commission 1990), and this stock may be considered depleted. Certainly the likelihood of animals from the U.S. north east coast straying into east coast Canadian waters must be much lower as a consequence of this die-off.

A wide variety of pollutants have been recorded in the tissues of this species (O'Shea et al. 1980; Geraci 1989; Morris et al. 1989). Geraci (1989) indicated that levels of contaminants, such as PCBs and DDE, in animals off the U.S. east coast are among the highest recorded from any cetacean worldwide, although the role of pollutants in mortality remains unknown. The potential effects of oil are largely unknown, but Würsig (1990) suggested that among the odontocetes, Bottlenose Dolphins are one of the few species that may be exposed to the highest risk. Another potential threat to this species is through competition with humans for food, by human over-utilization of fish stocks.

Because of the large numbers of animals held in captivity, and as a result of investigations into the recent U.S. east coast die-off, considerable research into causes of mortality have been undertaken. A variety of diseases and pathologies have been recorded from this species, including; acute pancreatitis, blastomycosis, chronic pancreatic fibrosis, gastric ulcers, hypertensive intracerebral hemorrhage, lobomycosis, malignant pustules, mitral valve endocardiosis, myocardial rhabdomyolysis, puerperal sepsis, renal tubular adenoma, and vertebral osteomyelitis (Tomilin 1957; Geraci and Gerstmann 1966; Medway et al. 1966; Sweeney and Ridgway 1975; Dudok van Heel 1977; Hall et al. 1977; Greenwood and Taylor 1979; Greenwood and Tinsley 1979; Cates et al. 1986; Alexander et al. 1989; Geraci 1989). A variety of bacteria, including; *Acinetobacter*, *Aspergillus fumigatus*, *Bacillus*, *Clostridium perfrengens*, *Edwardsiella*, *Erysipelothrix insidiosa*, *Klebsiella*, *Pasteurella multocida*, *Pseudomonas*, *Staphylococcus*, *Streptococcus*, *Vibrio damsela*, and *Vibrio alginolyticus*, have been recovered from this species (Fujioka et al. 1988; Geraci et al. 1966; Sweeney and Ridgway 1975; Greenwood and Taylor 1979; Schroeder et al. 1985; Geraci 1989). Viruses have also been recorded, including papovavirus and several reovirus-like forms (Geraci 1989). Heavy infestations of some parasites may contribute to mortality. A wide variety of parasites have been recorded, including *Anisakis tursionis*, *Anisakis typica*, *Anisakis marina*, *Braunina cordiformis*, *Campula oblonga*, *Campula delphini*, *Campula palliata*, *Corynosoma cetaceum*, *Crassicauda crassicauda*, *Diphyllobothrium* sp., *Gnathostoma* sp., *Halocercus lagenorhynchi*, *Isocyamus delphini*, *Monorygma grymaldii*, *Nasitrema delphini*, *Pholetes gastrophilus*, *Phyllobothrium delphini*, *Stenurus ovatus*, *Stenurus minor*, *Syncyamus* sp., *Synthesium tursionis*, and *Xenobalanus globicipitis* (Tomilin 1957; Johnston and Ridgway 1969; Zam et al. 1971; Margolis and Dailey 1972; Duguy 1978; Greenwood and Taylor 1979; Greenwood et al. 1979; Ross 1984).

Predation by sharks, evidenced largely by healed wounds and occasional shark stomach contents, has been recorded (Wood et al. 1970). Tomilin (1957) and Wells et al. (1980) reported that Killer Whales prey on Bottlenose Dolphins, although surprisingly, no records of actual predation by Killer Whales appear to be available (Jefferson et al. 1991). Würsig and Würsig (1979) reported two instances where Bottlenose Dolphins moved away from Killer Whales, and recorded one individual with possible

Killer Whale tooth rakes on its side. Death related to food acquisition has been recorded in several cases, by blockage of air passages because of attempted ingestion of large prey (Hult et al. 1980), or from injuries from encounters with ray spines (Walsh et al. 1988). Mass strandings of Bottlenose Dolphins usually only comprise a small number of individuals at a time, and occur infrequently (Sergeant 1982).

Special Significance of the Species

The Bottlenose Dolphin is the most common cetacean held in captivity for both public display and scientific research (Figure 4); they have been regularly kept in aquaria since 1914, and were first publicly displayed in Boston in 1861 (Leatherwood and Reeves 1982, 1983). Bottlenose Dolphins have been live-captured for display purposes around the world (Abel and Leatherwood 1985), and have been (or currently are) held in aquaria in several countries, including: Canada, England, France, Hong Kong, Indonesia, Israel, Japan, Netherlands, New Zealand, South Africa, Spain, and the United States (Defran and Pryor 1980). Some of these animals are taken from drive fisheries, and would otherwise be killed and used for human consumption (Abel and Leatherwood 1985). In recent years, swim-with-dolphin programs in captivity have become very popular; Linden (1989a) showed proceeds of $1 785 000 annually for four operations in Florida and Hawaii. The southeastern United States is the major area for live-capture operations (Burn et al. 1987).

Hybridization in captivity has been documented with the Rough-toothed Dolphin, False Killer Whale, and Risso's Dolphin (Shallenberger and Kang 1977; Nishiwaki and Tobayama 1982; Shimura et al. 1986). Interestingly, Fraser (1940) reported possible hybrids with Risso's Dolphins in the wild off Ireland, and Herzing (1990) reported hybrids in the wild with Atlantic Spotted Dolphins off the Bahamas.

Survival rates of Bottlenose Dolphins in captivity are fairly high; Demaster and Drevenak (1988) estimated mean annual survival rate in captivity of 0.93, for U.S. institutions. The ease of keeping this species, combined with the large number held in captivity, has resulted in numerous studies on a variety of factors related to cetacean biology in general. These have included determination of learning and intelligence characteristics, vision, hearing and echolocation, and pollution detection abilities (e.g., Lawrence and Schevill 1954; Johnson 1968; Hall et al. 1972; Geraci et al. 1983; Forestell and Herman 1988; Au and Moore 1988; Brill et al. 1988). They are also used in open-ocean free-ranging experi-

FIGURE 4. The Bottlenose Dolphin in the most widely kept species of cetacean in captivity. Photo by R.W. Baird/P.J. Stacey.

ments, such as diving physiology studies, diver assistance and rescue, and pingered object recovery (Irvine 1970), these being commonly associated with training done by the U.S. Navy. Individuals have been known to leave the study areas after a training session (Irvine 1970) and it is possible that animals occasionally observed outside the expected normal distribution range may include these escaped animals (*see* Ferrero and Tsunoda 1989). It has been reported in the popular literature that the U.S. Navy may be using Bottlenose Dolphins to patrol a submarine base at Bangor, Washington, in Puget Sound (Linden 1989b). If such is the case, sightings of animals from British Columbia waters in future years should be qualified with this in mind.

Associations with humans, beyond scavenging from fishing vessels or bowriding on boats, occur world-wide. In the Indian and Banana Rivers in Florida, Cato and Prochaska (1976) suggested that Bottlenose Dolphins may cause an estimated $441 000 damage to fishing gear annually, although some proportion of this damage may be due to sharks (Leatherwood 1979). In Shark Bay, Western Australia, groups of Bottlenose Dolphins swim close to shore to interact with people (Connor and Smolker 1985). Such behaviour also frequently occurs with Bottlenose Dolphins, usually solitary individuals, approaching divers and swimmers world-wide (Lockyer 1990). This "sociable" behaviour has been taken to an extreme in one area off Brazil, where Pryor et al (1990) reported that local fishermen and Bottlenose Dolphins cooperatively hunt Mullet, *Mugil cephalus*. The dolphins apparently cooperate in herding fish towards the fishermen, indicate the presence of the fish in turbid waters by characteristic surfacing patterns, and then feed on fish which scatter from the school when the hand-thrown net is used. Such cooperative associations in the wild between humans and other animals have also been noted elsewhere, both with birds or with other cetaceans (Wellings 1944; Isack and Reyer 1989).

Evaluation

The Bottlenose Dolphin is widespread and abundant in tropical and warm temperate seas worldwide. This species is, at most, only a rare visitor to Canadian waters, likely due to thermoregulatory constraints. As such, no COSEWIC status designation is required.

Acknowledgments

We thank the World Wildlife Fund (Canada) for providing financial assistance for the preparation of this report; Robert Campbell and COSEWIC for providing assistance and support; Bill Walker for providing information on the Willapa Bay records; Dwight Heritage for providing details on the cetacean incidental catch of the experimental squid fishery; Bob Kenney, CETAP, for providing details on the Canadian east coast records; Steve Leatherwood for providing photographs; and Tamara Guenther and several anonymous reviewers for helpful comments on the manuscript.

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Accepted 15 August 1993

Status of the Short-finned Pilot Whale, *Globicephala macrorhynchus*, in Canada*

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Stacey, Pam J., and Robin W. Baird. 1993. Status of the Short-finned Pilot Whale, *Globicephala macrorhynchus*, in Canada. Canadian Field-Naturalist 107(4): 481–489.

The Short-finned Pilot Whale, *Globicephala macrorhynchus,* appears to be in the northern limits of its normal range in the waters off British Columbia, and does not inhabit the waters off the east coast of the country. No COSEWIC designation is required regarding its status in Canadian waters. World-wide, one population of Short-finned Pilot Whales, off northern Japan, is currently considered at risk. Insufficient information is available to accurately evaluate its status elsewhere, and it is taken in small numbers both directly and incidentally in fisheries.

Dans le présent rapport, les auteurs examinent la biologie générale, le statut à l'échelon mondial et la gestion du globicéphale du Pacifique (*Globicephala macrorhynchus*), tout en accordant une attention particulière au statut de l'espèce dans les eaux canadiennes. Il semble que les eaux situées au large de la Colombie-Britannique consituent la limite septentrionale de l'aire de répartition du globicéphale du Pacifique et que l'espèce ne fréquente pas les eaux hauturières sur la côte est du Canada. Compte tenu du statut de l'espèce dans les eaux canadiennes, il n'est pas nécessaire de placer celle-ci dans une catégorie du CSEMDC. Sur la scène internationale, une population au large du nord du Japon est actuellement considérée comme en danger. Il n'y a pas assez de renseignements afin d'évaluer avec précision son statut ailleurs. Quelques spécimens sont capturés en petit nombre directement et comme prises accidentelles aux pêches.

Key Words: Short-finned Pilot Whale, Globicéphale du Pacifique, *Globicephala macrorhynchus*, Canada, status, cetacean, North Pacific.

This review summarizes the current state of knowledge of the Short-finned Pilot Whale, *Globicephala macrorhynchus* Gray, 1846, with special reference to its status and management in Canadian waters. This review has been undertaken by request of the Fish and Marine Mammal Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). It is the mandate of COSEWIC to review the status of all Canadian species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES has taken a conservative approach to cetacean management by listing all species under either Appendix I or II. Species listed under Appendix I are considered threatened or endangered; those listed under Appendix II, although not considered threatened, warrant regulation in international trade. Listing species such as the Short-finned Pilot Whale under Appendix II functions to prevent unregulated international trade of threatened species, since non-specialists may not be able to easily distinguish among products from different cetacean species.

The taxonomic history of the genus *Globicephala* is complicated (*see* Hershkovitz 1966). Two species of Pilot Whales are currently recognized world-wide; the Long-finned Pilot Whale (*Globicephala melas*), and the Short-finned Pilot Whale (*Globicephala macrorhynchus*). In the North Pacific, a separate species, the Pacific Pilot Whale (*Globicephala scammoni*) was formerly recognized (Bree 1971). Although there are historical records of Long-finned Pilot Whales off Japan (Kasuya 1975), only Short-finned Pilot Whales are thought to be currently present in the North Pacific. The existence of two forms of Short-finned Pilot Whales off Japan however, termed northern and southern forms, has been noted (Kasuya et al. 1988). Both Short-finned and Long-finned Pilot Whales are found in the North Atlantic, although only Long-finned Pilot Whales are found in the waters off eastern Canada.

The maximum recorded length for the Short-finned Pilot Whale appears to be 6.10 m for males, and between 5.25-5.50 m for females (Perrin and Reilly 1984). The shape of the head is bulbous, and the forehead sometimes overhangs the rostrum; there is no distinct beak (Leatherwood et al. 1988). The projection of the front of the melon over the rostrum occurs when the animal reaches a length of about 240 cm, at an age of about two years (Yonekura et

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*Reviewed and approved by COSEWIC 15 April 1993, report accepted, no status designation required.

al. 1980). The dorsal fin, being generally broader than it is tall, is distinctive (Figure 1). The falcate fin is usually rounded at the tip, and set well forward of the midpoint of the back. The pectoral flippers are long and sickle shaped. The tail stock is elongated and laterally compressed, and the flukes are notched and concave along the rear margin.

The colouration on the dorsal and lateral surfaces is dark grey, brown or black. In most individuals, this is broken by a light grey area, termed a saddle patch, located behind the dorsal fin (Figure 1). Miyashita et al. (1990) noted that of the two forms off Japan, only the northern form has the distinct saddle mark. There is a faint, lightly pigmented patch or blaze behind the eye, extending towards the anterior insertion of the dorsal fin (Yonekura et al. 1980). This patch is difficult to distinguish on live individuals seen from a distance, and disappears shortly after death. The ventral surface has a broad grey patch anterior to and between the flippers, which extends posteriorly as a thinning mid-ventral line, and disappears entirely about halfway to the distal tip of the flipper when pressed against the side of the body (Norris and Prescott 1961). The umbilical and genital areas are also surrounded by small grey patches. Distinguishing between the two species of Pilot Whales is difficult in the field. As the names imply, proportional flipper lengths in the two species generally differ. In Short-finned Pilot Whales, the flippers, from the anterior insertion to tip, range from 15.8 to 18.9% of the total body length, while in Long-finned Pilot Whales, this figure is 21.9 to 26.2% (Yonekura et al. 1980). From stranded or skeletal specimens, Short-finned can often be distinguished from Long-finned Pilot Whales by the fewer number of teeth; 7-9 in each side of the upper and lower jaws, as opposed to 9-12 in Long-finned Pilot Whales (Bree 1971).

Distribution

The Short-finned Pilot Whale is found world-wide in tropical and warm-temperate seas (Leatherwood and Dahlheim 1978). In the western Atlantic they occur from New Jersey, south throughout the Gulf of Mexico and the Caribbean Sea, to São Paulo, Brazil (Casinos and Bou 1980; Mead and Potter 1987; Schmiegelow and Filho 1989). This species has not been recorded from the Canadian east coast. In the eastern Atlantic there are records from as far north as Spain and France, and as far south as 15°S on the African coast (Collet and Duguy 1987; Nores and Perez 1988). This species is found throughout the Indian Ocean (Leatherwood et al. 1991).

In the eastern Pacific, Short-finned Pilot Whales have been reported as far north as the Alaskan Peninsula and the Gulf of Alaska (Orr 1951; Home 1980), down the coast of the Americas as far south

FIGURE 1. Short-finned Pilot Whales off California. Photo by S. Leatherwood.

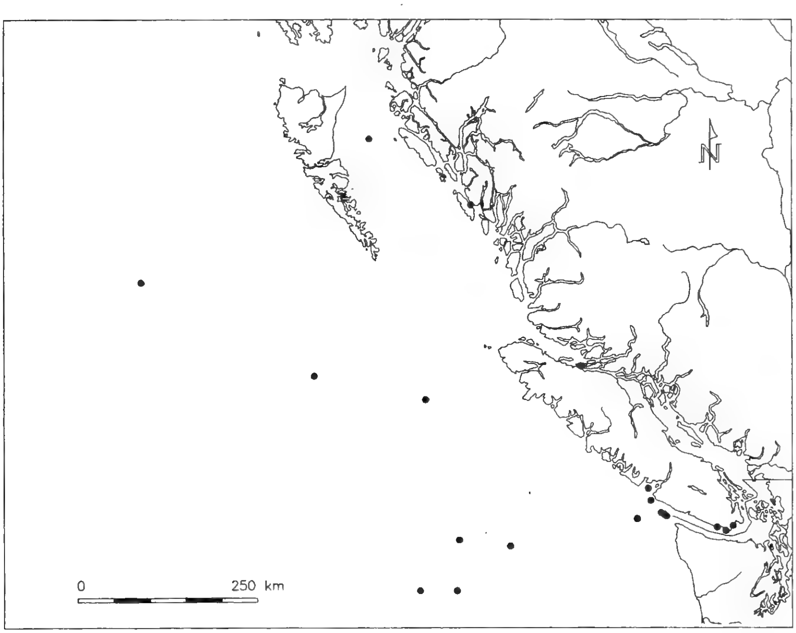

FIGURE 2. Records of Short-finned Pilot Whales in Canadian waters. No records from the Canadian east coast have been reported (Baird and Stacey 1993).

as Peru, and from the Hawaiian Islands (Scheffer and Slipp 1948; Shallenberger 1981; Van Waerebeek and Reyes 1986). In the western Pacific, Short-finned Pilot Whales are known from northern Japan (Wada 1988), to Tazmania (Nicol 1987).

Osgood (1901) and Wailes and Newcombe (1929) noted that Pilot Whales occurred regularly off the British Columbia coast. Some subsequent authors have accepted these early reports as authentic (Scheffer and Slipp 1948; Leatherwood and Dahlheim 1978; Home 1980), although Pike and MacAskie (1969) discounted them, believing them to be records of Killer Whales (*Orcinus orca*). Baird and Stacey (1993) recently reviewed and summarized the presence of Short-finned Pilot Whales in British Columbia waters (Figure 2), and noted that the infrequency of sighting records between 1954 and 1989 lend support to Pike and MacAskie's (1969) conclusions. However, as Shane (1985) noted, warm water El Niño events may disrupt the distribution of Short-finned Pilot Whales, and their presence in more northerly waters could increase during such periods (see Movements, below). In total, only 21 occurrences of Short-finned Pilot Whales have been reported from British Columbia waters to 1989, only one of which is a stranding record, that of a single individual (Pike and MacAskie 1969; Spong et al. 1972; D. F. Hatler 1972 [The mammals of Pacific Rim National Park. Unpublished report, National and Historic Parks Branch, Western Region, Calgary, Alberta]; Baird and Stacey 1993). Baird and Stacey (1993) concluded that Short-finned Pilot Whales should be considered rare in British Columbia waters; they are represented by only a few records in most, but not all, years. They caution however, that little sighting effort is made in the continental slope and offshore areas that characterize the general habitat of Short-finned Pilot Whales, so the species may be more common in B.C. waters than records indicate.

Protection

International

The Short-finned Pilot Whale is listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973 (CITES) (*see* Birnie 1982). Such listing allows for the regulation of international trade between members and non-members of the convention by requiring export permits from the country of origin. There appears to be no current international trade in Short-finned Pilot Whale products however. The International Whaling Commission (IWC) regulates the taking of whales in accordance with the current Schedule provisions, but whether this Commission's mandate covers the Short-finned Pilot Whale is unclear, as members of the Commission are divided as to whether "whale" refers to all cetaceans, or only to some species (Klinowska 1987, 1991).

National

Canada: Until they were replaced in 1993, the Cetacean Protection Regulations of the Fisheries Act of Canada of 1867 protected at cetacean species from hunting. "Hunting" was defined as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner", and could only be undertaken under licence. Aboriginal "hunting", however, could be undertaken without licences. The Cetacean Protection Regulations were replaced with the Marine Mammal Regulations of the Fisheries Act in early 1993. These regulations appear to provide no more or less protection by stating only that "no person should disturb a marine mammal except when under... the authorities of these regulations." No provisions for regulation of incidental catches in fishing operations exist. In terms of participation in the International Whaling Commission, Canada is not currently a member, having withdrawn in 1982 (IWC 1982).

United States: All cetaceans are protected through the Marine Mammal Protection Act of 1972, as well as through the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of the Fisherman's Protective Act.

Population Size(s) and Trends

No world-wide population estimates are available. In the recent IUCN cetacean Red Data Book, Klinowska (1991) noted that insufficient information is available to classify the world-wide status of this species. Using gel electrophoresis, Wada (1988) found significant differences in allelic frequencies between the northern and southern forms of the Short-finned Pilot Whale off Japan, implying that animals inhabiting localized areas may be reproductively isolated, and should be managed independently. Similar work does not appear to have been undertaken on this species elsewhere. In the western North Pacific, estimates for both the northern (5344, 95% CI 819-9669) and southern (53 003, 95% CI 18 409-87 597) forms off Japan have been presented (IWC 1987); based, however, on only five survey cruises in each area during 1984 and 1985. Subsequent estimates presented by Miyashita (*in press*) appear to indicate a decline in both populations, with 4 239 in the northern stock and 24 474 in the southern stock. The population in northern Japanese waters is currently considered at risk (IWC 1987; Perrin 1988; see Limiting Factors, below). Leatherwood and Reeves (1983) noted that the population of Short-finned Pilot Whales in the eastern tropical Pacific has been estimated at 60 000 individuals. Shallenberger (1981) notes that Pilot Whales are the most commonly observed small "whale" in the Hawaiian Islands. In areas where the range of this species overlaps with that of Long-finned Pilot Whales, estimates of abundance based on surveys are generally confined to estimates for the genus, since species identification of animals in the field is difficult (*see* Hain et al. 1985).

Habitat

Short-finned Pilot Whales generally inhabit warm temperate and tropical offshore waters, although there are also some records of individuals spending long periods in shallow inshore areas (Home 1980). Short-finned Pilot Whales have been recorded in areas with water temperatures as high as 29.2°C (Miyazaki and Wada 1978). Kasuya and Marsh (1984) noted that in the western North Pacific, they occur in waters with surface temperatures greater than 15°-16°C. Sea surface temperatures noted for six records from British Columbia waters range between 8° and 16°C (Baird and Stacey 1993).

General Biology

Reproduction

Perrin and Reilly (1984) reviewed reproductive parameters of this and other delphinids. There is a wide range of variation in many of the reproductive parameters of Short-finned Pilot Whales, probably because data has been summarized from several different populations. Extensive research on the life history and reproductive biology of this species has been undertaken off the coast of Japan, utilizing animals taken in fisheries. The following summary of information derived from these fisheries as well as from studies elsewhere follows through the life history of Short-finned Pilot Whales, including gestation, birth, weaning, growth, sexual maturity, and longevity.

Kasuya and Marsh (1984) found in their study that gestation lasts an average of 452 days. A single calf is usual (Kasuya and Marsh 1984), although Norris and Prescott (1961) noted several sightings of adults with two young, and suggested that multiple births may occasionally occur. Alternatively, such sightings may simply indicate periods of alloparental care, as is commonly observed with Killer Whales (*see* Waite 1988). Length at birth has been said to range between 122-146 cm (Caldwell et al. 1971a; Yonekura et al. 1980). Kasuya and Marsh (1984), studying the southern form of Short-finned Pilot Whales off Japan, estimated the mean length at birth as 139.8 cm, the neonatal sex ratio as approximately 1:1, with weaning occurring over an extended period. The first solid food may be taken as early as six months, and nursing continues to at least 2.75 years of age, with some animals possibly continuing to nurse until the age of 10 to 15 years (Kasuya and Marsh 1984).

For females, the mean age and length at attainment of sexual maturity has been estimated as nine years and either 301 or 316 cm (for animals from the central U.S. and Pacific coasts of Japan, respectively) (Kasuya and Marsh 1984; Mead and Potter

1987). At this age growth has almost ceased; off the Pacific coast of Japan the asymptotic length of 364.0 cm is reached at age 22 years for females (Kasuya and Matsui 1984). For males, the mean age and length at attainment of sexual maturity has been estimated at about 15 years and about 414 or 475 cm (for animals from the Pacific coast of Japan and central U.S. coast, respectively) (Kasuya and Marsh 1984; Mead and Potter 1987). Off the Pacific coast of Japan, males show a secondary growth spurt at age nine, and attain an asymptotic length of 473.5 cm at 27 years of age (Kasuya and Matsui 1984). The adult sex ratio is biased towards females; mortality for males is greater than for females (Kasuya and Marsh 1984). Marsh and Kasuya (1984, 1986) have found that females off Japan exhibit an extended post-reproductive period, with no pregnancies occurring in 76 females which were 36 years of age or older. Twenty-four percent of the 245 mature females examined had ovaries similar to those found in post-menopausal humans. Dentinal and cemental growth layers are deposited annually (Kasuya and Matsui 1984). The age of the oldest individuals examined from this fishery was estimated at 62 years for females and 45 years for males. Mean longevity for animals off Japan is estimated as 22.26 years for females and 12.11 years for males (Kasuya and Marsh 1984). Kasuya and Marsh (1984) found that breeding off Japan is diffusely seasonal, with a single peak in parturition in July-August. They suggest that the mating system is polygynous.

Movements

Individual Short-finned Pilot Whales can be photo-identified, based on dorsal fin shape and distinctive markings on the dorsal fin and saddle patch. This technique has been used for behavioural and population studies in two areas in the eastern North Pacific, off the California coast and in Hawaii, and off Japan (Shane 1984; Patten and Samaras 1985; Shane and McSweeney 1990; Miyashita et al. 1990). Shane and McSweeney (1990) used this technique to study site fidelity off California and Hawaii. Their results suggest a relatively high degree of site fidelity, at least seasonally, with resightings of individuals both within and between years (Shane and McSweeney 1990). From examination of animals killed in fisheries off Japan, Kasuya and Marsh (1984) suggest that females probably do not leave their mother's school, while males likely migrate between schools after weaning. Leatherwood et al. (1987) note that the population off southern California may have two components: some individuals appear to stay year-round in the area of the California Channel Islands and show an affinity for the coastal heads of deep submarine canyons, while others are seen in deeper waters offshore for most of the year. During the inshore movements of squid in late winter and early spring, some of the Short-finned Pilot Whales that are normally found offshore appear to move inshore (Leatherwood et al. 1987), forming large concentrations over the squid spawning areas. Numbers in inshore waters thus appear to peak in winter and spring. Shane (1984) suggests that inshore movements in the Catalina Island area were interrupted by the 1982-1984 El Niño warm water event. Movements in the eastern North Pacific north of latitude 40°N appear to be related to incursions of warm water (Leatherwood et al. 1987). The only records from British Columbia waters are from late spring through early fall, although it is difficult to determine if this accurately reflects their presence, since sighting effort is much lower in winter months (Baird and Stacey 1993).

Behaviour

Pilot whale groups range from single individuals to aggregations of several hundred (Irvine et al. 1979; Shallenberger 1981). Norris and Prescott (1961) noted that group structure can be categorized into three functional behaviours: travelling or hunting, feeding, and loafing. Short-finned Pilot Whales are frequently encountered "loafing" at the surface, resting with their dorsal fin and head visible (Leatherwood et al. 1988). "Play" behaviour often occurs at such times, including spyhopping, taillobbing, and occasionally breaching. Norris and Prescott (1961) reported an individual playing with kelp. When startled during "loafing" behaviour, Pilot Whales can be extremely difficult to approach for the rest of the day (Walker 1975). Travelling or hunting schools are characterized by animals spread out in a broad rank up to two miles in width, but only one or a few whales in depth, with individuals occasionally gathered in subgroups. In feeding schools, individuals tend to remain fairly independent of one another, exhibiting quick erratic movements during pursuit of food.

Short-finned Pilot Whales generally travel no more than four or five knots in the open ocean, although they are capable of rapid swimming (Norris and Prescott 1961). When beginning a long dive, the tail stock is exposed in an arching roll, and the flukes are often lifted above the surface (Reilly and Shane 1986). Norris and Prescott (1961) noted that the longest dive recorded from their observations was four minutes, fifty seconds. Among the species considered "blackfish" [Killer Whales, False Killer Whales (*Pseudorca crassidens*), Melon-headed Whales (*Peponocephala electra*), Pygmy Killer Whales (*Feresa attenuatay*), and Pilot Whales]. Pilot Whales are the least acrobatic (Leatherwood et al. 1988). Pilot Whales generally do not bowride on vessels (Walker 1975). Reilly and Shane (1986) report that the majority of sounds produced by the highly vocal Short-finned Pilot Whale are below 15 kilohertz.

Conspecific agonistic behaviour is evident towards smaller individuals, who frequently have numerous scars and tooth marks (Norris and Prescott

1961). Short-finned Pilot Whales have been recorded in association with several other species of cetaceans, including Bottlenose Dolphins (*Tursiops truncatus*), Rough-toothed Dolphins (*Steno bredanensis*), Northern Right Whale Dolphins (*Lissodelphis borealis*), Pacific White-sided Dolphins (*Lagenorhynchus obliquidens*), Risso's Dolphins (*Grampus griseus*), Common Dolphins (*Delphinus delphis*), and Grey Whales (*Eschrichtius robustus*), as well as California Sea Lions (*Zalophus californianus*) and seabirds (Norris and Prescott 1961; Leatherwood 1974; Kasuya and Marsh 1984; Reilly and Shane 1986; Au and Pitman 1988; Baird and Stacey 1993). Shane (1987) observed Risso's Dolphins apparently acting aggressively towards Short-finned Pilot Whales off California. Shallenberger (1981) noted that oceanic White-tipped Sharks occasionally follow Pilot Whales in the Hawaiian Islands.

Short-finned Pilot Whales feed primarily on squid. Perryman and Foster (1980) reported that Short-finned Pilot Whales have been observed chasing dolphins (*Delphinus delphis* and *Stenella* spp.) in the eastern tropical Pacific, and suggest that on occasion they may feed on young dolphins.

Limiting Factors

Actual predation by Killer Whales has not been observed (Jefferson et al. 1991), although remains of Short-finned Pilot Whales have been recovered from Killer Whale stomach contents off Japan (Nishiwaki and Handa 1958). Kasuya and Marsh (1984) described a possible interaction between Killer Whales and Short-finned Pilot Whales, where an aggregation of Pilot Whales and Bottlenose Dolphins became tighter as Killer Whales approached. Reilly and Shane (1986) reported that predation by sharks also occurs.

Short-finned Pilot Whales are taken in small numbers in fisheries, both directly and incidentally, throughout their range. During the nineteenth century, Short-finned Pilot Whales were frequently killed in the tropical Atlantic by pelagic whaling crews, both for practice, and to obtain meat and watch oil (Leatherwood and Reeves 1983). Off Japan, small numbers are taken incidentally in fisheries, while several hundred are taken annually in directed harpoon and drive fisheries (Ohsumi 1972, 1975; IWC 1991, 1992). Numbers taken in recent years have ranged from 569 in 1988 to 167 in 1990 (IWC 1990, 1992). Leatherwood and Reeves (1983) noted that small-scale hand-harpoon fisheries in the West Indies began in the 1930s, where they continue today (Reeves 1988). Catches have been reported from Cuba, Dominica, Martinique, St. Lucia and St. Vincent (Mitchell 1975; Price 1985). Those animals taken are used primarily for meat for human consumption, and for cooking oil (Caldwell et al 1971b). Caldwell and Caldwell (1975) report that on average, 224 individuals were taken in the fishery at St. Vincent between 1962 and 1974. Small numbers are taken incidentally in fisheries off Sri Lanka, as well as being directly taken by Lamalera whalers (Leatherwood et al. 1991). Hall and Boyer (1989, 1990) report that small numbers have been taken in the tuna purse-seine fishery in the eastern tropical Pacific. Miller et al. (1983, cited in Shane 1984) noted that between 4-12% of the estimated winter population off Catalina Island were being killed annually in a local squid fishery. Three individuals were incidentally caught in an experimental fishery in international waters offshore of British Columbia in 1957 (Pike and MacAskie 1969). One of these individuals was shot and taken aboard, while the other two escaped. Between 1983-1987, six individuals were incidentally caught in Canadian waters, and an additional five individuals in adjacent international waters, in an experimental fishery for Flying Squid (*Ommastrephes bartrami*) (Jamieson and Heritage 1987, 1988; Baird and Stacey 1993). This fishery has been discontinued. Some Pilot Whales (both Short- and Long-finned) were killed incidentally in the U.S. Swordfish drift gill-net fishery off the U.S. northeast coast (Anonymous 1991). Diamond et al. (1987) report on two individuals killed in a shark/swordfish drift gill-net fishery off southern California. Van Waerebeek and Reyes (1986) noted that small numbers have been killed incidentally in gill nets off Peru, as well as being taken in other fisheries in that area. As of 1983 a total of 226 individuals had been live captured world-wide for captivity (IWC 1984).

Relatively high levels of several heavy metals and organochlorines have been recorded in tissues from Short-finned Pilot Whales (Gaskin et al. 1974; Taruski et al. 1975; O'Shea et al. 1980; Wagemann and Muir 1984). However, the role which environmental contaminants play in the mortality of marine mammals is largely unknown. Some contaminants, such as mercury, have both natural as well as anthropogenic sources.

The two species in the genus *Globicephala* are among those cetaceans recorded to mass strand most frequently, and *G. macrorhynchus* has been recorded to mass strand on numerous occasions (Norris and Prescott 1961; Caldwell et al. 1970; Hall et al. 1971; Sergeant 1982). A variety of circumstances may contribute to mass strandings. Mitchell (1975) noted that mass strandings may significantly affect the size of local populations.

Pathology in the Short-finned Pilot Whale has been discussed by Benirschke and Marsh (1984). Hall et al. (1971) report on bacteria isolated from stranded individuals. Parasites recorded from this species include the cestodes *Monorygma* sp., and *Phyllobothrium* sp., and the trematodes *Nasitrema* *globicephalae* and *Nasitrema lanceolata* (Neiland et al. 1970; Walker 1975), although the exact role of these parasites in natural mortality is unknown. Morimitsu et al. (1987) have implicated the cranial parasites *Nasitrema gondo* in mass strandings off Japan. Caldwell et al. (1971a, 1971b) report that the barnacles *Conchoderma auritum* and *Xenobalanus globicipitus*, as well as cyamids and remoras have been found on this species.

Evaluation

Baird and Stacey (1993), in their review of this species off the B.C. coast, note that the Short-finned Pilot Whale is a rare but regular visitor to Canadian waters. No serious threats to its status in Canadian waters are apparent. As such, no COSEWIC status designation is required.

Acknowledgments

We thank the World Wildlife Fund (Canada) for financial assistance for the preparation of this report, Robert Campbell and COSEWIC for providing assistance and support, and Randy Reeves and several anonymous reviewers for helpful comments on the manuscript.

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Accepted 15 August 1993

Status of the Northern Bottlenose Whale, *Hyperoodon ampullatus*[*]

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Reeves, Randall R., Edward Mitchell, and Hal Whitehead. 1993. Status of the Northern Bottlenose Whale, *Hyperoodon ampullatus*. Canadian Field-Naturalist 107(4): 490–508.

The Northern Bottlenose Whale, *Hyperoodon ampullatus*, is a deep-diving, medium-sized teuthophage endemic in the North Atlantic Ocean. Its known distribution is centered in areas with cold, deep water along and seaward of the edge of the continental shelf. Migratory movements are poorly documented, as are stock relations among the animals found in apparently disjunct centers of spring and summer abundance. In the western North Atlantic, Bottlenose Whales are present during much of the year in The Gully near Sable Island (Nova Scotia) and in the Labrador Sea. Northern Bottlenose Whales were hunted mainly by British and Norwegian whalers during the second half of the nineteenth century and by Norwegian and Canadian whalers during the twentieth century. Although population size has been assessed in only relatively small parts of its total range, the Northern Bottlenose Whale remains widely distributed and locally abundant in some areas. It has been protected from commercial whaling since 1977 and is no longer hunted regularly on a large scale anywhere in its range. It is unlikely that the populations of this species have recovered fully from the effects of past commercial exploitation, but the species does not appear to be threatened or endangered at present. The Bottlenose Whales in The Gully appear to be non-migratory, and this population of a few hundred whales might be vulnerable to the environmental degradation associated with nearby oil and gas production.

La baleine à bec commune, *Hyperoodon ampullatus*, est un teuthophage de l'océan Atlantique Nord, de taille moyenne, plongeur de grandes profondeurs. Sa distribution connue est concentrée en eaux froides profondes, le long et au large du plateau continental. Les activités migratoires sont peu connues ainsi que les interrelations entre les animaux des grands regroupements apparemment distincts observés dans les centres de printemps et d'été. Dans l'Atlantique Nord de l'ouest, les baleines à bec communes se tiennent dans le "Gully", près de Sable Island, en Nouvelle-Écosse, et dans la mer du Labrador. Les baleines à bec communes ont surtout été chassées par les baleiniers britanniques et norvégiens durant la seconde moitié du 19^{e} siècle, et par des baleiniers canadiens et norvégiens au 20^{e} siècle. Bien que la taille des populations n'aient été evaluée que dans une petite portion de son aire de répartition, les baleines à bec communes sont encore répandues et nombreuses dans certains endroits. L'espèce est protégée de la pêche commerciale depuis 1977 et on n'en fait plus une chasse régulière, où qu'elle soit. Il est improbable que la baleine à bec commune soit complètement rétablie des effets de l'exploitation commerciale qu'elle a subie dans le passé, mais l'espèce ne semble pas présentement menacée ou en danger de disparition. Les baleines à bec commune du Gully semblent être non-migratoires et cette population de quelques centaines de baleines sont peut-être vulnérables à cause de la dégradation environnementale associée à la production d'huile et de gaz à proximité.

Key Words: Northern Bottlenose Whale, baleine à bec commune, *Hyperoodon ampullatus*, Cetacea, Odontoceti, whaling.

The Northern Bottlenose Whale, *Hyperoodon ampullatus* (Forster 1770) [Figures 1 and 2], of the North Atlantic Ocean is part of an antitropically-distributed species pair. Its congener, the Southern Bottlenose Whale, *Hyperoodon planifrons*, is a widely distributed inhabitant of the Southern Ocean. The recognition of two separate species of *Hyperoodon* rests most notably on the geographical isolation of the two groups and on the difference in shape of the maxillary crests, those of *Hyperoodon planifrons* being generally much flatter than those of *Hyperoodon ampullatus* (Fraser 1945; Mead 1989).

The Northern Bottlenose Whale was exploited in a multinational, multispecies pelagic whale fishery, involving mainly Great Britain and Norway, beginning in the second half of the nineteenth century. Its conservation status has been the subject of some discussion, particularly within the Scientific Committee of the International Whaling Commission (IWC) (e.g., Mitchell 1977b; Klinowska 1991). Since the early 1970s the Northern Bottlenose Whale has been essentially unexploited.

The purpose of this report is to review the current status of the Northern Bottlenose Whale, particularly in the western North Atlantic. In addition to reviewing the literature, we present some unpublished information on sightings and catches by British whalers during the nineteenth century and some biological data on whales taken off Nova Scotia during the 1960s. Also, we have compiled and interpreted

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[*]Report accepted by COSEWIC 15 April 1993 — no status designation required for the species.

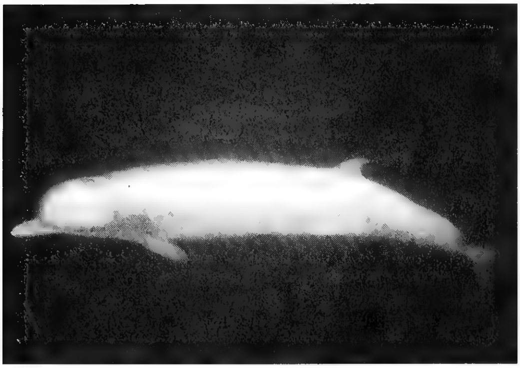


FIGURE 1. A Northern Bottlenose Whale in The Gully off Nova Scotia.

some recent sightings made off eastern Canada during environmental-assessment and other surveys.

Distribution and Stock Identity

Gray (1882), a Scottish whaler, gave the distribution of the Northern Bottlenose Whale as:

> … from the entrance of Hudson's Straits and up Davis Straits, as far as 70° north lat., and down the east side round Cape Farewell, all round Iceland, north along the Greenland ice to 77° north lat.; also along the west coast of Spitzbergen and east to Cherry Island [Bear Island or Bjornøya], in lat. 72° north and long. 19° east.

He had not observed it outside these limits but guessed that it could be found south to the Strait of Belle Isle in the west, and east as far as Novaya Zemlya. Norwegian whaling records indicate a distribution north to about 80°N off Svalbard (Christensen 1993). Bottlenose Whales have rarely been caught on the European continental shelf (Benjaminsen 1972). Only one was taken in the shallow North Sea during 1938-72, and none in the shallow Barents Sea in spite of intensive Norwegian whaling there (Benjaminsen and Christensen 1979). There are, however, records of Bottlenose Whales from Varanger Fiord, the Murman coast, and the White Sea (Birula 1934; Tomilin 1967; Golenchenko 1967; Ivashin 1988).

Areas of Bottlenose Whale abundance in the Northeast Atlantic are well defined from whaling records (Jonsgård and Øynes 1952; Benjaminsen 1972; Benjaminsen and Christensen 1979): (1) between Iceland and Jan Mayen, (2) southwest of Svalbard, (3) off the Möre coast of Norway, and (4) off the Andenes coast of Norway. The two coastal areas have narrow shelves, and the catches have been mainly in waters deeper than 1000 m.

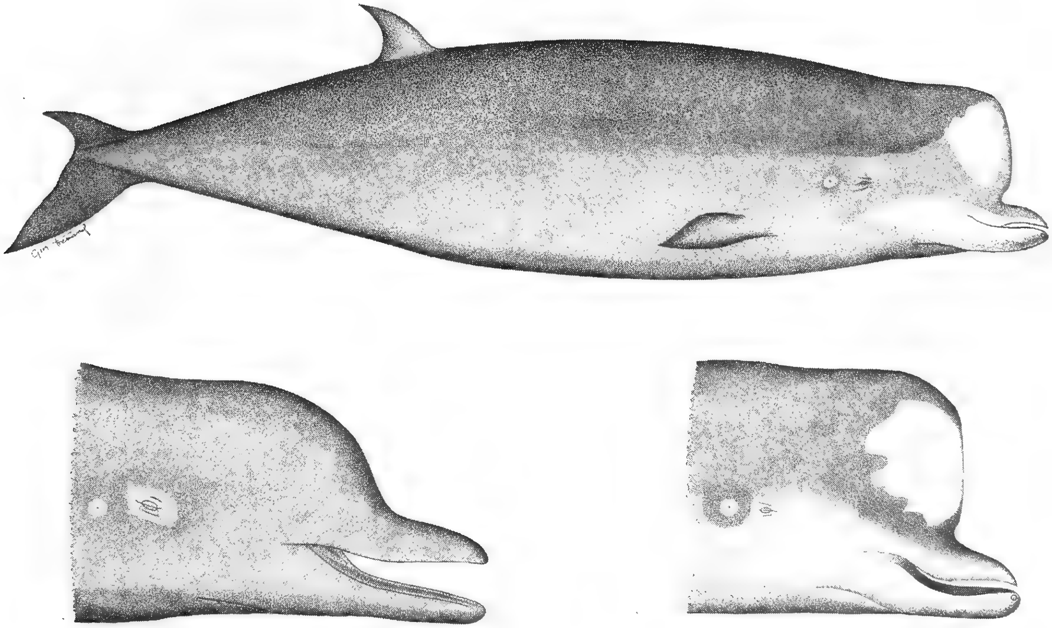


FIGURE 2. Copies of nineteenth-century lithographs of Northern Bottlenose Whales, published in 1893 by Swedish naturalist Axel Ohlin, showing general features of an adult male (upper), the head shape of an adult female (lower left), and the head shape of an adult male (lower right). (Drawings by G. Ferrand.)

Bottlenose Whales also have been taken in Denmark Strait, off southern Iceland, and between Iceland and Norway. They occur in deep waters south and west of Iceland during at least early June to early October (Sigurjónsson and Gunnlaugsson 1990).

Norwegian whalers were convinced that Bottlenose Whales reached the northernmost areas of their distribution in the Northeast Atlantic in spring and early summer, and that by July the whales had begun to migrate south (Ohlin 1893; Risting 1922; Jonsgård and Øynes 1952). Sigurjónsson and Gunnlaugsson (1990) found that Bottlenose Whales were most frequently observed on the Icelandic whaling grounds early in the June-October whaling season. After 14 July, they were less widely distributed, and their distribution was concentrated in the northwest corner of the operational area. The temporal and latitudinal pattern of strandings along European coasts has been interpreted as evidence of a seasonal north-south migration (Turner 1886; Fraser 1953; Benjaminsen and Christensen 1979).

The two known centers of spring and early summer abundance in the western North Atlantic are: (1) off Cape Chidley and across the mouth of Hudson Strait to the mouths of Frobisher Bay and Cumberland Sound, mainly along and just seaward of the 1000 m contour (Lindsay 1911; Christensen 1977; Benjaminsen and Christensen 1979) [Figure 3], and (2) in or near the entrance of The Gully near Sable Island off the Atlantic coast of Nova Scotia (Winn et al. 1970; Mitchell 1974; Mitchell and Kozicki 1975) [Table 1; Figure 4]. Detailed observations since 1988 indicate that the "Gully population" is based in a core area of about 12 km x 8 km centered around 43°50'N, 58°55'W (Faucher and Whitehead 1991; Faucher and Weilgart 1992; Figure 5). Bottlenose Whales are found in this core area year-round.

Norwegian whalers reported seeing several hundred Bottlenose Whales during spring and early summer at about 64°N off West Greenland (Benjaminsen and Christensen 1979). Observations around the southern coast of Greenland plotted by Jensen and Heide-Jørgensen (1993) indicate a distribution along and seaward of the 500 m contour.

Only two specimens have been recorded from the Gulf of St. Lawrence (Beaugé 1942; Mitchell 1977a), one from Trinity Bay (Sergeant and Fisher 1957), and one from the Bay of Fundy (Case and Densmore 1970; Mitchell and Kozicki 1975). These specimens have been considered either "strays" or

TABLE 1. Bottlenose Whale catches in Nova Scotia, 1964 to 1967. Data from International Whaling Statistics forms completed by whaling-station personnel. Positions plotted on Figure 4.

Date	Length (ft)	Sex	Females			Stomach Contents	Position
				Fetus			
			Pregnant	Length	Sex		
3 June 1964	25	M				—	43°N,58°W*
4 June 1964	24	M				—	43°50'N, 58°45'W
6 June 1964	23	F	X	2ft	M	—	44°00'N, 59°00'W
6 June 1964	24	F				—	44°00'N, 59°00'W
7 June 1964	24	M				—	43°40'N, 58°50'W
7 June 1964	23	M				—	43°40'N, 58°50'W
7 June 1964	24	F				—	43°40'N, 59°W
8 June 1964	25	F				—	43°30'N, 58°40'W
9 June 1964	21	M				—	43°40'N, 59°W
29 June 1964	23	F				—	43°40'N, 59°W
1 July 1964	25	F				—	43°40'N, 59°W
19 September 1964	26	F				—	43°48'N, 58°54'W
20 September 1964	25	F				—	43°48'N, 58°54'W
29 October 1964	25	F				—	43°48'N, 58°54'W
16 June 1965	25	M				—	43°50'N, 58°50'W
16 June 1965	26	F				—	43°50'N, 58°50'W
16 June 1965	21	F				—	43°50'N, 58°50'W
16 June 1965	25	F				—	43°50,N, 58°50'W
13 July 1965	26	F				—	43°35'N, 59°03'W
14 July 1965	20	F				—	43°35'N, 59°10'W
8 June 1967	22	M				Squid	43°50'N, 58°52'W
8 June 1967	24	M				Squid	43°49'N, 58°51'W
9 June 1967	23	M				Squid	43°49'N, 58°51'W
9 June 1967	25	F				Squid	43°49'N, 58°51'W
9 June 1967	23	M				Squid	43°49'N, 58°51'W

*Not plotted on Figure 4.

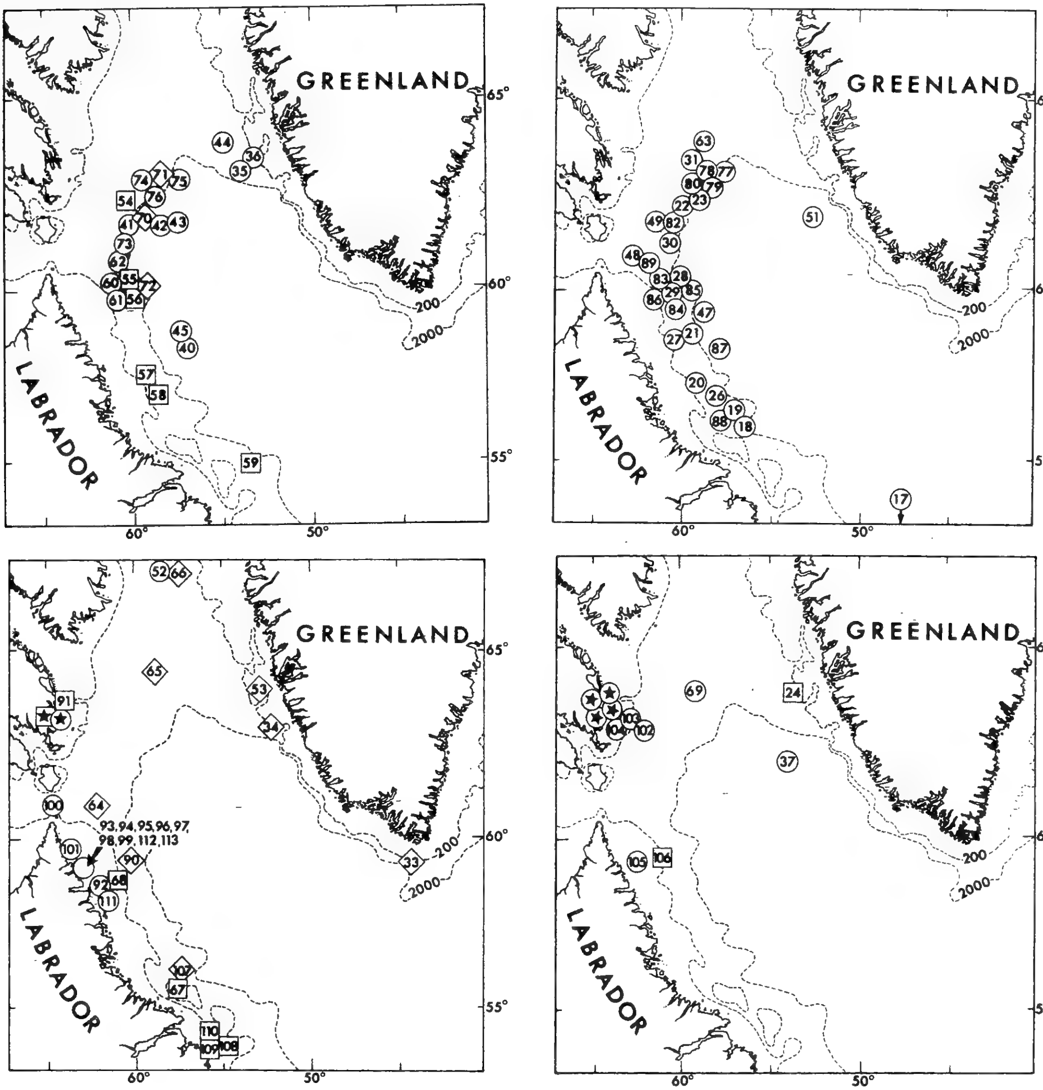


FIGURE 3. Positions of catches and sightings of Northern Bottlenose Whales, from Tables 2 and 3, by Record Number. The 200 and 2000 m contours are shown with dashed lines. Records are plotted roughly by season: upper left: Winter (February-April); upper right: Spring (May); lower left: Summer (June-August); lower right: Autumn (September-October). Stars are positions for sightings listed in Table 4.

individuals that had moved away from one of the local concentrations mentioned above (Mitchell and Kozicki 1975). The northernmost record for the west side of Davis Strait is a sighting 7 August 1906 at 67°04'N, 58°25'W, within sight of the east coast of Baffin Island, near Cape Dyer (*Eclipse* 1906). The southernmost record on the American east coast is of a capture near Newport, Rhode Island, at 41°30'N (Mitchell and Kozicki 1975).

We have no definite evidence that Bottlenose Whales move west through Hudson Strait and into Hudson Bay. If such movement occurs at all, it is exceptional. In the Churchill post journal of the Hudson's Bay Company, the entry for 22 August 1771 states that the crew of the whaling brig *Charlotte* saw a Bottlenose Whale in and near the Churchill River (Hudson's Bay Company Archives, Winnipeg, Manitoba, B.42/a/80/fo. 82d).

Although Mitchell and Kozicki (1975) were skeptical of Sergeant's (1961) suggestion that Bottlenose Whales winter in the Labrador Sea, British whalers commonly observed them at the South-West Fishing

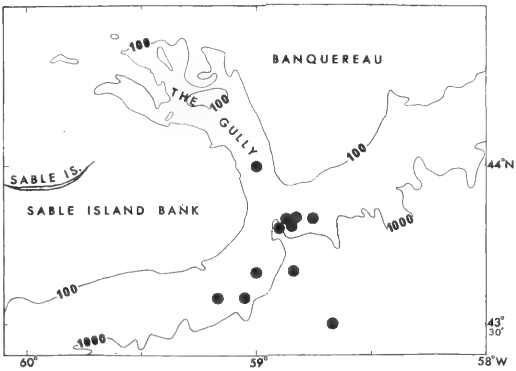


FIGURE 4. Catch positions of Northern Bottlenose Whales taken by catcher boats from Blandford, Nova Scotia, 1964-1967. Data from Table 1. The 100 and 1000 fathom contours are shown with solid lines.

in southern Davis Strait and the Labrador Sea (cf. Reeves et al. 1983) from as early as mid-April through May (Table 2), and recent sightings off the southeast coast of Baffin Island and in the Labrador Sea from February through October (Tables 3 and 4; Figure 3) indicate that at least some are present at high latitudes during much of the year. Together with the information from the Gully cited above, these data suggest that at least some Bottlenose Whales do not make seasonal migrations.

Mitchell and Kozicki (1975) speculated that some Bottlenose Whales winter on the continental slope and offshore from Cape Cod to the Grand Bank. However, during aerial surveys of the continental shelf and slope (to 5 nautical miles [9.3 km] seaward of the 1000 fathom [1829 m] isobath) between Cape Hatteras, North Carolina, and Cape Sable, Nova Scotia, from October 1978 to January 1982, only

TABLE 2. Bottlenose Whale catches and observations by Scottish whalers. Records from Davis Strait are plotted on Figure 3. (* = not plotted on Figure 3)

Record Number	Date	Bottlenose Whales			Location	Source
		Seen	Secured	Struck/Lost		
1	11 March 1862	3			63°55'N, 01°00'E*	*Active,* Lubbock (1937: 458)
2	18 May 1874	3			79°N, 00°03'E*	*Hope*, Gray (1933: 9)
3	11 March 1879	Some			64°32'N, 03°46'E*	*Perseverance* (1879)
4	25 April 1879	Some (chased)			70°44'N, 01°15'E*	*Perseverance* (1879)
5	26 April 1879	Some (chased)			—*	*Perseverance* (1879)
6	28 April 1879	Some (chased)			71°43'N, 00°45'E*	*Perseverance* (1879)
7	13-14 May 1879		5		66°53'N, 09°20'W*	*Perseverance* (1879)
8	15 May 1879	Some			—*	*Perseverance* (1879)
9	17 May 1879		2	1	67°18'N, 10°15'W*	*Perseverance* (1879)
10	18 May 1879	Some (chased)			64°06'N, 11°05'W*	*Perseverance* (1879)
11	29 May 1879	Some (chased)			68°15'N, 08°26'W*	*Perseverance* (1879)
12	10 July 1881		3 (while sealing)		68°15'N, 20°W*	*Thetis* (1881)
13	15 July 1881		5		70°44'N, 13°W*	*Thetis* (1881)
14	16 July 1881		3	2	near Jan Mayen*	*Thetis* (1881)
15	30 July 1881	Some		1	68°58'N, 13°54'W*	*Thetis* (1881)
16	31 July 1881	Some		2	68°31'N, 14°46'W*	*Thetis* (1881)
17	2 May 1885	Some			48°21'N, 47°16'W	*Esquimaux* (1885)
18	8 May 1885	"Several"			*ca* 56°N, 56°30'W	*Esquimaux* (1885)
19	10 May 1885		2	1	*ca* 56°30'N, 57°W	*Esquimaux* (1885)
20	11 May 1885	"Several"			57°19'N, 59°03'W	*Esquimaux* (1885)
21	12 May 1885		2		58°48'N, 59°29'W	*Esquimaux* (1885)
22	18 May 1885		2		62°17'N, 59°42'W	*Esquimaux* (1885)
23	19 May 1885	Some			*ca* 62°30'N, 59°W	*Esquimaux* (1885)
24	4 October 1885	"Several"			63°57'N, 53°43'W, within sight of Greenland coast	*Esquimaux* (1885)
25	23 April 1886	"Several schools"			*ca* 100 mi N of Lambness ("feeding")*	Gray (1887: 48)
26	24 May 1887	Some (chased)			56°58'N, 58°05'W	*Esquimaux* (1887)

Continued.

TABLE 2. *Concluded.*

Record Number	Date	Bottlenose Whales			Location	Source
		Seen	Secured	Struck/Lost		
27	25 May 1887	Some			08°37'N, 60°21'W	*Esquimaux* (1887)
28	26 May 1887		5		60°17'N, *ca* 60°30'W	*Esquimaux* (1887)
29	27 May 1887		8	1	*ca* 60°N, 60°30'W	*Esquimaux* (1887)
30	28 May 1887		1	1	60°12'N, 60°38'W	*Esquimaux* (1887)
31	26 May 1888	"A few"			63°29'N, 59°25'W	*Esquimaux* (1888)
32	1888		12		—*	*Esquimaux* (1888)
33	3 June 1890	"A few"			59°22'N, 44°17'W	*Polynia* (1890)
34	5 June 1890	Many			63°04'N, 52°15'W	*Polynia* (1890)
35	19 April 1891	"Several" (chased)			63°12'N, 53°45'W	*Maud* (1891)
36	20 April 1891	3			63°25'N, *ca* 53°30'W	*Maud* (1891)
37	16 Sept. 1891	"A few"			62°09'N, 54°01'W	*Maud* (1891)
38	16 April 1892	"A few"			59°N, 39°09'W*– whales going N	*Maud* (1892)
39	26 March 1893	"A few"			59°26'N, 24°15'W*– whales going S	*Eclipse* (1893)
40	12 April 1893	Some (chased)			*ca* 57-60°N, 57°W	*Eclipse* (1893)
41	16 April 1893	Some			61°53'N, 59°43'W	*Eclipse* (1893)
42	18 April 1893	"A few"			*ca* 62°N, 59°W	*Eclipse* (1893)
43	19 April 1893	3			*ca* 62°N, 58°W	*Eclipse* (1893)
44	22 April 1893	"A few" (Killer Whales also present)			64°N, 54°44'W	*Eclipse* (1893)
45	12 April 1894			1	58°55'N, 57°06'W	*Eclipse* (1894)
46	1894		3		—*	*Eclipse* (1894)
47	6 May 1899	"A few schools"			59°29'N, 58°42'W	*Diana* (1899)
48	8 May 1899	"A few"			60°51'N, 61°10'W	*Diana* (1899)
49	9 May 1899	Some (chased)			61°57'N, 60°27'W	*Diana* (1899)
50	4 November 1899	"Several"			58°29'N, 33°32'W*	*Eclipse* (1899)
51	4 May 1903	"Several"			62°05'N, 52°39'W	*Eclipse* (1903)
52	7 August 1906	Some (chased)			67°04'N, 58°25'W, in sight of Baffin Island	*Eclipse* (1906)
53	9 June 1913	Some			64°02'N, 53°04'W	*Erme* (1913)

two sightings were made that were probably of Northern Bottlenose Whales (Cetacean and Turtle Assessment Program 1982; Robert D. Kenney, personal communication, 19 February 1988). One was of a single animal near the Northeast Peak of Georges Bank on 30 May; the other of two animals near the shelf break east of Cape May, New Jersey, on 12 June.

There is no genetic or biochemical evidence for separate biological populations of Northern Bottlenose Whales, although their distribution in at least spring and early summer is apparently discontinuous. The IWC's Subcommittee on Small Cetaceans has recognized the likelihood of separate stocks (Mitchell 1975a). Patches of Bottlenose Whale abundance are widely spaced and thus might be taken to represent feeding substocks (*sensu* Katona [1986] for Humpback Whales, *Megaptera novaeangliae*). Mitchell (1977b) suggested that two statistical areas be used for convenience, dividing catches east and west of Cape Farewell into Northeast Atlantic and Northwest Atlantic, respectively.

Protection

The Northern Bottlenose Whale has been provisionally listed since 1977 as a protected species in the Schedule of the International Convention for the Regulation of Whaling. Since 1984 the species has been in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. This classification means that international commerce in products is banned. Before 1973, the market for toothed whale meat (from Bottlenose, Killer, *Orcinus orca*, and Pilot whales, *Globicephala melas*) obtained in the Norwegian small whale fishery was mainly for pet food in the United Kingdom and for animal food in the Norwegian fur industry (Jonsgård 1977). A British ban on the importation of whale meat for pet food in 1973 eliminated the international component of this market.

TABLE 3. Reported sightings of Northern Bottlenose Whales off Labrador and Baffin Island, 1977 to 1979.

Record Number	Date	Position	Number of whales	Comments	Source
54	10 February 1977	62°30'N, 60°19'W	2-3	Open water	MacLaren Atlantic Ltd. (1977: figure 4-30); Allen and Conover (1977: table 7)
55	18 February 1977	60°11'N, 60°31'W	2	$^{8}/_{10}$ pack ice	MacLaren Atlantic Ltd. (1977: figure 4-30); Allen and Conover (1977: table 7)
56	19 February 1977	59°49'N, 60°21'W	5-6	$^{2}/_{10}$ pack ice	MacLaren Atlantic Ltd. (1977:figure 4-30); Allen and Conover (1977: table 7)
57	21 February 1977	57°39'N, 59°07'W	3	$^{5}/_{10}$ pack ice	MacLaren Atlantic Ltd. (1977: figure 4-30); Allen and Conover (1977: table 7)
58	21 February 1977	57°03'N, 58°30'W	2-3	Light pack ice	MacLaren Atlantic Ltd. (1977: fig. 4-30); Allen and Conover (1977: table 7)
59	26 February 1977	54°51'N, 53°03'W	5-6	Open water	Allen and Conover (1977: table 7)
60	28 April 1977	60°01'N, 60°36'W	8-9	$^{5}/_{10}$ pack ice	Allen and Conover (1977: table 16)
61	28 April 1977	59°55'N, 60°38'W	8-12	$^{6}/_{10}$ pack ice	Allen and Conover (1977: table 16)
62	30 April 1977	60°55'N, 60°50'W	3	Ice edge	Allen and Conover (1977: table 16)
63	11 May 1977	64°00'N, 58°46'W	2	Open water	Allen and Conover (1977: table 16)
64	10 June 1977	61°03'N, 62°09'W	2	Open water	Allen and Conover (1977: table 22)
65	17 June 1977	64°30'N, 58°50'W	1	Ice edge	Allen and Conover (1977: table 22)
66	23 June 1977	66°55'N, 57°40'W	3	$^{8}/_{10}$ pack ice	Allen and Conover (1977: table 22)
67	30 July 1977	55°35'N, 57°33'W	5	Open water	Allen and Conover (1977: table 30)
68	31 July 1977	58°55'N, 61°17'W	1	Open water	Allen and Conover (1977: table 30)
69	21 September 1977	63°59'N, 59°00'W	2	Open water	Allen and Conover (1977: table 36)
70	19 March 1978	62°00'N, 59°14'W	2	Ice edge	Conover, Parsons, and Orr (1979: figure 5-35, table 7-8)
71	20 March 1978	63°00'N, 58°16'W	4	Ice edge	Conover, Parsons, and Orr (1979: figure 5-35, table 7-8)
72	22 March 1978	60°00'N, 59°25'W	2	Ice edge	Conover, Parsons, and Orr (1979: figure 5-35, table 7-8)
73	22 April 1978	61°28'N, 60°16'W	3		Conover and Stone (1979: figure 4-99, appendix table 13)
74	25 April 1978	62°56'N, 58°03'W	3		Conover and Stone (1979: figure 4-99, appendix table 13)
75	25 April 1978	62°55'N, 57°54'W	2		Conover and Stone (1979: figure 4-99, appendix table 13)
76	26 April 1978	62°58'N, 58°34'W	2		Conover and Stone (1979: figure 4-99, appendix table 13)
77	6 May 1978	63°01'N, 58°02'W	4		Conover and Stone (1979: figure 4-104, appendix table 16)
78	6 May 1978	62°57'N, 59°06'W	5-7	In pods of 2-3	Conover and Stone (1979: figure 4-104, appendix table 16)
79	7 May 1978	62°49'N, 59°01'W	2		Conover and Stone (1979: figure 4-104, appendix table 16)
80	7 May 1978	62°40'N, 59°27'W	1		Conover and Stone (1979: figure 4-104, appendix table 16)
81	10 May 1978	-	1		Conover and Stone (1979: appendix table 16)
82	14 May 1978	62°01'N, 60°12'W	2		Conover, Orr, and Parsons (1979: table 5-8-2)
83	15 May 1978	60°30'N, 60°55'W	2		Conover, Orr, and Parsons (1979: table 5-8-2)
84	15 May 1978	59°08'N, 60°27'W	4		Conover and Stone (1979: figure 4-107, appendix table 16)
85	15 May 1978	60°01'N, 60°03'W	2		Conover and Stone (1979: figure 4-104, appendix table 16)
86	16 May 1978	60°33'N, 60°55'W	2		Conover and Stone (1979: figure 4-104, appendix table 16)
87	18 May 1978	58°18'N, 58°08'W	10		Conover and Stone (1979: figure 4-107, appendix table 16)
88	19 May 1978	56°33'N, 57°13'W	5		Conover and Stone (1979: figure 4-107, appendix table 16,
89	28 May 1978	61°00'N, 60°49'W	2		Conover, Orr, and Parsons (1979: table 5-8-2)

Continued

TABLE 3. *Concluded.*

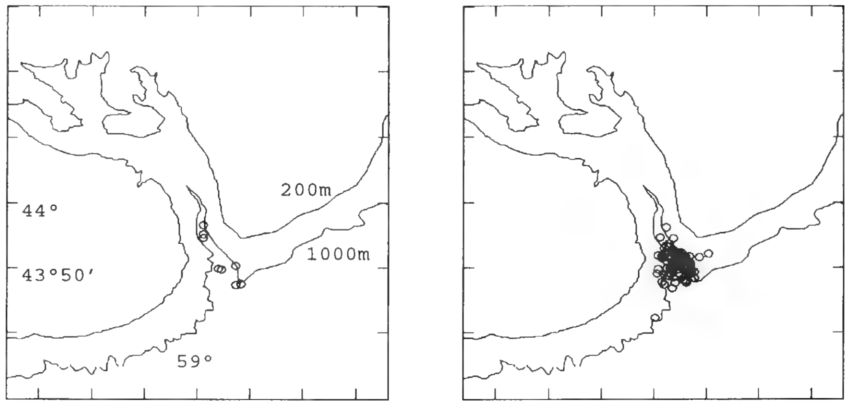
Record Number	Date	Position	Number of whales	Comments	Source
90	26 June 1978	59°30'N, 60°12'W	7		Conover, Orr, and Parsons (1979: table 5-8-3)
91	23 July 1978	63°44'N, 64°04'W	[1]	Identification uncertain	Conover, Orr, and Parsons (1979: table 5-8-4)
92	1 August 1978	58°43'N, 62°09'W	1		Conover, Orr, and Parsons (1979: table 5-8-5)
93	1 August 1978	59°14'N, 62°38'W	2		Conover, Orr, and Parsons (1979: table 5-8-5)
94	1 August 1978	59°11'N, 63°19'W	2		Conover, Orr, and Parsons (1979: table 5-8-5)
95	1 August 1978	59°21'N, 63°31'W	1		Conover, Orr, and Parsons (1979: table 5-8-5)
96	1 August 1978	59°09'N, 63°18'W	1	At mouth of fiord, 2 mi. from shore	Conover, Orr, and Parsons (1979: table 5-8-5)
97	1 August 1978	59°13'N, 62°58'W	2		Conover, Orr, and Parsons (1979: table 5-8-5)
98	1 August 1978	59°21'N, 62°53'W	3		Conover, Orr, and Parsons (1979: table 5-8-5)
99	1 August 1978	59°22'N, 62°52'W	3-5		Conover, Orr, and Parsons (1979: table 5-8-5)
100	2 August 1978	60°50'N, 64°35'W	1		Conover, Orr, and Parsons (1979: table 5-8-5)
101	22 August 1978	59°40'N, 64°10'W	10		Conover, Orr, and Parsons (1979: table 5-8-5)
102	7 September 1978	63°00'N, 62°24'W	1		Conover, Orr, and Parsons (1979: table 5-8-6)
103	7 September 1978	63°15'N, 63°20'W	1		Conover, Orr, and Parsons (1979: table 5-8-6)
104	12 September 1978	63°13'N, 63°48'W	1		Conover, Orr, and Parsons (1979: table 5-8-6)
105	18 September 1978	59°29'N, 62°26'W	1		Conover, Orr, and Parsns (1979: table 5-8-6)
106	4 October 1978	59°30'N, 61°00'W	1		Conover, Orr, and Parsons (1979: table 5-8-7)
107	16 June 1979	56°00'N, 57°20'W	6		Boles (1980: table 2)
108	18 July 1979	53°37'N, 55°41'W	2		Boles (1980: table 2
109	18 July 1979	53°40'N, 55°40'W	1		Boles (1980: table 2)
110	18 July 1979	53°52'N, 55°20'W	1		Boles (1980: table 2)
111	13 August 1979	58°30'N, 61°31'W	1		Boles (1980: table 2)
112	17 August 1979	59°17'N, 62°49'W	2		Boles (1980: table 2)
113	17 August 1979	59°20'N, 62°42'W	3		Boles (1980: table 2)

Like other cetaceans, the Northern Bottlenose Whale is fully protected by national legislation in the USA. In Canada, the Marine Mammal Regulations of 1993, under the Fisheries Act, allow Indians and Inuit to hunt cetaceans for their own use without a license (Anonymous 1993), but there has been no hunt for Bottlenose Whales in Canada in recent years. Neither Greenland nor Iceland has had an active or regular hunt for this species (Jensen and Heide-Jørgensen 1993; Víkingsson and Sigurjónsson 1993). The Faroe Islands is the only country that has regularly taken Bottlenose Whales in recent years; since the early 1900s no more than five have been taken in any one year (Bloch and Desportes 1993). The catch has been described as "traditional" and is said to result from the whales' tendency to "strand themselves, often in one particular locality" (Olafsson 1990; *also see* Sanderson 1992). Bottlenose Whales have not been hunted by Norway since 1973 (Christensen 1993).

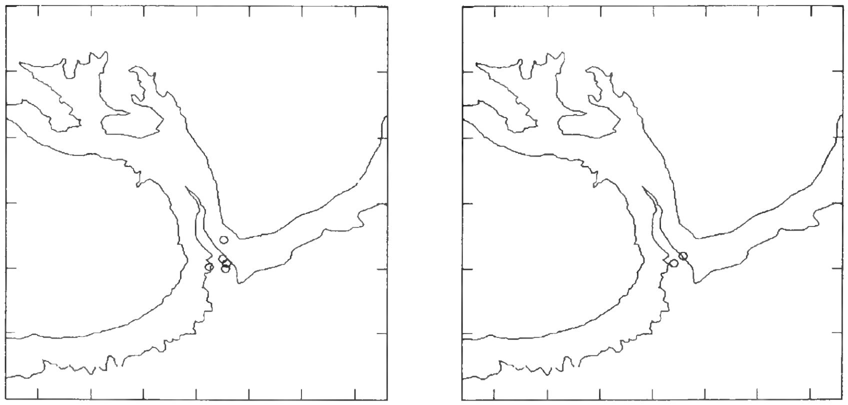
Several recent initiatives have been taken to protect the population of Bottlenose Whales in The Gully from the ill effects of industrial activity. In 1990 the oil company Lasmo declared a "Tanker Exclusion Zone" to keep its shuttle tankers from the Cohasset-Panuke oilfield away from The Gully, with the intention of reducing the probability of collisions, noise pollution, and other impacts on Bottlenose Whales (Faucher and Weilgart 1992). The Department of Fisheries and Oceans has sent letters to shipping companies and given advice in *Canadian Notice to Mariners* in the hope of reducing ship traffic in the entrance of The Gully. Finally,

TABLE 4. Sightings of Bottlenose Whales along the outer coast of Hall Peninsula, southeast Baffin Island (Smith et al. 1979).

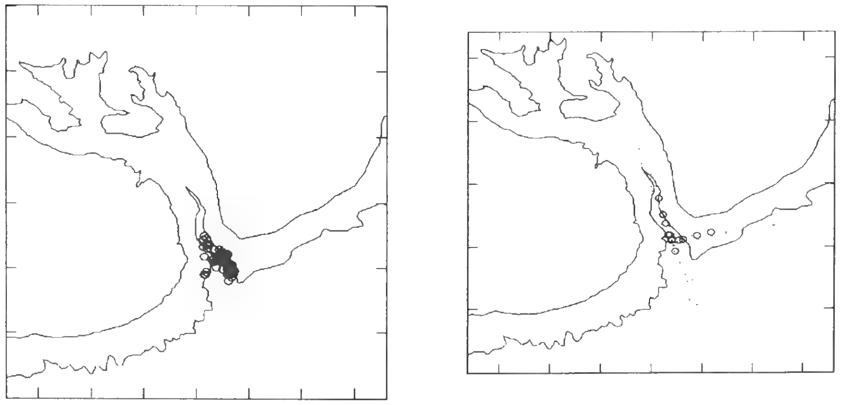
16 July 1978	63°28'N, 64°30'W in Winton Bay	1
30 August 1978	63°18'N, 64°31'W in Amor Smith Inlet	1
6 September 1978	63°31'N, 64°08'W	2 (one "large", one "small")
12 September 1978	63°23'N, 64°28'W	1
13 September 1978	63°23'N, 64°35'W	1 ("possible sighting only")
17 September 1978	63°48'N, 64°17'W	1



a) July-August 1988 b) July-August 1989



c) October 1989 d) February 1990



e) June-August 1990 f) Acoustic surveys 1990

FIGURE 5. Positions in which Northern Bottlenose Whales were photographically identified in The Gully area off the coast of Nova Scotia (from Faucher and Whitehead 1991) (panels a to e). Panel f indicates positions in which Bottlenose Whales were heard (o) or not heard (•) during acoustic surveys of The Gully area in 1990. The positions were obtained from Loran C.

the Bottlenose Whale habitat of The Gully is part of one of three areas being considered by Parks Canada for protected status in the Scotian Shelf region.

Exploitation

The British Fishery

The first sizeable catch on record was of 28 Bottlenose Whales by the *Chieftain* of Kirkaldy in about 1850 (D. Gray letter to T. Southwell, 1881, *in* Southwell 1860-1908; Lubbock 1937; Gray 1941). The *Polar Star* of Peterhead "tried the bottlenosed whale fishing" in 1860 (*Aberdeen Daily Free Press*, Aberdeen, Scotland, 31 January 1893), as did the Hudson's Bay Company's bark *Ocean Nymph* while en route to Hudson Bay in July 1866 (Hudson's Bay Company Archives, Winnipeg, Manitoba, C.1/617). In 1877 the *Jan Mayen* of Peterhead took ten Bottlenose Whales, having missed the annual seal hunt in the Greenland Sea (Gray 1941). When Gray (1882) verified from his catch in 1880 that the spermaceti from the male Bottlenose Whale's head had many of the same properties as the spermaceti from Sperm Whales, *Physeter catodon*, the hunt for Bottlenose Whales became more popular with the Scottish whalers

TABLE 5. Bottlenose Whale catches by Scottish vessels, 1877 to 1891, as recorded on annual lists prepared by David Bruce and Co. of Dundee. From Southwell (1860-1908) and other sources as noted.

Year	Vessel	Grounds	Whales	Oil (Tons)
1877	Jan Mayen	Cumberland Sound	10	—
1878	Jan Mayen	Greenland	9	—
1879	Jan Mayen	Greenland	1	—
	Perseverance	Greenland	7	6
1880	?	?	32	—
1881	Intrepid	Greenland	17	19
	Eclipse	Greenland	39	40
	Hope	Greenland	4	4
	Perseverance	Greenland	30	30
	Windward	Greenland	21	25
1882	Intrepid	Greenland	23	25
	Polar Star	Greenland	67	76
	Thetis	Greenland	8	9
	Alert	Greenland	9	8
	Eclipse	Greenland	203	230
	Superior	Cumberland Sound	*ca* 39	39[1]
	Windward	Greenland	103	114
1883	Active	Greenland	3	3
	Aurora	Greenland	9	?
	Intrepid	Greenland	1	—
	Polar Star	Greenland	61	63
	Star	Greenland	40	41
1883	Alert	Greenland	25	27
	Catherine	Cumberland Sound	43	?
	Eclipse	Greenland	157	150
	Erik	Greenland	92	90
	Perseverance	Greenland	24	24
	Windward	Greenland	80	76
1884	Active	Greenland	11	10
	Arctic	Davis Straits	17	17
	Aurora	Davis Straits[2]	3	3
	Esquimaux	Davis Straits	24	22
	Intrepid	Greenland	8	7
	Maud	Greenland	56	58
	Nova Zembla	Davis Str.	7	6
	Polar Star	Greenland	10	10
	Resolute	Greenland	3	3
	Star	Greenland	45	42
	Alert	Greenland	24	24
	Catherine	Greenland	22	21
	Erik	Greenland	14	15
	Earl of Mar	Greenland	12	12

Continued

TABLE 5. *Concluded.*

Year	Vessel	Grounds	Whales	Oil (Tons)
1884	Germania	Greenland	21	20
	Perseverance	Greenland	26	26
	Windward	Greenland	14	13
1885	Earl of Mar	Greenland	3	2
	Esquimaux	Davis Straits	6	6
	Intrepid	Greenland	3	—
	Maud	Davis Straits	8	8
	Polynia	Davis Straits	3	2
	Polar Star	Greenland	4	4
	Star	Greenland	27	24
	Alert	Greenland	4	4
	Catherine	Greenland	5	6
	Germania	Greenland	14	13
	Active	Greenland	7	5
1886	Chieftain	Davis Straits	13	12
	Maud	Davis Straits	6	6
	Polynia	Davis Straits	4	4
1887	Chieftain	Davis Straits	6	7
	Esquimaux	Davis Straits	14	16
1888	Esquimaux	Davis Straits	12	17
	Nova Zembla	Davis Straits	10	10
1889	Chieftain	Davis Straits	2	3
	Nova Zembla	Davis Straits	4	4
	Eclipse	Greenland	10	10
	Hope	Greenland	3	2
1890	Polar Star	Greenland	4	4
	Eclipse	Greenland	18	13
1891	Polynia[3]	Davis Straits	3	3
1892	Aurora	Davis Straits	1[4]	—
1893	Aurora[5]	Davis Straits	1	—

[1] 39 tons of Bottlenose oil brought to Scotland from "Fishing Station" in Cumberland Sound.
[2] Catches made between Resolution Island and Frobisher Bay (Lindsay 1911).
[3] Ship was lost on 11 July.
[4] Although no Bottlenose catch is given on Bruce's list, Southwell (1893) indicated that one was taken at the Southwest Fishing.
[5] Journal kept by James W. Allan, surgeon aboard the Aurora. Property of Glasgow University Library; microfilm copy in Old Dartmouth Historical Society.

(Reeves 1983). From 1877 to 1893 they took approximately 1669 Bottlenose Whales (Table 5).

The British fishery ended abruptly in 1892. Although Southwell (1885) blamed the decline of the fishery in 1884 on overhunting and bad weather, it seems clear that the British withdrawal was caused primarily by a steep reduction in the price of Bottlenose oil, from £60 per ton in the early 1880s to less than £20 per ton in the early 1890s (Figure 6).

The Norwegian Fishery

Norwegian sealers entered the seal fishery in the Greenland Sea in 1849 (Gray 1941) and made desultory attempts to take Bottlenose Whales. Vessels from Norway were outfitted specially for the Bottlenose fishery for the first time in 1883 (Nansen 1925). Besides carrying whaleboats for chasing, Norwegian Bottlenose Whale catchers had cannons mounted on the mothership (Ohlin 1893). The Norwegians took nearly 17 500 Bottlenose Whales from 1883 through 1892 (Christensen 1976). Most of the oil went to London and Glasgow, glutting the market and driving down the price of Bottlenose oil (D. Gray letter to T. Southwell, 1887, *in* Southwell 1860-1908). The Norwegian Bottlenose Whale fishery also affected American exports of Sperm oil by making large quantities of Bottlenose oil available in Europe at comparatively modest prices (e.g., letter from D. Gray to T. Southwell, 1894, *in* Southwell 1860-1908; *Whalemen's Shipping List*, New Bedford, Massachusetts, 55(5), 23 February 1897).

The highest catch on record was in 1896, when 80 Norwegian vessels took 3301 Bottlenose Whales

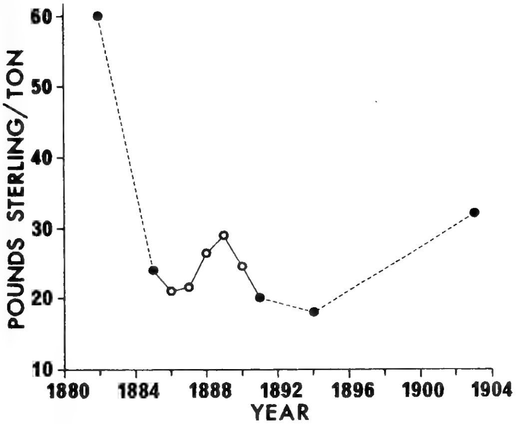


Figure 6. Trends in prices paid for Bottlenose Whale oil, 1881 to 1903. Data from Southwell Papers. Closed circles are exact; open circles are midpoints of a range.

(Christensen 1976, 1993). The total Norwegian catch through 1926 was more than 57 500. By 1927, the fleet of Bottlenose catchers had declined to a single vessel. No catch was reported from 1931 to 1936, but after 1937 Bottlenose whaling continued ancillary to the pelagic Minke Whale fishery. Long-finned Pilot Whales and Killer Whales were also taken (Mitchell 1977b). The total recorded Bottlenose catch by Norway from 1927 through 1973 was more than 5900 (Christensen 1976, 1993). Nearly all the Bottlenose Whales taken by Norwegian whalers from 1882 through 1973 were in the Northeast Atlantic, i.e. east of Cape Farewell, except for the 818 taken off Labrador in 1969-1971 (Christensen 1975; Benjaminsen and Christensen 1979).

The Canadian Fishery

The Northern Bottlenose Whale was a minor target of the whaling enterprise based at Blandford, Nova Scotia, between 1962 and 1967. During this six-year period 87 Bottlenose Whales were taken, mainly near Sable Island and the edge of the Grand Bank (Mitchell 1974; Table 1).

Other Fisheries

Small numbers of Bottlenose Whales were taken by catcher vessels off West Greenland (Jensen and Heide-Jørgensen 1993) and the Faroe Islands (Bloch and Desportes 1993), but in neither area were they a major target of shore-based commercial whaling.

Product Yields

A large adult male (Figure 7) could yield as much as 2 to 3 tons of oil and 2 to 3 hundredweight of spermaceti (Gray 1882, 1941), although the average oil yield was no more than a ton (Ohlin 1893) [Table 5]. Ohlin (1893) noted that the oil yield of an old male ("toendebund") was equivalent to that of three or four "smaller or ordinary" whales. Females produced no spermaceti. The major difference in yield between males and females may have induced the whalers to hunt selectively for adult males. As suggested by Mitchell (1977b), proportionately more of a given age or sex class may have been taken in the early years of the Bottlenose fishery if succorant behavior was stronger in, for example, adult females or dominant bulls than in other segments of the population. Gray's (1882) catch in 1882 consisted of 96 adult males, 56 females, and 51 "younger" males. The previous year at least 28% of his catch consisted of females (Table 6). Of 25 Bottlenose Whales taken off Nova Scotia for which sex was recorded, the male:female ratio was 2:3 (Table 1).

Whaling Tactics and Hunting Loss

The tendency of Bottlenose Whales to approach vessels and to gather round injured companions (succorant or care-giving behavior) meant that much

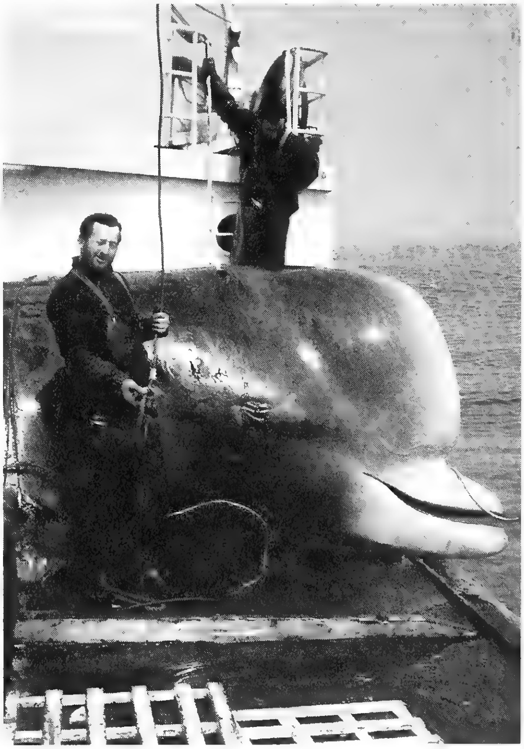


Figure 7. A 9-meter male Northern Bottlenose Whale aboard a Norwegian whaling vessel, June 1971 off Labrador (61-63°N, 60-61°W). [Photograph by Ivar Christensen.]

TABLE 6. Catch of Bottlenose Whales by the *Eclipse* in the Greenland Sea, 1881 [from a letter, D. Gray to T. Southwell, Peterhead, 6 January 1882, *in* Southwell (1860-1908)].

Date	Whales	Sex
19 April	1	F
24 April	1	?
25 April	1	?
26 April	3	?
27 April	2	1F;1?
28 April	3	?
29 April	3	1F;2?
2 May	7	1F;6?
3 May	1	?
7 May	2	?
8 May	2	2F
9 May	1	F
13 May	2	1M;1F
14 May	1	M
16 May	1	M
17 May	7	4M;3F
20 May	1	M

of a group could be killed in a day (Gray 1882). Although some Scottish whalers noted that the whales became warier after a few years of hunting pressure (Southwell 1884), the Norwegians continued to rely on the ship-approaching and succorant behavior of the Bottlenose Whales (Ohlin 1893).

Bottlenose Whales were difficult to kill and secure, and there was a substantial loss rate, at least in the early years (Gray 1882). On one day David Gray's crew fired 25 shots at Bottlenose Whales but fastened to only nine, two of which were lost when the harpoon broke (D. Gray letter to Southwell, 1881 *in* Southwell 1860-1908). In 1882 the crew of the *Eclipse* fired 338 shots, of which 224 "took effect"; 21 struck whales escaped when the harpoon drew or the line broke (Lubbock 1937).

Population Sizes and Trends

Mitchell (1975b) used catch data from the late nineteenth century (Risting 1922; Lubbock 1937) for a series of cumulative catch estimates of "initial" population size. Especially considering the late age at first ovulation and lengthy calving interval of Bottlenose Whales (Benjaminsen 1972; Christensen 1973) and that Mitchell used only data on secured catch and made no adjustment for hunting loss, his estimates ranging between 14 000 and 26 000 in the Northeast Atlantic in the 1880s are probably conservative.

A more complete series of Norwegian catch data indicated a total North Atlantic catch of 29 782 from 1890 to 1900 (Christensen 1976). Christensen (1976) reasoned that if one whale was struck and lost for every three or four secured during the early years of the fishery, then there must have been 40 000 to 50 000 Bottlenose Whales east of Greenland when whaling began. Mitchell (1977b) used Christensen's (1976) catch series and applied a 10% "lost-and-killed" rate, concluding that there must have been at least 28 000 Bottlenose Whales east of Greenland in 1889.

From shipboard sightings surveys in summer 1987, Gunnlaugsson and Sigurjónsson (1990) estimated 4925 (c.v. = 0.16) Bottlenose Whales at the surface in an area around Iceland, *ca* 07°W to 42°W and 55°N to 69°N, and 902 (c.v. = 0.45) around the Faroe Islands, *ca* 07°E to 12°W and 52°N to 67°N. The surveyed areas included a relatively small part of the species' range in the central and eastern North Atlantic. The estimates did not include a correction for submerged whales that were missed (negative bias), nor did they include an adjustment to account for the ship-approaching behavior of Bottlenose Whales (positive bias). Øien (1990) noted the difficulty of applying conventional line-transect analyses to sightings data for a species, like the Northern Bottlenose Whale, that has such prolonged dive times (14–70 min, *fide* Benjaminsen and Christensen 1979).

Catches of Bottlenose Whales west of Greenland have been much smaller than those east of Greenland. The total Scottish catch in "Davis Strait" was only 235 whales, 1877-1892 (Table 5). The cumulative Norwegian catch off Labrador was 818 whales, 1969-1971 (Christensen 1975). A total of 87 Bottlenose Whales was taken off Nova Scotia, 1962-1967 (Mitchell 1975b) [Table 1].

The reported catch of 20 Bottlenose Whales at Newfoundland in 1953, from the *International Whaling Statistics* (Mitchell 1975b: 54), is a transcriptional error. Twenty Minke Whales and one Bottlenose Whale were taken that year. The Bottlenose was one of two seen in Trinity Bay in the 1953 season (Sergeant and Fisher 1957). In waters along Hall Peninsula, southeastern Baffin Island, the Bottlenose Whale was judged to be the most common cetacean during the period from May to October 1978 (Smith et al. 1979). On the basis of mark-recapture estimates using photoidentification in 1988-1990, Faucher and Whitehead (1991) estimated that the resident population of Bottlenose Whales in The Gully area off Nova Scotia numbered in the low hundreds.

Habitat

Gray (1882) found the densest concentrations of Bottlenose Whales along the edges of pack ice in spring and summer, although he claimed that they were rarely encountered "amongst" the ice. In his experience, they seemed to prefer sheltered, open embayments, which they would leave as ice encroached. Norwegian whalers found Bottlenose Whales several nautical miles "inside the ice edge" off Svalbard and Labrador and on one occasion as much as 10 nautical miles into the ice off Labrador (Benjaminsen and Christensen 1979). Aerial observations along the ice edge off Labrador gave observers the impression that the whales were moving "in and out under the ice, possibly to feed" (Conover, Parsons, and Orr 1979: 5–20).

As indicated above, Bottlenose Whales are found in greatest abundance in waters deeper than 1000 m. Records of sightings made from Icelandic whaling vessels on the whaling grounds west and southwest of Iceland, 1979-1988, confirm that Bottlenose Whales inhabit waters mainly near or seaward of the 1000 m depth contour (Sigurjónsson and Gunnlaugsson 1990). The main concentration area was northwest of the Reykjanes ridge. Faucher and Whitehead (1991; and see Whitehead 1990) found that Bottlenose Whales can be consistently found in a very small area of approximately 12 km x 8 km at the entrance of The Gully off Nova Scotia. Individuals photoidentified during autumn and winter months had also been photographed during the summer, suggesting a non-migratory population.

The distribution of Bottlenose Whales during spring and early summer is said to be concentrated near the boundaries between cold polar currents and warmer Atlantic currents (Murray and Hjort 1912). They have been observed in areas with surface temperatures as high as 17°C (Winn et al. 1970) and as low as -2°C (Ohlin 1893). Benjaminsen and Christensen (1979) found them to be most abundant east and northeast of Iceland during April and May in waters with surface temperatures between -1.3° and -0.9°C.

General Biology

Life History

"Mature" fetuses were found in Bottlenose Whales in the Greenland Sea in May and June, and females accompanied by calves were seen there in June (Gray 1941). Based on the lengths of 251 fetuses and their dates of capture, Benjaminsen (1972) concluded that the peak of births is from April through June. He considered the mean length at birth to be about 3 m. Using the same sample of fetal lengths, Benjaminsen (1972) estimated the gestation period as about 12 months. Thus, the peak time of mating and births is spring and early summer. The lactation period has not been determined but is probably at least a year. The female reproductive cycle involves an average calving interval of at least two years (Mitchell 1975a; Benjaminsen and Christensen 1979).

Females reach sexual maturity at a length of 6.7 to 7.0 m (Benjaminsen 1972), which corresponds to an age of 8 to 13 dentinal growth-layer-groups (GLGs; probably formed annually) [Christensen 1973, 1975]. Christensen (1973) estimated that females ovulate for the first time at an age of 7 to 18 GLGs and that 80% attain sexual maturity at ages of 8 to 12 GLGs.

Sexual maturity in males is attained at a length of 7.3 to 7.6 m (Benjaminsen 1972). Benjaminsen (1972) estimated from a sample of 19 specimens that sexual maturity in males was reached at ages of 9 to 11 GLGs.

Christensen's (1973) age-length curve based on 75 males from Labrador indicated that lengths of 7.3 to 7.6 m correspond to ages of 7 to 9 GLGs. Testes weights plotted against age for the same sample suggested that accelerated growth of testes occurs at 8 to 12 GLGs. According to the histological appearance of the testes, all males younger than 7 GLGs were classified as immature, "maturing" whales (10-75% of tubules mature) were in the 7 to 11 GLG range, and all animals older than 11 GLGs were sexually mature (Christensen 1975; Benjaminsen and Christensen 1979).

Behavior

Bottlenose Whales are generally found in pairs or in groups of 4 to 10, "although many different herds are frequently in sight at the same time" (Gray 1882). In seven sightings of 31 whales in the Northeast Atlantic, the mean group size was 4.43 (c.v. 0.13 [Øien 1990]). Most groups observed in The Gully contained 1–4 whales; the largest number in a single group was 11 (Faucher and Whitehead 1991). Whalers described some segregation in Bottlenose Whale populations, with adult males sometimes travelling separately from the younger males and females (Gray 1882; Ohlin 1893; Christensen 1993). Faucher and Whitehead (1991) recognized three types of group: "male" groups containing 1–5 mature or maturing males; "female" groups containing 1–9 females and immatures; and "mixed" groups containing 2–8 females and immatures along with 1–3 mature or maturing males. The last of these usually had more females and immatures than males. Preliminary analyses of photoidentification data from The Gully suggest that there are long-term companionships between some males and between some females, but not between males and females (Faucher and Whitehead 1991).

Bottlenose Whales frequently approach stationary or slow-moving ships, and they may circle a vessel for longer than an hour. Their surfacing behavior can be quite variable. At times they remain still while at the surface; at other times they swim rapidly and erratically in different directions. Of 288 measured stays at the surface, 41% (117) lasted 5 min or less, and an additional 17% (49) lasted 6-10 min (Faucher and Whitehead 1991). After a deep dive a Bottlenose Whale often surfaces near the spot where the dive began (Christensen 1993). Observed dive durations in The Gully ranged between 1 and 180 minutes, with 48% (110) of the 229 recorded dives lasting 10 minutes or less and 11% (26) lasting longer than an hour (Faucher and Whitehead 1991).

Bottlenose Whales make a variety of low-intensity sounds in the range of human hearing (Winn et al. 1970) as well as more powerful ultrasonic clicks (Faucher and Whitehead 1991).

The squid *Gonatus fabricii* is apparently the most important prey of Northern Bottlenose Whales during the spring and summer. Some whale stomachs have been found to contain as much as 20 to 25 liters of beaks and other undigested parts of *Gonatus fabricii* as well as fish (Benjaminsen and Christensen 1979). In addition to squid, they take sea cucumbers (Holothuroidea), sea stars (Asteroidea), euphausiids, *Thysanopoda* sp., and Herring, *Clupea harengus*. Stomachs of whales killed off Iceland contained, in addition to squid, Cusk, *Brosmius brosme*, Lumpsucker, *Cyclopterus lumpus*, and Redfish, *Sebastes* sp.; those off Labrador, Greenland Halibut, *Reinhardtius hippoglossoides*, Redfish, Rabbit-fish, *Chimaera monstrosa*, Piked Dogfish, *Squalus acanthias*, Ling, *Molva olva*, Skate, *Raja* sp., and deep-sea prawns, *Pandalus* sp. (Benjaminsen and Christensen 1979).

Limiting Factors

Although British whalers found little or no evidence that Bottlenose Whales were preyed upon by Killer Whales (Gray 1941), Jonsgård (1968a) reported an observation by Norwegian whalers of a Bottlenose Whale being killed by Killer Whales as well as an attack by a pod of Killer Whales on two harpooned Bottlenose Whales. Jonsgård (1968b) described Bottlenose Whales with one or both flippers missing and mentioned that some injured animals bore tooth marks from Killer Whales. Bottlenose Whales that appear to be disoriented sometimes wander into shallow areas near shore (Kastelein and Gerrits 1991). They also come ashore alive occasionally (Anonymous 1990).

Bottlenose Whales are generally absent from semi-enclosed areas such as Hudson Bay, the Gulf of St. Lawrence, and the Baltic Sea. Their near total dependence on squid for food suggests that their overall distribution is determined largely by the availability of squid, particularly *Gonatus fabricii*. Bottlenose Whales characteristically inhabit specific ocean areas with particular conditions (see Habitat).

Special Significance of the Species

Apart from its economic significance, the Northern Bottlenose Whale is scientifically interesting. It has been considered "the Sperm Whale of the Ziphiidae" because of apparent similarities in morphology (e.g., strong sexual dimorphism, presence of spermaceti in the head) and behavior (e.g., group structure, deep diving, dietary preference for squid) between the two species (Mitchell 1977b). Whitehead (1990) suggested that in spite of some obvious similarities, Bottlenose Whales differ from Sperm Whales in that they are less wide-ranging and more tied to particular spots in the ocean where their peculiar habitat requirements are met. Clarke and Kristensen (1980) noted that the squids eaten by two stranded Northern Bottlenose Whales, one found at the Faroe Islands and one at Jutland in Denmark, were considerably smaller (average weight estimated at 157 g) than the squids eaten by Sperm Whales near Iceland (average 1540 g).

The large maxillary crests of the Northern Bottlenose Whale's skull are thought to have a function related to acoustic behavior (Norris 1964; Mitchell and Kozicki 1975). Similar maxillary crests are present in only one other cetacean genus, *Platanista*, the functionally blind river dolphins of the Indian Subcontinent that swim on their sides while scanning the bottom (sonically) for prey (Herald et al. 1969). It is not known whether the Bottlenose Whale is also a side-swimmer. The loud ultrasonic clicks of the Northern Bottlenose Whale (faster and at a higher frequency than those of Sperm Whales) are especially interesting (Faucher and Whitehead 1991).

Clarke (1986) referred to the value of studying the diet of deep-diving oceanic cetaceans, such as the Bottlenose Whales, as a way of assessing the distribution and ecology of squids and deep-sea fishes. In some respects at least, whales may be more efficient samplers of cephalopods than are trawl nets (Clarke 1980). Knowledge of squid distribution and ecology has also been used to make inferences about the movements of Bottlenose Whales (Clarke and Kristensen 1980).

The Northern Bottlenose Whale is reputed to dive for periods of up to two hours. Only the Sperm Whale is known to be capable of dives of comparable duration (Watkins et al. 1985). The Northern Bottlenose Whale's ship-approaching behavior and concentrated distribution make it a more promising species for observation than the other ziphiids, whose surface behavior is more cryptic (e.g., *see* Whitehead 1990; Faucher and Whitehead 1991).

Evaluation

There has been much controversy about the status of Northern Bottlenose Whales in the Northeast Atlantic and about the reasons for the westward expansion of the Norwegian fishery. This controversy has centered on questions about the relative importance of economic factors versus depletion of whales in causing the fishery's decline and the changes in areas of operation.

Nansen (1925: 235) stated that the decline of the Norwegian Bottlenose Whale fishery in the 1920s was caused by "the comparative scarcity of whales." However, there apparently were enough left to sustain catches totalling close to 6000 Bottlenose Whales ancillary to the Minke Whale fishery from 1937 to 1973.

A few years after Bottlenose whaling started north of Iceland and continued east of Iceland and near Jan Mayen, Bottlenose Whales were "scarcely to be seen in these areas" (Christensen 1975). By the late 1960s, "the vessels had to move into the Labrador Sea to catch this species." However, while acknowledging that the population of Bottlenose Whales might have been reduced between 1946 and 1972, Christensen et al. (1977) argued that the westward expansion of Norwegian whaling "was not caused by a drastic depletion of the stock or stocks in the North East Atlantic." Mitchell (1977b) noted that the peak catch of 689 in 1965 and the high catches of 477 and 529 in 1969 and 1970, respectively, were comprised largely of animals in Denmark Strait and Davis Strait "that had not been exploited heavily for over fifty years."

Christensen et al. (1977) were unable to explain the transfer of effort from the Spitsbergen catching ground to the North and East Iceland-Jan Mayen ground in the 1960s but concluded that "the available data do not indicate any depletion off Spitsbergen." In their view, the westward expansion of Bottlenose whaling to the Labrador Sea in 1969 was made possible by the entry of larger boats into the fishery. According to Christensen et al., the "availability" of Bottlenose Whales was sufficiently greater off Labrador than in the old catching grounds off Spitsbergen and north of Iceland to make it economically profitable for those whalers with large enough boats to travel the extra distance. These authors did not comment on why Bottlenose Whales were more "available" off Labrador than on the Northeast Atlantic catching grounds. One possibility is that the stock(s) between Europe and Greenland had become depleted after 80 or more years of whaling, while the whales off Labrador remained relatively undisturbed by whaling before the 1960s and were behaviorally naïve as well as densely distributed in areas of prime habitat.

Jonsgård (1977) discussed how market factors and meat prices affected the catching of Bottlenose Whales. Although the average value of a Bottlenose Whale exceeded that of a Minke Whale during 1946-1959, the values were essentially equivalent during 1960-1965. After 1965, the value of a Bottlenose Whale remained less than that of a Minke Whale. Jonsgård suggested that this trend may have been caused by the increasing size of the average Minke Whale taken. He explained the elimination of odontocetes from the catch after 1972 as due at least partially to the British ban on importation of whale meat for pet food and to the availability of less expensive substitutes for feeding fur-farm animals.

The status of Bottlenose Whales in the Labrador Sea is of particular interest to Canada. Christensen et al. (1977) noted a decline in the average number of whales taken per catcher there over the short period 1969-1971: 46.2 (5 vessels) in 1969, 37.4 (9 vessels) in 1970, and 37.8 (4 vessels) in 1971. They concluded that these data indicated a "reduced but not depleted stock off Labrador after 1972."

Canadian catches in The Gully declined from 1964 to 1967 (Table 1), but this may have been due partly to the increasing importance of Fin Whales, *Balaenoptera physalus*, and Sei Whales, *Balaenoptera borealis*, in this fishery (Mitchell 1974) rather than to a major decline in availability of Bottlenose Whales.

Mitchell (1975b) listed *Hyperoodon ampullatus* as a species that was heavily exploited and for which there was urgent need of population assessment. At the time, he considered the Northern Bottlenose Whale "vulnerable" according to the definition of Goodwin and Holloway (1972). It was formally assigned the status of "vulnerable" by the International Union for the Conservation of Nature and Natural Resources (IUCN; now World Conservation Union) in the Red Data Book in 1976 (Mitchell 1976). The species recently was removed from IUCN's "vulnerable" category and is now listed as "insufficiently known" (Klinowska 1991). Considering that the Northern Bottlenose Whale has not been exploited commercially since 1973 and that it is currently protected by the IWC, we conclude that the species, as a whole, does not require a COSEWIC status designation at this time. However, Whitehead (1990) and Faucher and Weilgart (1992) have expressed strong concern about the vulnerability of the Bottlenose Whales using The Gully because of: (1) the small size of the population, (2) the small extent of its year-round core habitat, and (3) the plans to develop nearby offshore oil and gas fields. The Gully is the only place in the world where a living ziphiid population has been closely studied. Any plans for offshore development involving ship traffic or other industrial activities on or near The Gully should be evaluated for their potential impact on Bottlenose Whales. A separate COSEWIC evaluation of this population is planned for 1994.

Acknowledgments

This report was prepared with a grant to Okapi Wildlife Associates from the Department of Fisheries and Oceans, and World Wildlife Fund Canada. Laurie Schell drafted the figures.

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[Note for whaling manuscript sources that are listed alphabetically by vessel name: PAC = Public Archives of Canada, Ottawa; SC = Stefansson Collection, Dartmouth College Library, Hanover, New Hampshire, USA (microfilm).]

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Accepted 31 December 1993

Status of Baird's Beaked Whale, *Berardius bairdii**

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Reeves, Randall R., and Edward Mitchell. 1993. Status of Baird's Beaked Whale, *Berardius bairdii*. Canadian Field-Naturalist 107(4): 509–523.

Baird's Beaked Whale, *Berardius bairdii*, is a large odontocete with a distribution restricted to the cool, deep waters of the northern North Pacific Ocean and contiguous seas. Off the Asian coast where the species has been exploited for centuries three stocks are recognized: Sea of Japan, Okhotsk Sea, and Pacific Ocean. Off North America the range extends from Alaska to Mexico. Baird's Beaked Whales are observed mainly over the continental slope and in pelagic areas with submarine escarpments and seamounts. They are deep divers that prey on squid and deep-sea fish. Schools of up to 30 animals have been observed, but groups of four to ten are more typical. Baird's Beaked Whales were exploited on a relatively small scale by shore-based whalers in the eastern North Pacific; 35 were taken in British Columbia between 1950 and 1966. Exploitation since the late 1960s has been limited to Japanese waters, where a national quota of about 60 Baird's Beaked Whales has been in effect since 1988. Sighting surveys on the whaling grounds indicate a population of several thousand Baird's Beaked Whales available to the fishery. There is no immediate concern for the survival of the species and no COSEWIC status designation is required.

La grande baleine à bec, *Berardius bairdii*, est un grand odontocète dont la distribution se limite aux eaux froides et profondes de l'océan Pacifique Nord et des mers contiguës. Au large des côtes d'Asie, où l'espèce est exploitée depuis des siècles, trois populations sont connues: une dans la mer du Japon, une dans la mer d'Okhotsk et une dans l'océan Pacifique. Au large de l'Amérique du Nord, on en trouve de l'Alaska au Mexique. On rencontre surtout la grande baleine à bec au dessus des pentes continentales sous-marines et des zones pélagiques escarpées et montagneuses. Ce sont des plongeurs de profondeurs qui se nourrissent de calmars et de poissons des eaux profondes. Des groupes comportant plus de 30 individus ont eté observés mais groupes de 4 à 10 se sont plus usuels. Les grandes baleines à bec sont pêchées à une échelle relativement petite dans le Pacifique Nord de l'est; on en capture 35 en Colombie-Britannique entre 1950 et 1966. Vers la fin des années 1960, l'exploitation en fut limitée aux eaux japonaises où est fixé un quota d'environ 60 individus depuis 1988. Des observations sur les sites de pêche à la baleine ont dénombré des populations de plusieurs milliers de grandes baleines à bec disponibles pour la pêche. À ce tire, l'espèce ne requiert pas une intervention de la part du CSEMDS.

Key Words: Baird's Beaked Whale, grande baleine à bec, *Berardius bairdii,* Cetacea, Odontoceti, whaling.

Baird's Beaked Whale, *Berardius bairdii* Stejneger 1883, is the largest species in the cetacean family Ziphiidae (Figure 1). It is sometimes called the Northern Giant Bottlenose Whale. Adult females, which are larger than males, reach a length of up to 12.8 m (Nishiwaki and Oguro 1971) and can weigh more than 11 metric tons (Balcomb 1989). The genus has an anti-tropical distribution: Arnoux's Beaked Whale, *Berardius arnuxii*, inhabits the South Atlantic and South Pacific oceans and may have a circumpolar distribution in the Southern Hemisphere (Brownell 1974; McCann 1975; Lichter 1986; International Whaling Commission 1989: 118), whereas *Berardius bairdii* is endemic to the North Pacific Ocean north of about 23°N (Balcomb 1989). Rice (1977, following Davies 1963) noted that the North Pacific form differs from the Southern Hemisphere form chiefly by its much larger size and suggested that the two might best be considered subspecies rather than separate species. The distinction at the species level stands (True 1910; Tomilin 1967: 408*n*,420), pending a comprehensive systematic review of the genus.

Baird's Beaked Whale was of minor importance in the now-defunct shore whaling industry on the west coast of North America, and it continues to be exploited on a relatively small scale in Japan. The purpose of this paper is to review the current status of Baird's Beaked Whale, particularly in the eastern North Pacific. It covers the species throughout its known range and addresses briefly the question of whether there is more than one biological population.

Distribution

In the eastern North Pacific the distribution of Baird's Beaked Whale has been described as extending from about 32°30'N off southern California to St. Matthew Island in the Bering Sea at about 60°N (Rice 1974; Mitchell 1975a). Leatherwood et al. (1982) gave the southern limit as 28°N (also see Pitman et al. 1989). Seven Baird's Beaked Whales mass-stranded in the southeastern Gulf of California,

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*Reviewed and approved by COSEWIC 8 April 1992, report accepted - no status designation required.

at about 24°N, in July 1986 (Aurioles-Gamboa 1992), and several sightings have been made in or near the mouth of this gulf (Vidal et al. 1993).

A reported sighting of two individuals in the southern Chukchi Sea near Cape Uelen in early September 1948 (Sleptsov 1961 [1970]) is the northernmost record for the species, but Tomilin (1967: 420) considered Cape Navarin (62–62°30'N) the normal northern limit on the west side of the Bering Sea. He claimed that natives of Bering Strait were unfamiliar with Baird's Beaked Whale and that it was very rare north of Olyutorskii Bay.

In the western North Pacific these whales are present in the Okhotsk Sea and Sea of Japan and along the Pacific coast of Japan south to southern Honshu at about 34°N (Kasuya 1971, 1986; Nishimura 1970; International Whaling Commission 1989). Sightings and strandings are common at the Commander (True 1910; Barabash-Nikiforov 1938; Marakov 1967), Aleutian (Scheffer 1949; Leatherwood et al. 1983), and Pribilof islands (True 1910). Reported sightings in the western and central North Pacific as far south as 25°N (Ohsumi 1983; Kasuya and Ohsumi 1984) have been questioned as possibly resulting from misidentifications (International Whaling Commission 1983b: 158; 1989: 117). Balcomb (1989) however, in a review of Baird's Beaked Whale, considered its range to be extensive across the North Pacific north of 35°N, particularly centered in areas with submarine escarpments and seamounts.

Published distribution maps differ in showing a broad latitudinal and longitudinal distribution (Rice 1978) versus a restricted one (Mörzer Bruyns 1971:chart 9) and a distribution across the Aleutian Basin of the western Bering Sea (Nishiwaki 1966: figure 10) or not (Rice 1986). We consider the latitudinal limits of distribution given by Tomilin (1967) and Kasuya (1986) for the west and Leatherwood et al. (1982) for the east to be the best reflection of current knowledge, except that the extreme southern limit for the east is several degrees farther south (*see* Balcomb 1989; Aurioles-Gamboa 1992; Vidal et al. 1993.

Baird's Beaked Whales may be migratory (International Whaling Commission 1989), but movements by individuals have not been studied. Kasuya (1986) suggested that the population off the Pacific coast of Japan moves northward in summer as a response to the seasonal expansion of the warm surface water of the Kuroshio Current (defined as the 25°C isotherm). The species is essentially absent from Japanese coastal waters from January to April, with only small numbers present in December and May (Kasuya 1971; Nishiwaki and Oguro 1971).

Rice (1974) concluded from the timing of catches that Baird's Beaked Whales have two peaks of abundance off central California - one in July and the other in October (Table 1; Figure 2). Aerial surveys off central and northern California during 1980-1983 provided no evidence of a north-south migration but did suggest inshore-offshore movements, with sightings in all months except December, January, and April and a peak of sightings in September and October (Dohl et al. 1983). A few Baird's Beaked Whales were taken off Grays Harbor, Washington, in April, May, July, and September (Scheffer and Slipp 1948), and there is an early October record of a group of six sighted off Westport, Washington (Wahl 1977). A beaked whale that stranded near Ozette, Washington, in February 1988 was initially reported as a juvenile Baird's Beaked Whale (Baird and Stacey 1988) but proved upon examination of the skull to have been a whale of the genus *Mesoplodon* (R. W. Baird, Marine Mammal

TABLE 1. Information on 17 Baird's Beaked Whales taken by the U.S.A., 1949-1966, from forms submitted to the Bureau of Whaling Statistics, Sandefjord, Norway.

Date	Catch Position	Sex	Length (feet)
6 May 1951	40°00'N, 125°00'W	M	34
21 October 1957	38°00'N, 123°30'W	F	36
12 July 1958	37°38'N, 123°12'W	F	35
1 October 1959	38°00'N, 123°00'W	M	34
17 September 1959	37°40'N, 123°10'W	M	37
1 October 1960	37°44'N, 123°18'W	M	35
29 September 1960	37°40'N, 124°20'W	M	35
24 June 1961	38°04'N, 123°15'W	M	36
26 July 1961	37°30'N, 122°59'W	M	33
26 July 1961	37°30'N, 122°59'W	M	33
9 July 1961	37°45'N, 123°21'W	M	35
24 May 1963	38°00'N, 123°30'W	M	35
6 June 1963	36°10'N, 123°10'W	M	36
18 September 1964	37°25'N, 122°59'W	M	36
3 October 1965	37°20'N, 123°30'W	M	33
3 October 1965	37°20'N, 123°25'W	M	33
20 August 1966	38°00'N, 123°25'W	M	34

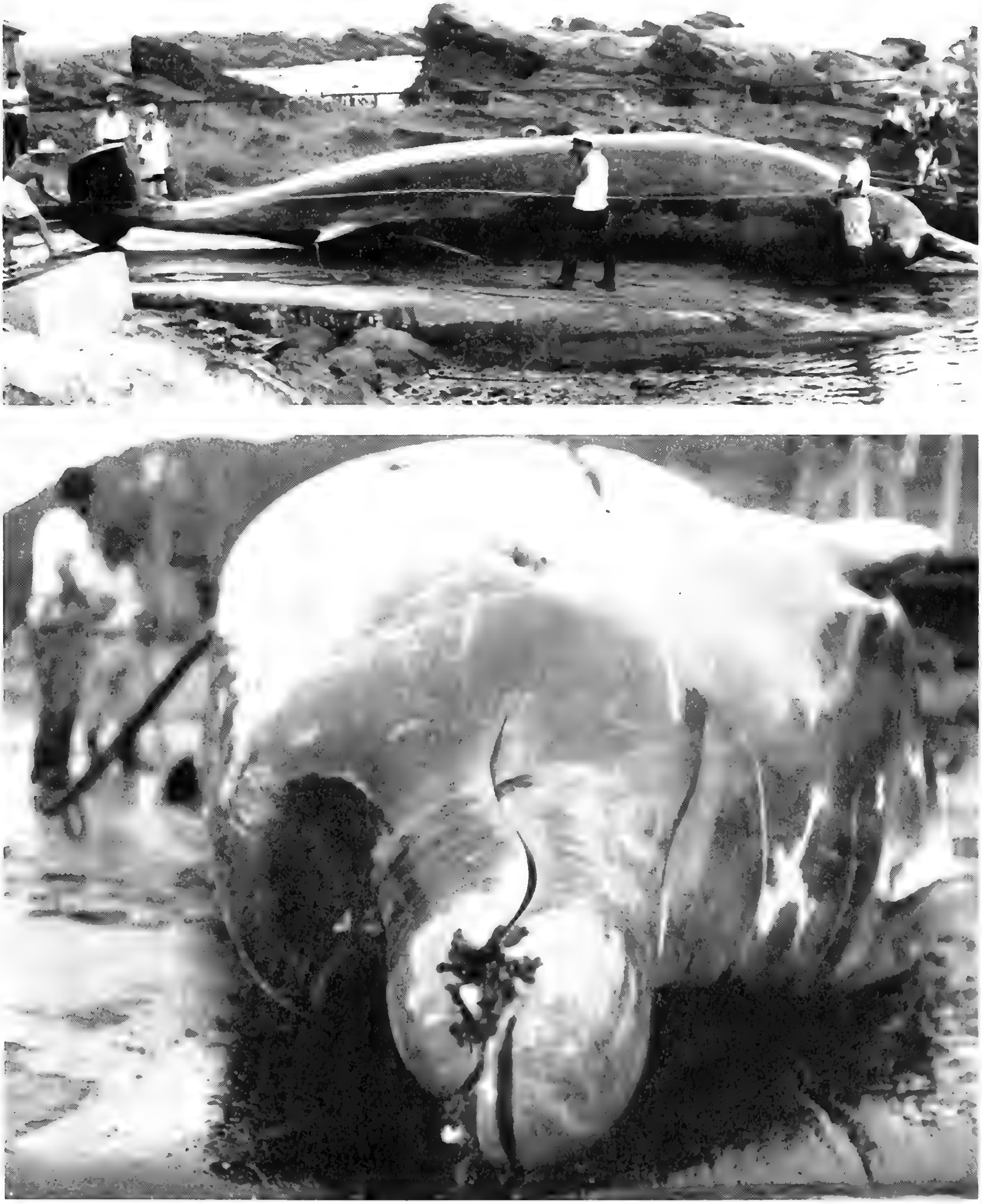

Figure 1. Baird's Beaked Whales at a shore station in Japan. The upper panel shows the animal in dorsal view. The lower panel is a face-on view showing the long "beak", the two exposed teeth at the front of the lower jaw, and clusters of stalked barnacles surrounding these teeth. Photos courtesy of H. Omura, from Leatherwood et al. (1982: 90).

Research Group, Victoria, British Columbia, personal communication).

Off the west coast of Vancouver Island whalers reported seeing Baird's Beaked Whales throughout the whaling season from May through September, especially in July and August (Pike 1953; Pike and MacAskie 1969; Reeves et al. 1985). Most catches were made in August (14 of 24; 58%) [Table 2].

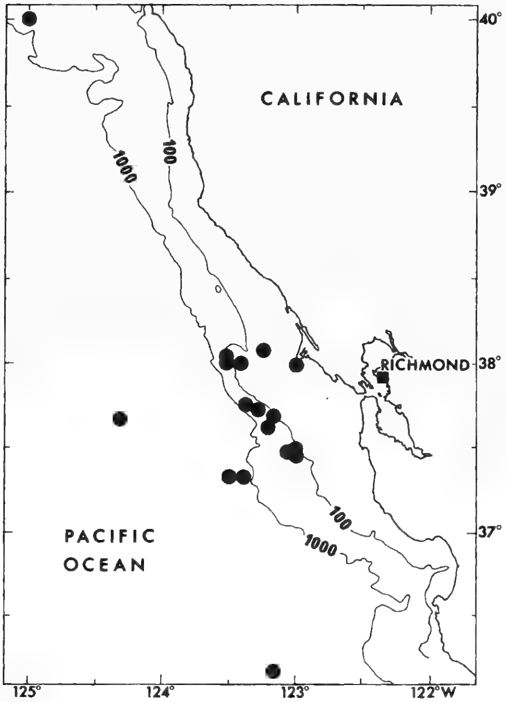

FIGURE 2. Catch positions of Baird's Beaked Whales killed off central and northern California, 1951-66 (see Table 1). The 100 and 1000 fathom contours are shown.

Catch positions were centered along and between the 100- and 1000-fathom contours (Figure 3).

Stock Identity

Omura et al. (1955) suggested from the timing of hunting seasons that the Baird's Beaked Whales hunted in the Okhotsk Sea belonged to a different population from those hunted off the Pacific coast of Japan. Kasuya and Ohsumi (1984) considered that the bimodal peaks in catches in the Okhotsk Sea reflected the whalers' preference for catching Minke Whales, *Balaenoptera acutorostrata*, and thus did not necessarily indicate variation in the availability of Baird's Beaked Whales. Kasuya (1986) and Kasuya and Miyashita (1989) suggested that separate populations occur in the Sea of Japan, the Okhotsk Sea, and the Pacific Ocean off Japan between the fronts of the Kuroshio and Oyashio currents. Shallow straits (less than 200 m deep) may act as barriers separating the Sea of Japan and Okhotsk Sea stocks (La Perouse and Tatarskiy straits) and the Sea of Japan and Pacific Ocean stocks (Tsugaru Strait) [Kasuya 1986].

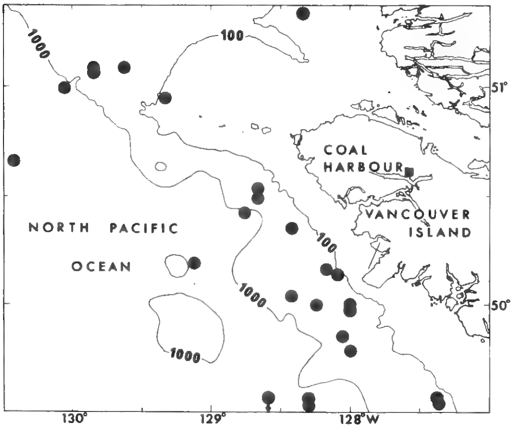

FIGURE 3. Catch positions of Baird's Beaked Whales killed off Vancouver Island, 1950-66 (see Table 2). The 100 and 1000 fathom contours are shown.

Available data are inadequate for addressing questions of stock relations and boundaries elsewhere in the North Pacific (International Whaling Commission 1984b:151). Sightings from Japanese vessels suggest that Baird's Beaked Whales may have a continuous distribution from coastal waters of Japan offshore across the central North Pacific (Kasuya and Ohsumi 1984). The records in Tables 3 and 4 include occurrences at high latitudes in spring, summer, and fall and at low latitudes in all four seasons (Figure 4). There is some suggestion that Baird's Beaked Whales are present throughout much of the year in some areas, e.g., off central and northern California (Dohl et al. 1983; Leatherwood et al. 1987). The distribution suggested by the records plotted on Figure 4 is biased by observational effort, and apparent hiatuses are suspect.

Protection

In Canadian waters whaling is prohibited, except by license or aboriginal entitlement, under the Marine Mammal Regulations of 1993. In U.S. waters Baird's Beaked Whale is protected under the Marine Mammal Protection Act of 1972. There is no whaling in Mexican waters at present.

In 1982 the Scientific Committee of the International Whaling Commission (IWC) evaluated the status of the stocks of *Berardius bairdii* exploited off Japan and concluded that the annual average catch of 39 whales for 1972-1981 "over a short period would not seriously affect the stock" (International Whaling Commission 1983b: 159–160). The government of Japan set a national quota of 40 Baird's Beaked Whales per year beginning in 1983 (International Whaling Commission 1983a: 28; 1984a: 16–17). The quota was increased to 60 for the 1988 season as an "emergency" measure to compensate for the closure of the Japanese Minke Whale fishery (Anonymous 1990; International Whaling Commission 1990: 22). For the 1990 season the quota was reduced to 54. The IWC's legal competence to

TABLE 2. Information on 25 Baird's Beaked Whales taken by Canada, 1949-1966, from forms submitted to the Bureau of Whaling Statistics, Sandefjord, Norway.

Date	Catch Position	Sex	Length (feet)
6 July 1950	50°00'N, 128°00'W	M	33
18 August 1951	50°N, 128°W	F	29
18 August 1953	49°51'N, 128°03'W	M	32
24 June 1953	49°31'N, 128°18'W	M	33
24 June 1953	49°31'N, 128°18'W	M	36
26 July 1953	50°57'N, 129°20'W	M	32
20 June 1954	50°02'N, 128°25'W	M	18
10 August 1954	50°21'N, 128°25'W	M	34
11 August 1954	51°00'N, 130°02'W	M	34
4 June 1955	50°09'N, 128°05'W	M	33
31 August 1955	50°11'N, 129°09'W	M	34
13 August 1955	50°26'N, 128°45'W	M	33
15 May 1956	49°47'N, 128°00'W	F	37
10 May 1957	51°05'N, 129°50'W	M	35
10 May 1957	51°05'N, 129°50'W	M	37
27 August 1957	51°20'N, 128°20'W	M	35
27 August 1957	50°00'N, 128°15'W	M	35
21 August 1958	50°32'N, 128°40'W	M	35
20 August 1958	51°05'N, 129°37'W	M	35
27 August 1962	50°10'N, 128°10'W	M	33
30 May 1963	48°32'N, 128°35'W	M	36
2 August 1963	49°32'N, 127°22'W	M	33
2 August 1963	49°32'N, 127°22'W	M	35
11 August 1966	50°30'N, 128°40'W	M	34
24 September 1966	50°40'N, 130°25'W	M	34

manage the exploitation of this species is not recognized by Japan.

Baird's Beaked Whale has been in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since May 1984. This has meant that international trade in products is prohibited. Since the only current direct fishery is in Japan, where there is

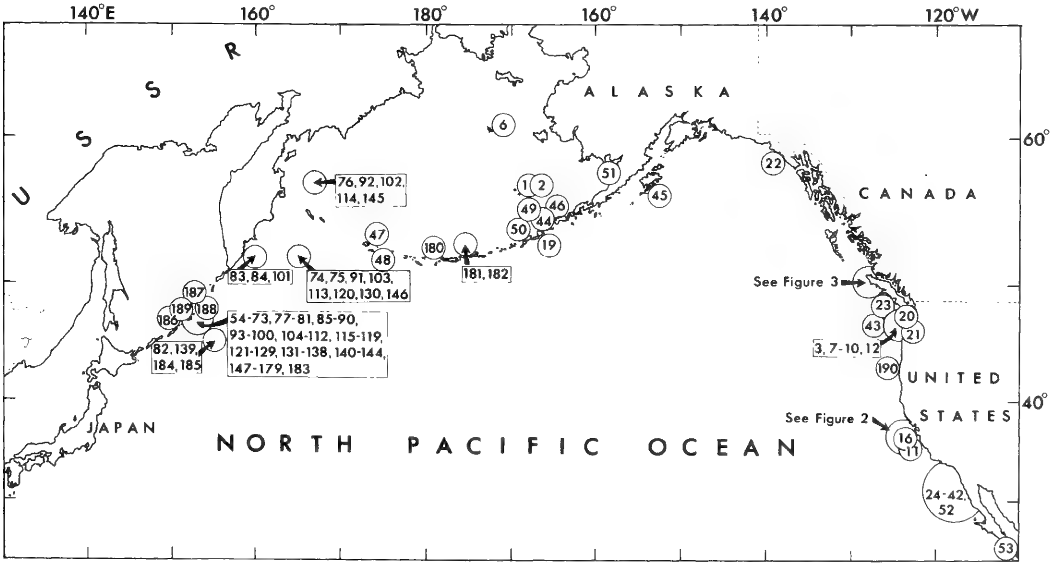

FIGURE 4. Localities of sightings, strandings, and takes of Baird's Beaked Whales (see Tables 3 and 4). Numbers are keyed to record numbers in tables.

TABLE 3. Records of Baird's Beaked Whale. See Figure 4 for plotted positions; records marked by an asterisk (*) are not plotted. PC = personal communication, 1 March 1988.

Record Number	Date	Position	Number of whales			Source
			Seen	Taken	Stranded	
1	16 June 1903	St. George Is., Pribilofs			2	True (1910)
2	21 August 1909	St. George Is., Pribilofs			1	True (1910)
3	1912	Off Bay City, Washington		2		Scheffer and Slipp (1948)
4	1915	Kyuquot, British Columbia*		1		Pike and MacAskie (1969)
5	1916	Kyuquot, British Columbia*		1		Pike and MacAskie (1969)
6	July 1916	St. Matthew Island, Bering Sea			1	Hanna (1920)
7	April 1918 or 1919	Off Bay City, Washington		1		Scheffer and Slipp (1948)
8	May 1918 or 1919	Off Bay City, Washington		1		Scheffer and Slipp (1948)
9	July 1918 or 1919	Off Bay City, Washington		1		Scheffer and Slipp (1948)
10	September 1918 or 1919	Off Bay City, Washington		1		Scheffer and Slipp (1948)
11	1 Oct 1920	Off Monterey, California		1		Davidson (1929)
12	1922	Off Bay City, Washington		2		Scheffer and Slipp (1948)
13	1923	Kyuquot, Naden Harbour or Rose Harbour, B.C.*		2		Pike and MacAskie (1969)
14	1924	Rose Harbour or Naden Harbour, B.C.*		1		Pike and MacAskie (1969)
15	1925	British Columbia*		3		Pike and MacAskie (1969)
16	ca 1 June 1925	Santa Cruz, California			1	Davidson (1929)
17	1928	Rose Harbour or Naden Harbour, B.C.*		1		Pike and MacAskie (1969)
18	1929	Rose Harbour or Naden Harbour, B.C.*		1		Pike and MacAskie (1969)
19	Fall 1948	Unalaska Is., Aleutians			1	Scheffer (1949)
20	Spring 1949	Between Queets and Kalaloch,Washington			1	Scheffer and Slipp (1948)
21	Early July 1950	Ocean City, Washington			1	Slipp and Wilke (1953)
22	1956	Dry Bay, Alaska			1	Leatherwood et al. (1983: table 13)
24	12 January 1971	29°00'N, 120°15'W	3			Leatherwood (PC)
25	30 December 1971	32°28'N, 118°13'W	5			Leatherwood (PC)
26	7 January 1972	32°47'N, 119°21'W	1			Leatherwood (PC)
27	3 February 1972	29°27'N, 118°27'W	12			Leatherwood (PC)
28	5 February 1972	29°08'N, 118°17'W	6-7			Leatherwood (PC)
29	3 February 1972	30°01'N, 118°31'W	4			Leatherwood (PC)
30	30 May 1972	32°12'N, 118°55'W	4			Leatherwood (PC)
31	6 June 1972	33°30'N, 120°23'W	6			Leatherwood (PC)
32	8 June 1972	31°39'N, 117°41'W	2			Leatherwood (PC)
33	13 June 1972	32°18'N, 119°08'W	6-9			Leatherwood (PC)
34	15 August 1972	*ca* 120 nm SW of San Clemente Island	+			Leatherwood (PC)
35	17 August 1972	32°21'N, 120°00'W	+			Leatherwood (PC)
36	24 August 1972	28°14'N, 116°31'W	2+			Leatherwood (PC)
37	15 September 1972	32°15'N, 120°15'W	3			Leatherwood (PC)
38	17 October 1972	31°15'N, 120°05'W	6			Leatherwood (PC)
39	2 December 1972	32°14'N, 119°15'W	small			Leatherwood (PC)
40	3 October 1973	32°25'N, 119°07'W	8			Leatherwood (PC)

Continued.

TABLE 3. *Concluded.*

Record Number	Date	Position	Number of whales			Source
			Seen	Taken	Stranded	
41	20 December 1973	32°18'N, 117°58'W	2			Leatherwood (PC)
42	27 August 1976	33°00'N, 118°40'W	2			Leatherwood (PC)
43	3 October 1976	75km WNW of Westport, Washington	6			Wahl (1977)
44	15 August 1977	Dutch Harbor, Aleutians			1	Leatherwood et al. (1983: table 13)
45	24 April 1978	Sitkalidak Island, Alaska			1	Leatherwood et al. (1983: table 13)
46	15 November 1978	Cataract Cove, Unimak Is., Aleutians		1		Leatherwood et al. (1983: table 13)
47	14 July 1979	Niziki Is., Semichi Is.			1	Leatherwood et al. (1983: table 13)
48	25 July 1979	Buldir Is., Aleutians			1	Leatherwood et al. (1983: table 13)
49	7 Sepember 1979	55°02'N, 167°46'W			1 (skull)	Leatherwood et al. (1983: table 13)
50	10 August 1982	53°27'N, 168°56'W, off Umnak Is., Aleutians	4			Leatherwood et al. (1983)
51	July 1983	Egegik Lagoon, Bristol Bay			1	Leatherwood et al. (1983: table 13)
52	(January or February) 1985	30°01.4'N, 117°56.6'W	7+			Leatherwood (PC) Leatherwood et al. (1987)
53	July 1986	Southeastern Gulf of California, *ca* 24°N			7	Aurioles-Gamboa (1992)
53a	May 1977	Clam Beach, Northern California			1	Sullivan and Houck (1979)

a strong domestic market, international trade is unlikely to occur. Baird's Beaked Whales have never been held in captivity.

Population Sizes and Trends

There are no estimates of historical population size in any area, nor are there recent or current estimates for the eastern North Pacific. Rice (1974) judged that Baird's Beaked Whales were not common off central California although he had previously described them as "frequently seen" there from at least June to October (Rice 1963). They were also seen "frequently" on the whaling grounds off Vancouver Island (Pike and MacAskie 1969). However, Baird and Stacey (1988) reported that sightings were "very uncommon" near Vancouver Island.

The population summering off the Pacific coast of Japan between 34°N and 39°N was estimated in 1984 as 3547 (S.E. 1046); when corrected by a factor of 1.19 to account for submerged whales, this gave a "more realistic minimum" estimate of 4220 (Miyashita 1986). The correction factor was calculated from a simulation model using dive-time data from Kasuya (1986). The model assumed that if a school surfaced on the transect line within the maximum observed sighting distance of 5.4 nautical miles it was certain to be seen. A new estimate, based on 11 surveys conducted between 1983 and 1989, totaled 5870 whales, broken down as follows: 3950 (CV=0.27) off the Pacific coast, 1260 (CV=0.45) in the Sea of Japan, and 660 (CV=0.27) in the Okhotsk Sea (Miyashita 1991; International Whaling Commission 1991).

Exploitation

In Japan, Baird's Beaked Whales have been hunted since the early 17th century or earlier (Omura et al. 1955; Ohsumi 1983; Freeman 1988). Before World War II they were hunted only in Chiba prefecture. After the war the number of vessels engaged in "small-type whaling" in Japan increased to a maximum of 80 in 1950. Baird's Beaked Whales began to be taken in areas outside Chiba along with other small and medium-sized odontocetes and Minke Whales (Nishiwaki and Oguro 1971). About 600 Baird's Beaked Whales were taken between 1907 and 1947 (Ohsumi 1983). From 1948 to 1986 the cumulative catch by Japan was 3900, with a peak of 322 (382 according to Nishiwaki and Oguro [1971:Table 1]) in 1952 (Ohsumi 1983, supplement-

TABLE 4. Information on 137 Baird's Beaked Whales taken by the U.S.S.R., 1949-1974, from forms submitted to the Bureau of Whaling Statistics, Sandefjord, Norway.

Record Number	Date	Catch Position	Sex	Length (cm)	Station/ Expedition
54	27 May 1949	47°N, 153°E	M	1050	Kuril Islands
55	4 July 1949	47°N, 153°E	M	1120	Kuril Islands
56	16 July 1949	47°N, 153°E	M	1000	Kuril Islands
57	29 July 1949	47°N, 153°E	M	890	Kuril Islands
58	14 August 1949	47°N, 153°E	F	970	Kuril Islands
59	6 September 1949	47°N, 153°E	M	900	Kuril Islands
60	15 September 1949	47°N, 153°E	M	900	Kuril Islands
61	7 October 1949	47°N, 153°E	M	1020	Kuril Islands
62	25 October 1949	47°7, 153°E	M	1080	Kuril Islands
63	25 October 1949	47°N, 153°E	M	1140	Kuril Islands
64	25 October 1949	47°N, 153°E	M	1080	Kuril Islands
65	7 May 1950	47°N, 153°E	M	850	Kuril Islands
66	9 May 1950	47°N, 153°E	M	970	Kuril Islands
67	13 May 1950	47°N, 153°E	F	1000	Kuril Islands
68	27 May 1950	47°N, 153°E	M	960	Kuril Islands
69	19 July 1950	47°N, 153°E	M	1070	Kuril Islands
70	5 August 1950	47°N, 153°E	M	1100	Kuril Islands
71	13 August 1950	47°N, 153°E	M	1010	Kuril Islands
72	23 August 1950	47°N, 153°E	F	960	Kuril Islands
73	4 September 1950	47°N, 153°E	M	1040	Kuril Islands
74	30 May 1950	52°N, 165°E	M	1140	Aleutians
75	11 June 1950	52°N, 165°E	M	730	Aleutians
76	19 June 1950	57°N, 167°E	M	1020	Aleutians
77	12 May 1951	47°N, 153°E	M	830	Kuril Islands
78	7 June 1951	47°N, 153°E	F	990	Kuril Islands
79	12 August 1951	47°N, 153°E	F	1050	Kuril Islands
80	30 August 1951	47°N, 153°E	M	1020	Kuril Islands
81	8 September 1951	47°N, 153°E	M	1050	Kuril Islands
82	13 July 1951	45°N, 155°E	M	1000	Aleutians
83	22 October 1951	52°N, 158°E	M	600	Aleutians
84	22 October 1951	52°N, 158°E	M	800	Aleutians
85	28 May 1952	47°N, 153°E	M	1010	Kuril Islands
86	19 June 1952	47°N, 153°E	M	1020	Kuril Islands
87	25 July 1952	47°N, 153°E	M	1000	Kuril Islands
88	31 August 1952	47°N, 153°E	M	1070	Kuril Islands
89	13 September 1952	47°N, 153°E	F	990	Kuril Islands
90	22 September 1952	47°N, 153°E	M	1000	Kuril Islands
91	30 May 1952	52°N, 165°E	M	570	Aleutians
92	12 July 1952	57°N, 167°E	M	1020	Aleutians
93	1 July 1953	47°N, 153°E	M	1100	Kuril Islands
94	22 July 1953	47°N, 153°E	F	1030	Kuril Islands
95	24 July 1953	47°N, 153°E	M	1050	Kuril Islands
96	11 August 1953	47°N, 153°E	M	1010	Kuril Islands
97	5 September 1953	47°N, 153°E	M	920	Kuril Islands
98	21 September 1953	47°N, 153°E	M	980	Kuril Islands
99	24 September 1953	47°N, 153°E	M	1000	Kuril Islands
100	11 October 1953	47°N, 153°E	M	1040	Kuril Islands
101	5 May 1953	52°N, 158°E	M	920	Aleutians
102	3 July 1953	57°N, 167°E	F	1060	Aleutians
103	7 July 1953	52°N, 165°E	M	1000	Aleutians
104	29 August 1954	47°N, 153°E	M	1000	Kuril Islands
105	14 September 1954	47°N, 153°E	M	1000	Kuril Islands
106	14 September 1954	47°N, 153°E	M	980	Kuril Islands
107	12 October 1954	47°N, 153°E	M	1060	Kuril Islands
108	13 October 1954	47°N, 153°E	M	980	Kuril Islands
109	20 October 1954	47°N, 153°E	M	1000	Kuril Islands
110	29 October 1954	47°N, 153°E	F	1000	Kuril Islands
111	4 November 1954	47°N, 153°E	M	720	Kuril Islands
112	4 November 1954	47°N, 153°E	M	640	Kuril Islands
113	17 June 1954	52°N, 165°E	M	1020	Aleutians

Continued

TABLE 4. *Continued.*

Record Number	Date	Catch Position	Sex	Length (cm)	Station/ Expedition
114	20 July 1954	57°N, 167°E	M	920	Aleutians
115	25 June 1955	47°N, 153°E	M	750	Kuril Islands
116	30 June 1955	47°N, 153°E	F	1080	Kuril Islands
117	1 July 1955	47°N, 153°E	M	1100	Kuril Islands
118	1 July 1955	47°N, 153°E	M	960	Kuril Islands
119	26 October 1955	47°N, 153°E	M	1070	Kuril Islands
120	17 July 1955	52°N, 165°E	F	1060	Aleutians
121	5 June 1956	47°N, 153°E	M	1050	Kuril Islands
122	23 July 1956	47°N, 153°E	M	1000	Kuril Islands
123	5 August 1956	47°N, 153°E	M	1080	Kuril Islands
124	21 August 1956	47°N, 153°E	M	980	Kuril Islands
125	18 September 1956	47°N, 153°E	M	680	Kuril Islands
126	26 September 1956	47°N, 153°E	M	810	Kuril Islands
127	27 September 1956	47°N, 153°E	M	900	Kuril Islands
128	28 September 1956	47°N, 153°E	M	720	Kuril Islands
129	6 October 1956	47°N, 153°E	M	970	Kuril Islands
130	30 August 1956	52°N, 165°E	M	900	Aleutians
131	13 May 1957	47°N, 153°E	M	1020	Kuril Islands
132	13 May 1957	47°N, 153°E	M	910	Kuril Islands
133	1 June 1957	47°N, 153°E	F	1000	Kuril Islands
134	11 June 1957	47°N, 153°E	M	1070	Kuril Islands
135	18 June 1957	47°N, 153°E	F	960	Kuril Islands
136	14 July 1957	47°N, 153°E	M	970	Kuril Islands
137	30 August 1957	47°N, 153°E	F	900	Kuril Islands
138	15 September 1956	47°N, 153°E	M	1050	Kuril Islands
139	16 May 1957	45°N, 155°E	M	980	Aleutians
140	16 May 1958	47°N, 153°E	M	1010	Kuril Islands
141	15 June 1958	47°N, 153°E	M	960	Kuril Islands
142	16 June 1958	47°N, 153°E	M	830	Kuril Islands
143	9 August 1958	47°N, 153°E	M	620	Kuril Islands
144	11 August 1958	47°N, 153°E	M	1020	Kuril Islands
145	10 June 1958	57°N, 167°E	M	1010	Aleutians
146	1 September 1958	52°N, 165°E	M	1050	Aleutians
147	30 May 1959	47°N, 153°E	M	1000	Kuril Islands
148	23 June 1959	47°N, 153°E	M	950	Kuril Islands
149	26 June 1959	47°N, 153°E	M	680	Kuril Islands
150	28 June 1959	47°N, 153°E	F	1010	Kuril Islands
151	28 June 1959	47°N, 153°E	M	1070	Kuril Islands
152	25 August 1959	47°N, 153°E	M	880	Kuril Islands
153	26 August 1959	47°N, 153°E	F	1050	Kuril Islands
154	1 September 1959	47°N, 153°E	M	970	Kuril Islands
155	12 June 1960	47°N, 153°E	M	1120	Kuril Islands
156	12 June 1960	47°N, 153°E	F	1000	Kuril Islands
157	12 June 1960	47°N, 153°E	M	1030	Kuril Islands
158	29 June 1960	47°N, 153°E	F	1010	Kuril Islands
159	30 August 1960	47°N, 153°E	M	820	Kuril Islands
160	13 September 1960	47°N, 153°E	M	1020	Kuril Islands
161	5 October 1960	47°N, 153°E	F	1040	Kuril Islands
162	5 October 1960	47°N, 153°E	F	1010	Kuril Islands
163	5 October 1960	47°N, 153°E	F	980	Kuril Islands
164	5 October 1960	47°N, 153°E	F	1050	Kuril Islands
165	12 October 1960	47°N, 153°E	M	980	Kuril Islands
166	12 October 1960	47°N, 153°E	M	900	Kuril Islands
167	14 October 1960	47°N, 153°E	M	1120	Kuril Islands
168	14 October 1960	47°N, 153°E	M	1100	Kuril Islands
169	14 October 1960	47°N, 153°E	M	1120	Kuril Islands
170	14 October 1960	47°N, 153°E	M	1000	Kuril Islands
171	14 October 1960	47°N,153°E	M	1100	Kuril Islands
172	14 October 1960	47°N,153°E	M	1000	Kuril Islands
173	17 June 1961	47°N,153°E	F	1090	Kuril Islands
174	5 July 1961	47°N, 153°E	F	650	Kuril Islands

Continued

TABLE 4. *Concluded.*

Record Number	Date	Catch Position	Sex	Length (cm)	Station/ Expedition
175	4 October 1961	47°N, 153°E	M	990	Kuril Islands
176	19 June 1962	47°N, 153°E	F	1040	Kuril Islands
177	29 July 1962	47°N, 153°E	M	1010	Kuril Islands
178	3 June 1963	47°N,153°E	M	1000	Kuril Islands
179	14 August 1963	47°N,153°E	M	1040	Kuril Islands
180	23 April 1963	52°21'N,178°48'W	M	1000	Vladivostok
181	16 September 1963	52°39'N,175°18'W	M	1000	Vladivostok
182	16 September 1963	52°39'N,175°18'W	M	1020	Vladivostok
183	27 May 1964	47°N, 153°E	M	800	Kuril Islands
184	21 June 1972	45°N,155°E	M	1000	Dalnij Vostok
185	22 June 1972	45°N,155°E	M	1030	Dalnij Vostok
186	21 June 1972	46°36'N,150°46'E	F	1050	Vladivostok
187	22 June 1972	48°33'N, 153°10'E	F	980	Vladivostok
188	2 October 1972	47°36'N,153°13'E	M	990	Vladivostok
189	27 May 1974	47°06'N,151°55'E	F	1170	Dalnij Vostok
190	3 July 1974	42°47'N, 125°02'W	F	980	Dalnij Vostok

ed since 1981 by data from International Whaling Statistics [IWS]; the cumulative catch of 485 mentioned in International Whaling Commission [1983b: 158] appears incorrect). From 1972 to 1990 the catch of Baird's Beaked Whales in Japan averaged 40 per year (International Whaling Commission 1992: 183).

Baird's Beaked Whales are hunted primarily to supply fresh or dried meat for human consumption (Nishiwaki and Oguro 1971; Freeman 1988). The blubber is sold and is eaten dried or fried. Bones are used to make fertilizer. Although Tomilin (1967: 426) described the blubber and meat of Baird's Beaked Whale as inedible, noting their laxative properties, the people of Chiba have a special preference for the meat (Kasuya and Ohsumi 1984; Freeman 1988).

Soviet commercial whalers exploited Baird's Beaked Whales on a limited scale, taking approximately 100 during 1933-1954 (Tomilin 1967:426) and 76 during 1955-1974 (Table 4).

There is no reason to believe that *Berardius bairdii* was taken in large numbers at any time or in any area of the eastern Pacific. Only about 60 were reported as taken during 1912-1966 in all areas combined. This includes commercial shore whaling in California (Table 1), Washington (Scheffer and Slipp 1948), British Columbia (Table 2), and Alaska (Pike and MacAskie 1969). Catch statistics for early years at some stations were not given by species. The total catch of 35 in British Columbia, 1950-1966, listed by Mitchell (1975b) from IWS and summarized in International Whaling Commission (1983b: 158), is incorrect due to typographical errors and instead should be 25 (Table 2). One whale (rather than 9) was taken in 1950; one (rather than 3), in 1956, as indicated in the IWS volumes cited by Mitchell (1975b). The published record has been further muddled by the reference to a total catch of 135 Baird's Beaked Whales in Canada between 1934 and 1966 (International Whaling Commission 1992: 183), probably due to another typographical error.

A perceived problem has arisen in interpreting catch records because of the possibility that more than one kind of "bottlenose" whale is present in the North Pacific. The Japanese name for Baird's Beaked Whale is *tsuchi-kujira*. *Tsuchi* refers to an old-fashioned wooden hammer that was shaped like a bottle; *kujira* means "whale". In Chiba Baird's Beaked Whale is popularly known as *tsuchimbo* (Omura et al. 1955). Although neither Omura et al. (1955) nor Tomilin (1967) gave credence to the belief that a species of the genus *Hyperoodon* was present in the western North Pacific and thus probably included in the Japanese and Soviet whale catches, Nishiwaki and Oguro (1971) considered the *tsuchi-kujira* caught off Hokkaido in the southern Okhotsk Sea to be *Hyperoodon ampullatus*, the Northern Bottlenose Whale (see Nishiwaki 1966; Mitchell 1975a: 967 *note* 4). Nishiwaki (1966, 1967) also suggested that *Hyperoodon ampullatus* might exist in the Sea of Japan. Data presented by Slipp and Wilke (1953), Nishimura (1970), and Kasuya (1986) confirm that *Berardius bairdii* is present in the Sea of Japan and southern Okhotsk Sea and that this species is the principal beaked whale caught off Hokkaido. There is no unequivocal evidence that the Northern Bottlenose Whale, or any other species of *Hyperoodon*, inhabits the cold temperate and subarctic waters of the North Pacific. However, sightings in the central and western tropical Pacific of what are probably *Hyperoodon* cf. *planifrons* are documented with photographs and other evidence (Leatherwood et al. 1982: 92-93; Kasuya 1986: 77n;

Anonymous 1988; Pitman et al. 1989). *Hyperoodon planifrons* has otherwise been viewed as a circumpolar Southern-Hemisphere endemic.

Habitat

Baird's Beaked Whales off Japan feed during early summer and autumn on benthic or epibenthic prey in waters 1000 to 3000 m deep affected by a cold subsurface current (Kasuya 1986). The whaling grounds off Japan are over deep water near the coast. Groups of seven to 11 whales have been seen in April and May in the northern Okhotsk Sea where the water is less than 500 m deep (Fedoseev *as cited in* Ivashin 1986 and *in* Kasuya 1986). Although Dohl et al. (1983) considered their observations of Baird's Beaked Whales off central and northern California to contradict the claim by Leatherwood et al. (1982) that the species is most frequently seen in waters deeper than 1000 fathoms [sic], their data in fact support Leatherwood et al.'s statement (which refers explicitly to 1000 m rather than 1000 fathoms). Most of the catches off central California (Figure 2) and Vancouver Island (Figure 3) were made along or seaward of the 100-fathom contour.

Dohl et al. (1983) considered the distribution of this species in their California study area to be related to warm water since most of their sightings were in areas characterized by a warm-water gyre. By contrast, sightings in the northwestern Okhotsk Sea in April-May and December (Fedoseev *as cited in* Ivashin 1986) and observations in and near ice fields (see below) indicate that these whales can also occur in very cold water.

General Biology

Behaviour

Baird's Beaked Whales are known to be deep divers and have been likened in this regard to Sperm Whales, *Physeter catodon* (Scammon 1874; Tomilin, 1967). Kasuya (1986) reported dives of undisturbed whales lasting 67 minutes, with an average of about 20 minutes (n = 30). One group remained at the surface for 14 minutes, but most periods at the surface lasted less than 5 minutes. Whalers told Pike (1953) that a 10.1 m whale took 500 fathoms [ca 914 m] of line "straight down at an amazing speed".

Baird's Beaked Whales usually occur in small to medium-sized groups of up to 30 individuals. Three independent data sets gave similar results: aerial observations off Japan (n = 91) - mean 4.5, modes at 2-3 and 8-10 (Kasuya 1971); shipboard observations off Japan (n = 42) - mean 7.4, mode at 4 (Kasuya 1986); aerial observations off California (n = 19) - mean 3.7, maximum 9 individuals (Dohl et al. 1983).

Several authors have noted that groups of Baird's Beaked Whales are close-knit and remain together when chased (Pike 1953; Tomilin 1967). However, they are not known to display epimeletic or succorant behaviour when a member of the group is wounded or killed (Tomilin 1967). Only two mass strandings have been documented for this species, one involving seven and the other four individuals (Aurioles-Gamboa 1992).

Most of the whales (70% or more) taken in whale fisheries have been males (Pike and MacAskie 1969; Rice 1974; Ohsumi 1983; Kasuya 1986). Because females grow larger than males, and whalers are thought to select for larger individuals, the preponderance of males in the catches has been taken to suggest that there is some degree of geographical segregation between the sexes (Omura et al. 1955; Rice 1974; Ohsumi 1983). However, Kasuya (1986) concluded that the skewness of catches more likely is due to a behavioral difference that makes males more catchable than females. He reasoned that since the catches sampled the populations in various parts of their range, even if there were substantial segregation, females should be better represented in the overall catch, assuming that they are as catchable as males. In a mass stranding of seven Baird's Beaked Whales in Mexico, four were males (Aurioles-Gamboa 1992). The size range of the males was 10.83–11.35 m, while the females were 9.05 – 10.55 m long.

On the basis of a sample of four to six stomachs from whales killed on the northern summering grounds Tomilin (1967: 422) judged *Berardius bairdii* to feed primarily on squid. Six of eight specimens examined at whaling stations in Richmond, California, had food remains in their stomachs, mainly macrourid fishes and the squids *Gonatus fabricii* and *Onychtoteuthis* sp. (Rice 1963). The stomach contents of 10 whales taken off Vancouver Island included squid (seven stomachs), bones mainly from small Rockfish, *Sebastodes* sp. (seven stomachs), and skate egg-cases (two stomachs) [Pike and MacAskie 1969]. In a much larger sample of whales taken off Japan with food in their stomachs (n = 383), 41% had eaten deep-sea fish and 29% had eaten squid (Nishiwaki and Oguro 1971). The remainder had eaten various other fishes.

Life History

Life-history parameters have been estimated from specimens taken in Japanese shore whaling (see Mead 1984 for a review; Kasuya et al. 1989 for an update). Average lengths at attainment of sexual maturity are 9.8–10.6 m for males and 10–10.4 m for females (Omura et al. 1955; Kasuya et al. 1989), corresponding to ages of 6–10 years and 10–14 years, respectively (Kasuya 1977; Kasuya et al. 1989). Fifty percent of males are mature at 9.5 m (n = 92); females, 9.9 m (n = 21) [Ohsumi 1983]. Males reach physical maturity at a mean length of 10.45 m and a mean age of slightly more than

10 years; females at 11 m and ages greater than 15 years (Kasuya 1977; Kasuya et al. 1989). The oldest specimen recorded from a sample of 135 animals was an 84-year-old, based on the number of cemental layers in a sectioned tooth, with each layer believed to represent one year (Kasuya et al. 1989; International Whaling Commission 1989: 118).

The gestation period was calculated as 17 months using a birth length of 458 cm (*from* Omura et al. 1955) and a hypothetical linear growth curve (Kasuya 1977). The peak of mating was estimated to occur in October and November, with most births in March and April. Dohl et al. (1983) observed nine Baird's Beaked Whales "engaged in apparent reproductive activities" off northern California, in September. Ohsumi (1983) estimated the gestation period to be 16.7 months by analysis of interspecific relationships among several biological parameters. The sex ratio at birth is essentially 1:1 (Omura et al. 1955). The length of lactation has not been estimated but is probably more than one year (Ohsumi 1983: table 4; International Whaling Commission 1983b). Tomilin (1967) referred to a 5.8-m specimen with milk in its stomach. The apparent pregnancy rate is about 0.30, and there is no evidence that this rate declines with increasing age. The ovulation rate is 0.47. However, females 20–54 growth layers (years?) old were scarce and females older than 54 were absent in the studied sample (Kasuya et al. 1989; International Whaling Commission 1990:118).

Although their impressive diving capabilities have been cited to support the supposition that Baird's Beaked Whales are immune from predation (Tomilin 1967), the stomachs of several Killer Whales, *Orcinus orca*, taken off Japan were found to contain the remains of *Berardius bairdii* (Nishiwaki and Handa 1958). Baird's Beaked Whales are heavily infested with parasites in the stomach, liver, blubber, and kidneys. Extensive tissue pathology has been observed in the kidneys due to the nematode *Crassicauda giliakiana* (International Whaling Commission 1989: 118). Ohsumi (1979) estimated the natural mortality rate as 0.083 based on interspecific relationships among certain biological parameters.

Limiting Factors

Baird's Beaked Whales are endemic to the North Pacific ocean basin, where they inhabit primarily deep, cool waters (Balcomb 1989). They prey on squids and deep-sea fishes (International Whaling Commission 1989: 118). In much of their range little or no sea ice forms. Heavy ice coverage in the northern Bering and Chukchi seas may help to exclude them from the High Arctic. However, in the Okhotsk Sea these whales have often been seen "among the ice floes", sometimes even in "narrow crevices which could hardly let through their heads" (Tomilin 1967: 422). An Arnoux's Beaked Whale lived for more than four months, before being shot, while ice-entrapped in a pool of water in the Antarctic pack ice (Taylor 1957).

The tendency of Baird's Beaked Whales to remain along or seaward of the 1000-m contour and to feed on squid and deep-sea fish suggests that they occupy a well-defined pelagic niche. Suitable habitat and food resources appear to be available over a large area. The nature and extent of competitive interactions between this and other species, such as other ziphiids and the Sperm Whale, are unknown.

The Boso ground where much of the whaling for Baird's Beaked Whales takes place begins about 20 miles from the mouth of Tokyo Bay. Maritime traffic into and out of Tokyo Bay is extremely heavy, and Nishiwaki and Sasao (1977) suggested that this traffic had caused the whales to change their migration routes. However, this suggestion has not been borne out in subsequent analyses of catch per unit of effort (CPUE).

Special Significance of the Species

Baird's Beaked Whale is one of the few ziphiids to have been exploited commercially, probably because of its large size, its availability to shore-based whalers, and its catchability. Many of the other ziphiids are smaller and more cryptic in their behaviour. As indicated previously, Baird's Beaked Whale has traditional economic importance to the people of Chiba prefecture, Japan.

Evaluation

There is no immediate cause for concern about the survival of the species. Although analyses of CPUE in Japanese coastal whaling have given ambiguous results (International Whaling Commission 1983b: 159; 1984b: 151; 1989: 118; Ohsumi 1983; Kasuya and Ohsumi 1984), the aggregate level of exploitation in the western Pacific has declined considerably during the last 20 years. If significant depletion resulted from the Japanese and Soviet harvests prior to the 1970s, the lessened whaling pressure during the 1970s and 1980s may have permitted some recovery. Assuming a current population size of about 4000 whales off the Pacific coast of Japan (Miyashita 1986, 1991), the catch of 54 to 60 whales permitted under the Japanese national quota since 1988 would represent a removal rate of 0.015 per year. Since the estimate of 4000 does not account for all of the whales in the Sea of Japan and Okhotsk Sea, where some of the catch is made, the removal rate may be less than 0.015. No data are available on the number of harpooned whales that are lost, but it is believed to be very low (International Whaling Commission 1985: 135). It is uncertain whether recent and current hunting levels in Japanese waters are sustainable and if they will allow substantial population recovery.

Exploitation of Baird's Beaked Whales in the eastern Pacific has been desultory and sporadic; there has been essentially no direct exploitation during the past 25 years. Large numbers of Baird's Beaked Whales are not known to be taken incidentally in any fishery. No major portion of their habitat is known to be under direct or immediate threat. We conclude, specifically with respect to the eastern Pacific, that the species does not require a status designation at this time, although a "rare" designation may be appropriate for Canadian inshore waters and the continental-shelf region.

Acknowledgments

This review was requested by the Committee on the Status of Endangered Wildlife in Canada and made possible by a grant to Okapi Wildlife Associates from the Department of Fisheries and Oceans and World Wildlife Fund Canada. Laurie Schell prepared the maps. We are grateful to Stephen Leatherwood for allowing us to publish his sighting records in Table 3.

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Accepted 15 August 1993

Status of the Beluga, *Delphinapterus* leucas, in Western and Southern Hudson Bay*

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Richard, Pierre R. 1993. Status of the Beluga, *Delphinapterus leucas,* in western and southern Hudson Bay. Canadian Field-Naturalist 107(4): 524–532.

In mid-July, the western Hudson Bay Beluga stock ranges in coastal waters from Eskimo Point to the Ontario border with concentrations at the estuaries of the Seal, Churchill and Nelson rivers. At the same time, another population of Belugas occupies southern Hudson Bay coastal waters with concentrations at the estuaries of the Severn and Winisk rivers. The relationships between the western Hudson Bay stock and other Hudson Bay summer populations are unclear. It is not known how many separate genetic stocks there are. Current annual removals from hunting and live-captures can be sustained by the western Hudson Bay stock; it is thought to be stable. The effect of hydro-electric development on the estuarine habitat of the stock is unknown.

A la mi-juillet, la population de Bélugas de l'ouest de la baie d'Hudson occupe les eaux côtières situées entre Eskimo Point et la frontière de l'Ontario, formant des concentrations aux estuaires des rivières Seal, Churchill et Nelson. En même temps, une autre population de bélugas occupe les eaux côtières du sud de la baie d'Hudson, formant des concentrations aux estuaires des rivières Severn et Winisk. Les liens entre le stock de l'ouest de la baie d'Hudson et les autres populations estivales de la baie d'Hudson ne sont pas clairs. Nous ne savons pas combien il y a de stocks génétiques distincts. Le stock de l'ouest de la baie d'Hudson peut soutenir les retraits annuels causés par la chasse et les captures. On en déduit que la population est stable. On ne connaît pas les effets qu'on pu avoir le développement hydro-électrique sur l'habitat estuarien de ce stock.

Key Words: Beluga, Belukha, White whale, *Delphinapterus leucas,* stock size and trend, western and southern Hudson Bay.

The white whale, Beluga or Belukha, *Delphinapterus leucas* (Pallas, 1776) is an odontocete cetacean of the family Monodontidae. It has a blunt head, a slight beak, a fat stocky body (Figure 1) and lacks a dorsal fin. Young are slate or brown colored and become progressively lighter colored as they mature. Adults are generally pure white but their skin may appear a light shade of yellow in spring or early summer during the molt. Lack of a dorsal fin and presence of thick skin are characteristics of ice-adapted cetaceans shared by the Beluga.

There are differences in size and weight among Belugas of different geographical locations. Western Hudson Bay Belugas are small in comparison to other Canadian populations (Sergeant and Brodie 1969); female and male adults of age 10 years or more reach mean lengths of about 310 cm and 350 cm respectively and weight about 280-320 kg. Newborn calves average 150 cm and 60 kg.

Comparisons of length and girth at age indicate that western Hudson Bay Belugas are smaller than Belugas from Cumberland Sound and the high Arctic but not different from eastern Hudson Bay or Ungava Bay stocks (Sergeant and Brodie 1969; Finley et al. 1982; Doidge 1990; Stewart *in press*). The morphometric differences suggest that western Hudson Bay Belugas are a different genetic stock than Cumberland Sound Belugas. There is no significant difference with the neighbouring stock of eastern Hudson Bay and no morphometric data from northern and southern Hudson Bay Belugas.

Several authors have argued that there is sufficient evidence and compelling conservation reasons to class populations of Belugas occupying different geographical locations in summer as separate management stocks (Finley et al. 1982; Reeves and Mitchell 1989a). The underlying assumption is that each stock is a discrete population of Belugas with little or no exchange of animals with other stocks. In this report, I refer to geographically defined summer populations as stocks. However, the issue of stock discreteness of Hudson Bay and neighbouring populations is not clearly resolved, as discussed above and in later sections (see below, Distribution, Behavior and Adaptation).

Distribution

Western Hudson Bay Belugas concentrate at the estuaries of the Seal, Churchill and Nelson rivers in July and August (Doan and Douglas 1953; Sergeant

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*Reviewed and approved by COSEWIC - April 1993, report accepted, no status designation required.

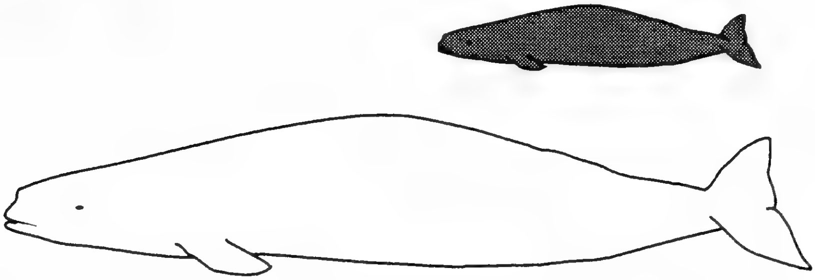

FIGURE 1. Adult Beluga, Belukha or white whale, *Delphinapterus leucas*, and newborn calf.

1973). During July and August 1981, reconnaissance surveys along the coast of western Hudson Bay, Richard et al. (1990) found Belugas to be widely distributed between these estuaries. They were more abundant in July than in August. In July 1987, Belugas were observed throughout all survey transects from Eskimo Point to the Ontario border, and during one survey of the Nelson concentration, which extended as far as 110 km from the coast and 140 km from Port Nelson, Belugas were found throughout the surveyed area (Richard et al. 1990).

During similar reconnaissance surveys in July 1981 and 1987, Richard et al. (1990) found that Belugas occupied coastal areas of southern Hudson Bay. In July 1987, they counted a total of 1269 Belugas during a first transect flown approximately three km from shore. Most Belugas were concentrated near the estuaries of the Severn and Winisk rivers, but dispersed groups were seen all along the transect. Richard et al. (1990) saw a total of 30 Belugas on a transect 28 km offshore and parallel to the coast.

Belugas are regular summer occupants of southern Hudson Bay. Sergeant (1968) mentions "herds (of Belugas) extending at least to Winisk". D. H. Johnston (1961. *Manuscript*. Marine Mammal surveys, Hudson Bay 1961. Ontario Department of Lands and Forests, Toronto, Ontario. 32 pages: author's collection) mentions that "during summer months, the schools of Belugas move randomly along the coastline, with large concentrations centered along the bigger river mouths". He reports sightings of 100 Belugas at both the Severn and Winisk estuaries in July 1961. Belugas have been reported by local Indians before spring breakup at both the Severn and Winisk estuaries (Johnston 1961). Herds of 100 to 150 Belugas have been seen near the mouth of the Winisk River on 1 July 1979 and 25 June 1982 (K. F. Abraham, Ontario Ministry of Natural Resources [OMNR], Moosonee, Ontario; personal communication). The Cree report the occurrence of Belugas "in summer" at the mouth of the Severn River (Abraham, personal communication).

Other than western and southern Hudson Bay, Belugas are found throughout James Bay and are widespread from the Nastapoka coast in Northern Quebec to the Belcher Islands (Smith and Hammill 1986). The combination of the above Beluga observations in western, southern, and eastern Hudson Bay and James Bay is an unbroken distribution from west to east along the coasts of Hudson Bay and James Bay (Figure 2). A fourth summer stock occurs around Southampton Island, northern Hudson Bay, in July (Richard et al. 1990).

Winter survey results (Figure 3) indicate that Hudson Bay Belugas winter in Hudson Strait (Finley et al. 1982). Surveys in March 1981 (Finley et al. 1982) and 1983 (Richard et al. 1990) failed to find a large concentration in northern Hudson Bay, a hypothesized wintering area for the western Hudson Bay stock (Sergeant 1973). On the other hand, March 1981 surveys resulted in a very large number of sightings throughout the Hudson Strait pack ice, suggesting a winter population of the same magnitude as the western Hudson Bay summer stock (Finley et al. 1982).

Few Belugas winter in Hudson Bay (Figure 3). Local sources have reported occasional winter sightings at the floe edge of Daly Bay (G. Pryznick, Department of Fisheries and Oceans [DFO], Yellowknife, Northwest Territories; personal communication), Chesterfield Inlet (Sergeant 1973), Eskimo Point (Sergeant 1973), in Lyon Inlet and off Cape Bylot (65°20′N, 84°10′W), and northern Southampton Island (Richard, unpublished data). Belugas have also been seen in James Bay (Jonkel 1969), in Hudson Bay near the Belcher Islands (Breton et al. 1984) and in Roes Welcome Sound (Finley et al. 1982) during winter months. The numbers reported are relatively small and suggest that only a small proportion of the Belugas that summer in Hudson Bay or James Bay also winter there.

The above observations show that mixing between neighbouring stocks is possible during summer and winter months. On the other hand, there is evidence from mitochondrial DNA analysis of skin tissue that most Belugas sampled at Eskimo Point and

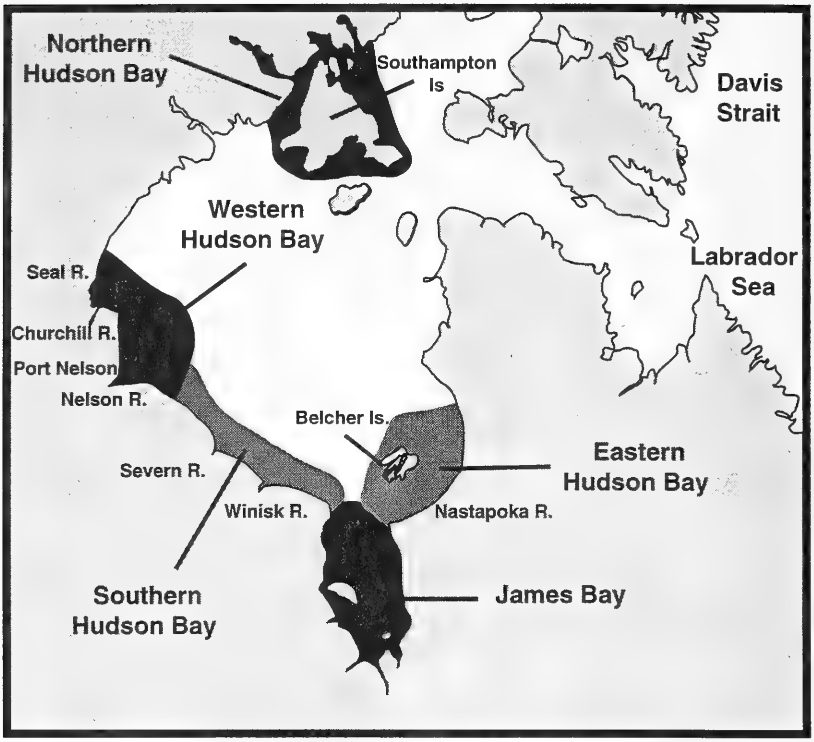

FIGURE 2. Range of western, southern and other Hudson Bay Beluga populations in summer.

Churchill in western Hudson Bay belong to different maternal lineages than those of Belugas sampled at the Nastapoka River of eastern Hudson Bay (Helbig et al. 1989; Brennin 1992). These sampling locations are at the western and eastern extremes of the continuous summer range of Belugas described above (Figure 2). No genetic sampling has been done in other more central locations, such as the Nelson, Severn and Winisk estuaries. Sampling of these locations is needed to determine if the genetic types found at the extremes mix there or if they form other genetic types.

The potential for exchange is greatest in winter when most sub-arctic Belugas occupy a relatively small geographical area from northern Hudson Bay to southeast Davis Strait and the Labrador Sea. More importantly, mating is thought to occur in April or May (Brodie 1971; Sergeant 1973) while many Belugas are still in the winter range, which means that genetic mixing through cross-breeding could also take place.

Protection

International

Regulation of international trade between members of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and between non-members and Convention members, has been established by listing the Beluga (see Cetacea) under Appendix II of the Convention. The Convention came in effect in Canada in 1975. Between 1975 and 1993, a total of 53 live-captured belugas, or an average 2.94 Belugas per year, have been traded to other countries under a CITES permit.

National

Beluga management in Canada is conducted by the Department of Fisheries and Oceans (DFO) under the authority of the Fisheries Act of 1867 and the Marine Mammal Regulations of 1993 which provide for the protection of habitat, management of the species and control of the harvest*.

The Marine Mammal Regulations limit Beluga hunting without a licence to the Indian and Inuit natives of Canada. A native resident of the Northwest Territories, Yukon, Quebec or Newfoundland may without a licence take Belugas for food, social or ceremonial purposes, and may buy, sell, trade or barter Belugas within these areas with other native residents. Exceptions are made for beneficiaries of native land claim agreements if the agreements contain specific terms limiting buying, selling, trading or bartering.

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*Beluga management is subject to clauses of various recent native land claim agreements.

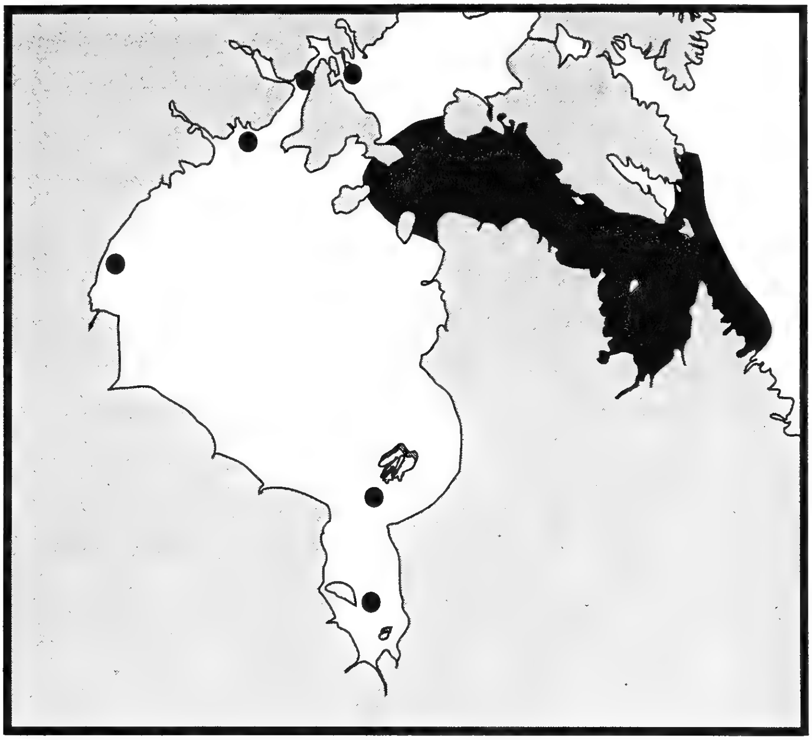

FIGURE 3. Range of Hudson Bay Beluga populations in winter, including occasional sightings (solid circles).

Non-native hunting is controlled by licences which can be issued to a person who wishes to obtain Beluga for food. They may not buy, sell, trade or barter Beluga parts. Only two to five Belugas have been hunted annually by non-native residents of Churchill, Manitoba between 1973 and 1993.

The Marine Mammal Regulations also establish conditions that are to be met by all Beluga hunters. They state that no person shall hunt without the necessary equipment to retrieve any animal killed or wounded during a hunt and without making a reasonable effort to do so. They prohibit wastage of any parts suitable for food. Hunting of calves and females accompanied by calves is prohibited. Hunters are prohibited from hunting Belugas with rifles or shotguns with a muzzle energy less than 1500 foot pounds and with rifled slugs or bullets that are not full-jacketed.

Finally, with the exception of hunting activities, there is a general prohibition on disturbance of Belugas. DFO has guidelines for non-hunting activities which may otherwise cause disturbance to Belugas. Moving, tagging or marking of Belugas for experimental, scientific, educational, or public display purposes is regulated by licences. Applicants for live-capture licences must comply with conditions set by the Beluga live-capture guidelines of the Department of Fisheries and Oceans. These conditions pertain to the methods of capture, transport, care and husbandry of Belugas. Licences are approved by the Minister of Fisheries and Oceans. Between 1967 and 1993, a total of 68, or 2.6 Belugas per year, have been live-captured in Churchill.

Population Size and Trends

In July 1987, Richard et al. (1990) flew broad coverage surveys of the Nelson and the Churchill and Seal estuaries and surrounding Hudson Bay waters. Two separate surveys resulted in total estimates for the western Hudson Bay stock of 23 000 Belugas (95% Confidence Interval (c.i.): 10 300 - 58 300) and of 25 100 (95% c.i.: 18 300 - 32 800) respectively. Their results are uncorrected for submerged animals and are therefore negatively-biased estimates of true population size. In addition, they counted 1300 Belugas during reconnaissance surveys flown along the coast of southern Hudson Bay in the days that followed.

These numbers far exceed the 1965 estimates of 8 000 to 10 000 for the western Hudson Bay stock (Sergeant 1973, 1981). The difference is understandable when one considers that previous estimates were derived from surveys limited to waters 10 or

40 km inshore, depending on the area (Sergeant 1973). The coverage of western Hudson Bay reported by Richard et al. (1990) extended between 40 and 110 km offshore. In the area of the Nelson estuary which had the largest Beluga concentration their surveys covered an area of 15 000 km^2, more than ten times the area of previous surveys. Previous estimates relied on rough extrapolations for submerged animals (Sergeant 1973, 1981). In their estimates, Richard et al. (1990) did not correct for submerged animals because adequate methods are not available for such corrections (Smith and Hammill 1986; Richard et al. 1990). Despite the lack of correction for submerged animals, their results were substantially higher. These differences in methods of estimation and coverage preclude any statement on population trend between 1965 and 1987.

Habitat

Western and southern Hudson Bay Belugas concentrate at the mouths of the Nelson, Churchill, Seal, Severn and Winisk rivers in summer (*see above,* Distribution). It has been postulated that Beluga neonates in particular can reduce their energy expenditures while occupying warm estuarine waters (Sergeant and Brodie 1969). Thyroid hormone production increases during estuarine occupation, suggesting that growth in animals of all ages is enhanced during summer (St-Aubin and Geraci 1989). Warm estuaries could provide a less energetically demanding environment at a time when fat reserves are mobilized for growth (St-Aubin and Geraci 1989). Belugas also molt their skin in summer and have been observed rubbing themselves on the bottom (Finley et al. 1982). Belugas occupying rivers occasionally feed on various prey species (*see below*, Feeding).

The Churchill-Nelson river diversion for hydroelectric power created in the early seventies has greatly reduced the freshwater flow to the Churchill estuary and increased the winter flow to the Nelson estuary. These habitat modifications may have caused the distribution pattern of Belugas and their prey to change. Information on their past and present distribution is insufficient to reach any conclusion on the impact this diversion has had on the Belugas. Continued development on the Nelson and proposed developments on the Seal River are specific concerns. Also of concern is the release of pollutants such as mercury into the Nelson River as a result of the reservoirs created by the hydro-electric project.

The winter habitat of western Hudson Bay Belugas is thought to include the whole of Hudson Strait (*see above*, Distribution). In Hudson Strait, Belugas were found in higher numbers in loose pack ice (26% to 75% cover) than in heavy pack ice (>75% cover) while no Beluga was seen in ice-free waters east of the pack (McLaren and Davis 1982). There is no information on trends in quality and quantity of winter habitat.

General Biology

Reproductive Biology and Mortality

Estimates of life history parameters for western Hudson Bay Belugas were obtained by sampling animals caught at Churchill and Whale Cove (Sergeant 1973). Animals were aged by counting dentinal growth layers on longitudinal thin sections of teeth. There has been some controversy over whether one or two growth layers are deposited every year (Brodie 1969; Sergeant 1973; Braham 1984), but evidence from a few captive animals lends support to the two-growth-layer-per-annum hypothesis (Brodie 1982; Goren et al. 1987).

Age is, therefore, estimated as half the number of growth layers. Tooth wear complicates the aging of older animals by removing the layers deposited at the apex of the teeth (Sergeant 1973). Consequently, maximum life span cannot be ascertained precisely. The maximum number measured for Churchill and Whale Cove animals is 50 dentinal layers (or 25 years), but studies of tooth and mandibular layers suggest that Belugas can probably reach 30 years (Brodie 1969).

Western Hudson Bay Beluga females reach sexual maturity at a mean age of five years and give birth to a single calf after a gestation of about 14.5 months (Sergeant 1973). Calves are suckled for about two years, and the calving interval is estimated to be three years for most females. About 25% of females sampled apparently started a new pregnancy while still lactating (Sergeant 1973). Breeding has never been observed but is thought to peak in April or May. Calving takes place from June to early September the following year, with a peak somewhere between late June and late July (Sergeant 1973).

The annual sustainable yield of the western Hudson Bay stock is not known because age-specific mortality rates cannot be estimated from existing data. It was suggested that 5% is a permissible rate of harvest for western Hudson Bay Belugas (Sergeant 1981), but the data used to support this argument is tenuous (Richard and Orr 1986; Reeves and Mitchell 1989b).

Attempts have been made to model the rate of increase of delphinids and monodontids, including Belugas, from published fecundity rates and a range of adult and juvenile mortality rates (Reilly and Barlow 1986; Kingsley 1989; Béland et al. 1988). There are few estimates of rate of increase for cetaceans; those that are available for odontocetes, Killer Whales *(Orcinus orca)* and Striped Dolphins *(Stenella coeruleoalba)* range from 1.7% to 3.2% (Perrin and Reilly 1984). These models and estimates suggest that the intrinsic rate of increase of

Belugas is about 2 to 3% per year. Annual rates of population increase of 2 to 3% would allow an annual sustainable harvest rate of roughly 2 to 3% from the Western Hudson Bay's stock.

Feeding

Inspection of stomach contents from Belugas caught in the Churchill River in summer indicate that Belugas feed mainly on Capelin, *Mallotus villosus* (Doan and Douglas 1953; Sergeant 1973; Watts and Draper 1986). The remains of "estuarine fishes", including Pike, *Esox lucius,* and Cisco, *Coregonus* sp., as well as squid beaks, Annelid Worms, *Nereis* sp., and Shrimp, *Sclerocrangon* sp., were found in a few stomachs.

No quantitative analysis was made of the stomach contents but it was suggested that Belugas did not feed extensively during their stay at Churchill since a large proportion of stomachs were empty (Sergeant 1973). However, digestion in odontocete whales is rapid and little soft tissue may remain in their stomachs a few hours after ingestion (Finley and Gibb 1982). Consequently, absence of food in the stomach of Belugas could be a consequence of the delay between feeding and sampling, rather than a lack of feeding.

Inspection of stomachs of four Belugas caught in August at the Nelson estuary also indicated that Capelin were consumed in that area, along with whitefish and a few other species (Comeau 1915). Belugas caught at Whale Cove in August (Sergeant 1973) had a predominance of shrimp (*Pandalus montagui, Eualus* sp., and other species) in their stomachs. Fishes noted in a few stomachs included Sand Lance *(Ammonodytes americanus)*, Greenland Cod *(Gadus ogac)*, and Arctic Charr *(Salvelinus alpinus)*. Capelin apparently do not occur at Whale Cove (Sergeant 1973). The winter diet of Belugas in Hudson Strait is not known.

Species Movement

It is unclear what route is taken by Belugas to reach the western Hudson Bay and Ontario summering areas. On the Keewatin coast, Belugas are rarely seen or hunted in spring and early summer (Richard et al. 1990). A population of 23 000 Belugas migrating near the Keewatin coast in May and June would not go unnoticed. On the east side of Hudson Bay, reports of a spring southward migration of Belugas are well documented (Finley et al. 1982; Breton et al. 1984).

In the fall, a return northward migration occurs along both the east and west coasts of Hudson Bay (Sergeant 1973; Finley et al. 1982). This northward migration is apparent from catch records and local informants (Breton et al. 1984; Gamble 1984, 1987a,b, 1988) and was demonstrated at least for the western Hudson Bay by recoveries at Whale Cove and Repulse Bay of Belugas tagged at the Seal River (Sergeant 1973). Our 1981 reconnaissance surveys show a reduction in density on the Manitoba coast in August and an extension of the range of Belugas northward along the Keewatin coast (Richard et al. 1990).

Behavior and Adaptability

Beluga in the Churchill River appear to have adapted to local traffic which consists mostly of whale watching tour boats. Continued harassment by hunters can cause Belugas to temporarily vacate an estuary, but they usually return within a few hours, or sometimes after a few days of absence (Caron and Smith 1990; J. Orr, DFO, Winnipeg, Manitoba, personal communication). It is unclear how Belugas react to changes in freshwater flow into the estuaries that they occupy.

Several authors have speculated that the same Belugas tend to occupy the same estuaries every summer (Brodie et al. 1981; Finley et al. 1982). The only evidence of philopatry (site fidelity) and site tenacity comes from a study by Caron and Smith (1990) of individually recognizable Belugas at the Nastapoka estuary of eastern Hudson Bay. Their work also suggests that the Nastapoka estuary had a preponderance of calves and females. If so, other age and sex classes were under-represented in the estuary and could, at least in a given year, be less site tenacious than the river occupants.

Limiting Factors

Potential limiting factors include ice entrapment (Mitchell and Reeves 1981; Brodie 1982), and predation by polar bears and killer whales (Smith 1985; Lowry et al. 1987a,b). The contribution of each of these factors to overall natural mortality is difficult to quantify and has not been estimated. There is insufficient evidence to determine whether western or southern Hudson Bay Beluga have been affected by habitat loss, or if they have suffered from direct or indirect environmental contamination.

Human predation is probably one of the most, if not the most, important limiting factors of the western Hudson Bay stock (Table 1). No hunting for Beluga takes place in southern Hudson Bay (Abraham, personal communication). The mean annual landed catch of Belugas (including live-captures) along the western Hudson Bay coast (Churchill to Rankin Inlet) between 1981 and 1991 was 125 Belugas while northern Hudson Bay communities (Chesterfield Inlet, Coral Harbour and Repulse Bay) took an average of 104 Belugas. Part of the catch from the latter communities probably also came from the small stock of 1000 or more which summers in northern Hudson Bay.

In addition, the western and southern Hudson Bay stocks are probably hunted in spring and fall by Hudson Strait and Ungava Bay communities. The mean annual catch from northern Hudson Strait

TABLE 1: Reported harvest from Western and Northern Hudson Bay, and Hudson Strait. Sources are Strong (1989) for NWT communities and M. Breton (DFO, Quebec, Quebec; personal communication) for Northern Quebec.

	Year											
Location	81	82	83	84	85	86	87	88	89	90	91	Annual Average (to nearest integer)
Western Hudson Bay												**125**
Churchill	1		7	13	16	5	15	11	4	2	4	7 (includes live-captures)
Arviat	52	45	61	60	85	75	70	45	70	70	25	59
Whale Cove	22	6	8	24	19	35	30	16	27	27	25	21
Rankin Inlet	61	37	33	69	36	30	30	27	40	40	20	38
Northern Hudson Bay												**104**
Chesterfield Inlet	11	3	5	12	28	23	34	15	20	20	20	17
Repulse Bay	56	34	18	30	3	20	30	47	20	20	13	26
Coral Harbour	8	33	64	116	76	50	29	38	67	67	125	61
Northern Hudson Strait												**35**
Cape Dorset	1	3	46		21	2	9	10	18	39	37	18
Lake Harbour	16	4		9	9	19	34	9	28	21	28	17
Southern Hudson Strait — Ungava Bay												**176**
Ivujivik	58	126	69	69	42	5	24	19	118		31	56
Salluit	57	41	53	29	10	24	20	16	53	17	28	31
Kangirsujuaq	14	21	22	26	64	22	28	28	28	24	39	28
Qartaq	28	25	38	46	29	21	21	15	35	18	29	27
Kanqirsuk	14	9	12	3	7	9	8	7	11	10	12	9
Aupaluk	4	2	3	2	3	3	1	2	3	5	9	3
Tasiujaq	5	6	13	4	9	14	4	11	9	3	2	7
Kuujjuaq	30	29	12	5	2	10	5	2	8	3	3	9
Kangirsualujjuaq	26	12	3	5	3	5	2	1	0	0	7	5
Killiniq/Tarpangajuq	0	0	0	0	8	1	0	8	0	0	0	1
Overall Annual Average												**440**

communities was 35 Belugas, while Hudson Strait and Ungava Bay communities of northern Quebec took an average of 176 Belugas per year (Table 1).

Belugas caught by Hudson Strait communities probably belong in part to the western and southern Hudson Bay stocks and in part to the northern, eastern Hudson Bay, Ungava Bay and South East Baffin stocks, which also are thought to migrate to Hudson Strait for the winter (Finley et al. 1982; Richard and Orr 1986). The contribution of each stock to the Hudson Strait catch is unknown.

Assuming the worst case scenario that the entire catch of these communities came solely from the western Hudson Bay stock, the total average annual catch would be 440 Belugas (Table 1). Hunting losses during Beluga hunts have been estimated at about 10 to 20% (Richard and Orr 1986; T. Strong, DFO, Winnipeg, Manitoba; personal communication), therefore removals of 1.1 to 1.25 times the landed catch (440), or 484 to 550 Belugas, are to be expected from these hunts. That level of annual removal represents 2.1% to 2.4% of our western Hudson Bay population estimate of 23 000 (see above, Population Size and Trend).

It is more than likely that a portion of the total annual catch (484 to 550) comes from a mixture of eastern, southern and northern Hudson Bay Belugas because all three stocks also spend winter and part of spring and fall in Hudson Strait and are therefore susceptible to being hunted by local hunters. Also, the size of the western Hudson Bay stock used in the above calculations is uncorrected for submerged animals and therefore probably an underestimate (see above, Population Size and Trend). Consequently, the actual removal from the western Hudson Bay stock is probably smaller than 484 to 550, and certainly within sustainable harvest limits of 2 to 3% (see above, Reproductive Biology and Mortality).

The effect of present harvesting levels on the southern Hudson Bay stock cannot be fully assessed until its relationship with other stocks is determined and more information can be obtained on the proportion of the catch which belongs to each stock.

Special Significance of the Species

The Beluga is one of the few truly arctic whale species, living year-round in ice-covered waters and exhibiting several adaptations for its arctic environment. It is an important resource for the Inuit. The skin or *muktuk* is a favoured food which is rich in nutritive value and often in short supply in many communities. Consequently, there is a great demand for trade in *muktuk* from communities which have fewer opportunities to hunt Belugas. The hunting of

Belugas in western Hudson Bay has long been an important cultural and subsistence activity for a people to whom hunting and culture are synonymous and where diet is composed largely of wild foods.

The pure white color of the Beluga, its gregariousness and concentration in the Churchill estuary, an area easily accessible, have made it a popular tourist attraction. Belugas captured in Churchill are kept in several North American aquaria where their docility and playfulness have captured the public's imagination around the world.

Evaluation

Although there are no data to determine a trend in abundance, the western Hudson Bay stock appears to be large, despite a substantial harvest and habitat modifications. Therefore, it is recommended that the western Hudson Bay Beluga stock not be placed in any of the COSEWIC categories (Cook and Muir 1984). The status of the southern Hudson Bay stock should be reviewed as information on its size, relationship to other stocks and harvest levels become available. A more precise delineation of the Hudson Bay stocks is needed to determine if there are one, two, or several stocks and how they contribute to the catch of different hunting communities bordering Hudson Bay and Hudson Strait. Research should also focus on determining more precisely what constitutes critical habitat for Belugas, particularly the importance of estuaries and the effects of hydroelectric developments.

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Accepted 3 February 1994

Status of the Baffin Bay Population of Beluga, *Delphinapterus leucas**

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In summer, Belugas of the Canadian eastern high arctic are found in the waters of the central archipelago. Large numbers, up to 5000, frequent the estuaries of Somerset Island. Belugas migrate through Lancaster Sound in the fall to over-winter in Baffin Bay and Davis Strait. Estuaries are considered critical habitat for Belugas because of their repeated seasonal occupation. Disturbance by man is caused by vessel traffic, in particular ice-breakers evoke a fleeing response at distances greater than 35 km. Development of hydrocarbon resources carries the inherent risk of oil spills to which Belugas are moderately susceptible. Belugas are hunted for subsistence purposes by the Inuit of Canada and Greenland. No quotas regulate catch size in either country. Migration patterns indicate a single stock, but differences in contaminant levels of Canadian and Greenlandic Belugas suggest stock separation. From a population of approximately 12 000, on average 50 Belugas are harvested in the Canadian high arctic and 700 in Greenlandic waters annually, which raises concern that exploitation exceeds production. Current population levels indicate that Baffin Bay Belugas are not rare or endangered, but management issues need to be addressed through co-operation between native hunters and government authorities. Because demographic parameters are poorly known (especially catch sizes in West Greenland) and Belugas are susceptible to over-harvesting, the Baffin Bay stock of Belugas should be considered vulnerable until better information on population trends is available.

Key Words: Beluga, *Delphinapterus leucas*, White Whale, béluga, marsouin blanc, Cetacea, Odontoceti, Monodontidae, Baffin Bay, vulnerable species.

The Beluga, *Delphinapterus leucas* (Pallas, 1776), a White Whale (Figure 1) without a fin, derives its common name from the Russian word for white. However, in the Soviet Union this name refers to the White Sturgeon, *Acipenser huso*; *belukha* being the name of the White Whale. Other common names are White Whale (English), *marsouin blanc* or *béluga* (French), *qilaluga* (Inuttitut), *qilaluaq qaqortoq* (Greenlandic), *weisswal* (German), *hvidhval, hvidfisk* (Danish) and *mjaldur* (Icelandic) [M.P. Heidi-Jorgensen, Greenland Fisheries Research Institute, Copenhagen, Denmark; personal communication; Brodie 1989].

The asymptotic length of Belugas from West Greenland is 386 cm for females and 483 cm for males. These animals can weigh up to 1200 kg (Heide-Jorgensen and Teilmann *in press*). The skin of Belugas changes from the slate grey to brown of neonates to a dark grey or blue that progressively lightens with age to white, leaving only the trailing edges of the flippers and flukes dark in most animals (Vladykov 1944; Kleinenberg et al 1969; Brodie 1971; Sergeant 1973). Sexual maturity has been correlated with the onset of white coloration in some populations, but this does not apply universally (Doidge 1990a).

Based on ear bone morphology, Kasuya (1973) proposed an affinity between the Beluga, and the Irrawaddy River Dolphin, *Orcaella brevirostris*, leading others (Barnes 1976; Gaskin 1982; Barnes et al. 1985) to expand the Family Monodontidae to include *Orcaella*. Using immunological and enzyme electrophoresis procedures, Lint et al. (1990) found a close relationship between *Delphinapterus leucas* and *Monodon monoceros* (Narwhal) to the exclusion of other species and concluded that *Orcaella* was definitely not a member of Monodontidae.

Belugas are capable of diving to 647 m and remaining submerged for at least 16 minutes (Ridgway et al. 1984). They feed on a variety of fish and invertebrates of benthic and pelagic origin. In Canadian arctic waters, Arctic Cod (*Boreogadus saida*) and Greenland Halibut (*Reinhardtius hippoglossoides*) are important prey (Davis et al. 1980; Bradstreet et al. 1986). On the wintering grounds in Disko Bay, Belugas feed on redfish (*Sebastes* spp.) and Greenland Halibut (Heidi-Jorgensen and Teilmann *in press*).

Distribution

The distribution of Belugas is characterised by a disjunct circumpolar range with distinct concentrations that occupy traditional, non-overlapping summering areas (IWC 1980). In summer, Belugas in the eastern Canadian high Arctic occur in Barrow Strait, Prince Regent Inlet, Peel Sound and Jones Sound. These whales are isolated from western Arctic Belugas by a longitudinal gap (approximately 100° to

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*Reviewed and approved by COSEWIC April 1992; status assigned — Vulnerable.

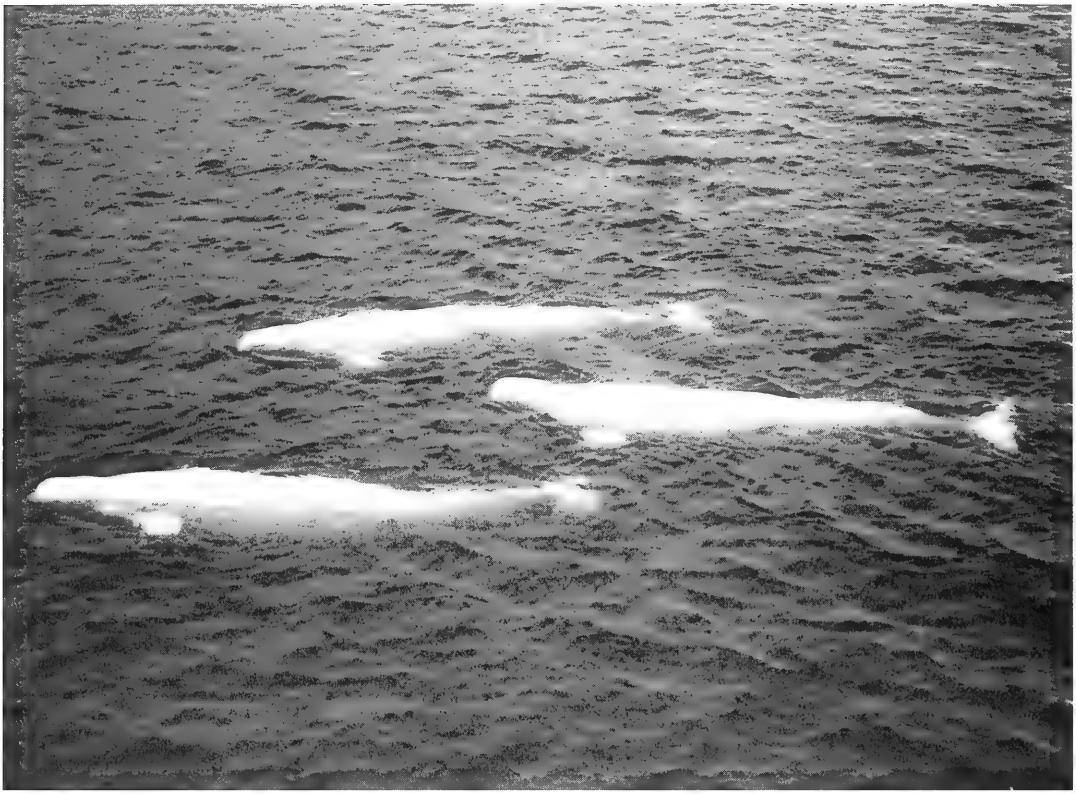

FIGURE 1. Three adult Belugas, *Delphinapterus leucus*, in Cunningham Inlet, Somerset Island, Northwest Territories, August 1982. Photograph by D.W. Doidge.

120°W) in the western Arctic islands (Finley et al. 1987), and by nearly 2000 km from the nearest summer concentration of Belugas in Cumberland Sound, S.E. Baffin Island (Brodie 1971). The Belugas that summer in the eastern Canadian high Arctic appear to winter off the West Greenland coast (Figure 2), therefore we refer to them as the Baffin Bay population.

Belugas concentrate in traditional summer estuaries, particularly those of Somerset Island, from mid-July to mid-August (Heyland 1974; Sergeant and Brodie 1975; Finley 1976; Smith et al. 1985). Estuarine concentrations of Belugas occur at Creswell Bay, Cunningham Inlet, Elwin Bay, and Garnier Bay on Somerset Island, Maxwell Bay on Devon Island and Brodeur River and Cape Kater on the Brodeur Peninsula, Baffin Island. In late summer, Belugas disperse southward through Peel Sound as far as northern Franklin Strait and estuarine concentrations have been observed around southeastern Prince of Wales Island (Coningham Bay) in late August (Finley and Johnston 1977). Belugas do not usually penetrate much further west than western Barrow Strait.

In September, Belugas exit Lancaster Sound and move northeastward toward Greenland (LGL 1983). Catch statistics indicate a southward migration along the West Greenland coast to wintering grounds south of Disko Island (Degerbol and Neilsen 1930; Vibe 1950; Kapel 1977). As many as 500 Belugas overwinter in flaw leads in the northern periphery of the "Northwater" (Finley and Renaud 1980). Aerial surveys have identified overwintering grounds of Belugas in Davis Strait off southwest Greenland (67° to 70°N) where the majority of whales occurred in pack-ice within 50 km of the coast (McLaren and Davis 1981, 1983; Heidi-Jorgensen et al. 1992). None was observed in the open water along the coast south of 67°N, but catch statistics (Kapel 1977) show that in some years, e.g. 1967 to 1974, Belugas occur as far south as 63°N, along the advancing pack-ice edge. Based on his review of the history of the distribution of Beluga in West Greenland waters, Heidi-Jorgensen (1992) concluded that Beluga no longer winter south of 65°N. A large geographic gap separates the Davis Strait wintering grounds from the apparent wintering grounds in Hudson Strait of Belugas from Hudson Bay and Cumberland Sound (Finley et al. 1982).

A few Belugas are sometimes caught during the summer in the northernmost districts of Greenland: Upernavik and Avanersauq, but no surveys have been conducted to determine the size of this summer population (Heide-Jorgensen 1990). No estuarine concentrations are known to occur along the West

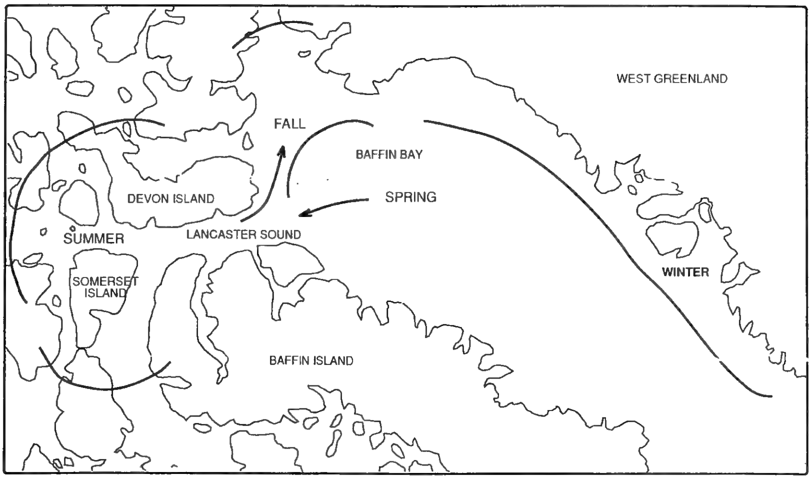

FIGURE 2. Distribution and migration routes of Baffin Bay Belugas.

Greenland coast and the population there in summer is considered small (Reeves and Mitchell 1987). It is unclear what the relationship is between the Greenlandic and Canadian summering groups or between the Northwater and Davis Strait wintering groups of whales. Because these seasonal ranges are connected by the migration route (see below), there is no reason to suspect that these groups are segregated during the breeding season in spring.

Based on differences in body size, Sergeant and Brodie (1969) proposed discrete populations of Belugas in the eastern Arctic. Although the sample size from Ellesmere Island was very small, Sergeant and Brodie (1969) suggested that they were transitional in size between Canadian and the larger Belugas found in West Greenland. In a re-analysis of the data, Doidge (1990b) showed the difference in body size between Beluga populations was not as great as previously thought.

Migration

A few hundred Belugas overwinter in flaw leads at the entrances of Lancaster and Jones Sounds (Finley and Renaud 1980), but the bulk of the migrants from wintering grounds in Davis Strait do not arrive in the Baffin Bay "Northwater" until late June (LGL 1983). Belugas cross Baffin Bay north of 76°N, then move southward along ice edges to the entrance of Lancaster Sound. In most years, when not covered by fast-ice, the peak migration of Belugas through Lancaster Sound occurs between mid-June and mid-July. Whales follow the south coast of Devon Island westward toward their summering grounds (Johnson et al. 1976; LGL 1983). In years when the entrance to Lancaster Sound is obstructed by ice into July, large numbers of Belugas congregate along the ice-edge. In such ice-barrier years, Belugas may cross Lancaster Sound along the ice-edge to the northern Baffin coast (LGL 1983; Finley et al. 1990).

Belugas are virtually absent from Lancaster Sound from late July to early September. The autumn migration of Belugas out of Lancaster Sound is rapid; the bulk of the population passes eastward in large herds in mid-September (LGL 1983). Most whales follow a narrow corridor along the south coast of Devon Island, then head north, crossing Jones Sound to southeastern Ellesmere Island (LGL 1983). Belugas are present in the Thule district, NW Greenland in October (Vibe 1950) and catch statistics from Melville Bay (72° to 75°N) show that Belugas pass there during October and November (Kapel 1977). No southern migration of Belugas occurs along the northeast coast of Baffin Island (Koski and Davis 1979). This pattern of Beluga migration appears unchanged from that of the 19th century (Reeves and Mitchell 1987).

Protection

National

Canada: In Canada, Beluga protection regulations have been issued under the Fisheries Act of 1867 since 1949. Reeves and Mitchell (1989) reviewed the history of this legislation and its subsequent amendments. These regulations have been modified over the years, primarily in response to commercial and native hunting pressure in Hudson Bay and Cumberland Sound. In recent years, quotas have been set for harvests in northern Quebec and southeastern Baffin Island. No restrictions apply to the aboriginal take of Baffin Bay Belugas in Canada provided they are used for subsistence purposes. In 1966, a substitution to the Fisheries Act disallowed the sale or barter of Beluga products, but a 1967 amendment then allowed residents to sell Beluga parts or carcasses to a whale factory that was operating at the time in Hudson Bay. Commencing in 1980, Indians and Inuit within the Northwest Territories were permitted to trade or barter Beluga products if the transactions were recorded. Also in 1980, restrictions were placed on hunting methods: hunters must be equipped with a boat, harpoon and float and rifles larger than 0.22 calibre; calves and females with calves were fully protected and non-native residents required licenses to hunt Belugas.

On 4 February 1993, the Beluga Protection Regulations were revoked by the Government of Canada and replaced by the Marine Mammal Regulations, effective 24 February 1993 (*Canada Gazette*, 24/2/93, SOR/DORS 93-56). In the Northwest Territories, only the native persons can hunt Belugas or trade in their products. No quotas apply to Beluga hunting in the Canadian high arctic, but the killing of calves (animals less than 2 m in length) or an adult accompanied by a calf is prohibited. The revised regulations delete the restrictions on calibre and specify instead a minimum muzzle energy of 1500 foot-pounds and use of full metal-jacketed bullets. A shotgun with rifled slugs may be used if the muzzle energy exceeds 1500 foot-pounds. No person is allowed to disturb Belugas unless hunting for them.

Belugas are susceptible to disturbance and over-exploitation when occupying estuaries (Caron and Smith 1990), yet no legislation specifically protects such habitat in the high Arctic.

Greenland: In West Greenland, Beluga hunting is regulated by various local rules, some following traditional practices (Dahl 1990), but harvest size is not limited (Heide-Jorgensen 1990).

International

Until 1992, no agreements existed for the international management or protection of the Baffin Bay population of Belugas that is evidently shared by Canadian and Greenlandic Inuit. In 1979, the Scientific Committee of the International Whaling Commission (IWC) recommended the development of cooperative international research programs between countries sharing common stocks of Beluga whales. Noting the high catches of Belugas in West Greenland, the IWC Sub-Committee on Small Cetaceans urgently recommended that Canada and Denmark initiate studies on this population. In 1980, the Sub-Committee recommended that management of Belugas be initiated, but no action was taken by the Commission (IWC 1980). In 1981, Canada withdrew from the IWC. Dialogue between Greenland and Canada continued and in 1992 the Canada-Greenland Joint Commission for the Conservation and Management of Narwhals and Belugas was formed.

International trade in Beluga Whales, their parts and derivatives is regulated under Appendix II of the Convention on International Trade in Endangered species of Wild Fauna and Flora (CITES). This listing requires the prior grant of a CITES export permit from the country of origin before export may occur.

Population Size and Trend

The first, crude population estimate of 10 000 was based on the number of Belugas seen during aerial reconnaissance at the major estuaries of the high arctic islands (Sergeant and Brodie 1975). Finley (1976) estimated that in late July of 1975, at least 5000 Belugas were in the estuaries of Somerset Island. Based on strip-transect surveys, he estimated another 2700 were in the offshore waters of Barrow Strait. These surveys did not include the offshore summer range of Prince Regent Inlet. Using the results of extensive systematic surveys flown in July 1981, Smith et al. (1985) estimated 4200 to 16 500 Belugas occurred in the offshore waters of Somerset Island with an additional 2064 animals in estuaries. The clumped distribution of Belugas and the degree of survey coverage led to the wide confidence intervals associated with this estimate. These figures should be considered minimal since they are uncorrected for submerged animals (Smith et al. 1985) and surveys did not cover potential summering areas in Peel Sound, Jones Sound, or West Greenland (Heide-Jorgensen 1990). In 1984 and 1985, several hundred Beluga were sighted during aerial surveys in Peel Sound (P. Richard, Department of Fisheries and Oceans, Winnipeg, Manitoba; personal communication). Recent satellite tagging of Belugas indicates that, when offshore, they can spend a large portion of the time submerged and thus undetectable by aerial reconnaissance (Martin and Smith 1992).

Aerial photographic surveys of the major estuarine concentrations of Belugas provide the most accurate assessment of that portion of the population inhabiting coastal waters. Unlike most subarctic estuaries used by Belugas, high Arctic estuaries have transparent waters in which submerged whales can be easily seen and photographed (Heyland 1974). Although Beluga numbers in estuaries can fluctuate from day to day (Finley 1976; Hay and McClung 1976), shore-based observations indicate that during August the numbers of whales in the major estuaries are fairly consistent. Belugas in the major estuaries on 2 and 3 August 1973 numbered 8900; half of these being in the estuaries of Somerset Island (Sergeant 1979). Peak numbers are usually higher at Creswell Bay (3000 to 5000) compared to Cunningham Inlet (1000 to 2000) (Heyland 1974; Finley 1976; Sergeant 1979).

During autumn, Belugas migrate in large herds out of Lancaster Sound along the south coast of Devon Island (Finley and Johnston 1977; Koski and Davis 1979). Because the migration is rapid, unidirectional, and follows a narrow corridor along the coast, autumn surveys of this area likely provide the best estimates of population size. Koski and Davis (1979) estimated that 10 250 to 12 000 Belugas moved past Cape Warrender during September, 1979, with a peak passage between 14 and 18 September.

Concern has been expressed that this population is declining due to excessive hunting by Greenlandic and Canadian Inuit (Reeves and Mitchell 1987; Heide-Jorgensen 1990). The abundance index, derived from aerial surveys flown over the wintering grounds in 1990 and 1991, has declined significantly ($p = 0.13$) from that calculated from similar surveys in 1981 and 1982 (Heidi-Jorgensen et al. 1992). Although the 13% probability level is higher than that normally used in statistical practice, the repercussions of Type II statistical error to management decisions justifies the concern over population trend.

Harvest Methods

Historically, Belugas were hunted for subsistence by the Inuit using harpoon and kayak in Canada (Kemper 1980) and Greenland (Kristiansen and Henningsen 1964). Between 1874 and 1898, Scottish whalers operated a drive fishery at Elwin Bay, Somerset Island, where they killed an estimated 10 985 Belugas (Reeves and Mitchell 1987).

In Canada, Belugas are now hunted from motor boats. Whales are usually herded into shallow water and shot, and may be harpooned (Kemper 1980; Doidge and Finley, personal observations). In West Greenland, Belugas are caught by drive fisheries at Upernavik, by nets or are pursued and shot and/or harpooned (Heide-Jorgensen 1990). Motor boats are banned for whale hunting purposes in some areas (Heide-Jorgensen 1990).

Catch Size

Canada: Baffin Bay Belugas are hunted by Canadian Inuit from settlements that border the summer range and migration routes. Strong (1989) summarized government records of catches of Beluga for these settlements for the period 1955 to 1987 (Table 1). Harvest surveys in these communities between 1979 and 1983 (Finley and Miller 1980; Donaldson 1988) show good agreement on catch size and indicate the harvest has been less than 50 Belugas annually. A declining trend is seen in the number caught over the last three decades, but the proportional catch between the settlements remains the same. The communities of Grise Fiord, Resolute Bay, and Creswell Bay account for the majority of the catch. Pond Inlet and Arctic Bay, situated on the south side of Lancaster Sound, are not on the main migration route so catches there are lower (Kemp et al. 1977). Kuuganayuk, the outpost camp at Creswell Bay, is situated near a major estuarine concentration of Belugas; but, due to the small number of people who had been living there, this settlement harvested few Belugas (Kemp et al. 1977). In the fall of 1991, the Inuit family which had been living there permanently moved to Resolute Bay (Welch 1993). Typically, most whales are taken at Resolute Bay during the autumn migration from mid-August to early September. Hunters at Grise Fiord anticipate the arrival of Belugas for early September (Riewe 1977; Bradstreet et al. 1986; Donaldson 1988). In winter, Inuit occasionally discover Belugas entrapped by ice, whereupon the whales are usually harvested (Freeman 1968).

Annual variations in ice condition cause major fluctuations the number of Belugas caught by Canadian Inuit communities. For example, no Belugas appeared at Grise Fiord between 1969 and 1972 owing to heavy ice conditions (Riewe 1977). Furthermore, the presence of concentrations of Arctic Cod near communities can attract Belugas and influence harvest size, as was the case at Resolute Bay in 1976 (Bradstreet et al. 1986).

TABLE 1. Summary of reported catches of Belugas in the eastern high Arctic (Source: Strong 1989).

Year	GF	RB	CB	AB	PI	Total
1955	14	.	.	.	.	14
56	6	.	77	.	2	85
57	15	.	94	.	.	109
58	5	.	92	.	.	97
59	25	.	98	.	26	149
60	35	.	46	.	.	81
61	10	.	26	.	.	36
62	75	.	3	.	.	78
63	83	.	3	.	.	86
64	20	.	16	16	1	53
65	48	.	.	1	.	49
66	118	.	.	2	1	121
67	0	.	.	1	.	1
68	0	.	.	.	.	0
69	.	.	.	.	.	.
70	0	.	.	.	.	0
71	.	36	.	.	.	36
72	.	.	.	.	.	.
73	20	42	.	3	5	70
74	6	16	.	2	0	24
75	10	11	14	.	.	35
76	15	11	.	.	.	26
77	11	17	.	0	0	28
78	15	1	1	0	0	17
79	12	6	.	31	2	51
80	16	.	.	0	0	16
81	47	8	.	0	0	55
82	6	8	0	2	0	16
83	6	18	.	0	1	25
84	21	1	12	13	0	47
85	6	6	8	1	0	21
86	0	1	5	0	0	6
87	25	0	0	0	9	34

GF – Grise Fiord; RB – Resolute Bay;
CB – Creswell Bay; AB – Arctic Bay;
PI – Pond Inlet.

Greenland: In contrast to the small harvests in the Canadian high Arctic, the reported annual harvest of the communities in West Greenland averaged 700 Belugas (range 216 to 1874) during the period 1954 to 1987 (Table 2). Heide-Jorgensen (1990) cautioned that the Greenlandic statistics are incomplete, particularly in recent years when several Greenlandic settlements stopped reporting their catches. He suggested that 500 to 1000 Belugas are taken annually in Greenland. Applying an estimated loss rate of 25% to catches in Canada and West Greenland, Heide-Jorgensen (1990) suggested the total removal due to hunting was, at least, 875 to 1500 Belugas annually.

The catch record in Greenland is occasionally punctuated by large catches of Belugas at "savssats" or ice-entrapments on the wintering grounds, in particular Disko Bay (Porsild 1918). The highest catch from a savssat is estimated at 1326.

Loss Rates

Unlike the situation with most other hunted populations of Beluga in Canada, most of the Beluga catch from the Baffin Bay population are not taken at the summer concentrations at estuaries, but during the autumn migration. As Belugas migrate along the coast they are intercepted and driven into shore. Therefore, loss rates from other Canadian hunts (e.g., Fraker 1980) are not applicable to the Baffin Bay population. The portion of Belugas that are lost due to sinking or that die later from bullet wounds is not known.

Statistics on loss rates from various types of Narwhal hunting (Finley et al. 1980; Finley and Miller 1980; Weaver and Walker 1988) are not applicable to Beluga hunts because Belugas tend to sink more readily than Narwhals when shot (Finley, personal observation). However, most Belugas are taken in shallow water so loss rates are likely lower than the 30 to 60% reported for Narwhal hunts.

Table 2. Summary of estimated catches of Belugas in West Greenland reported to the IWC.

	District												
Year	TH	UP	UM	JA	CH	GD	EG	KA	HO	SU	GT	FR	Total
1954	.	16	61	1326	69	241	88	50	23	.	.	.	1874
55	.	10	3	39	13	75	107	41	11	1	.	.	300
56	.	9	8	89	2	75	155	52	29	5	.	.	424
57	.	6	11	191	8	66	96	30	95	.	.	.	503
58	.	3	4	50	5	8	90	29	35	1	.	.	225
59	.	12	12	48	5	46	112	32	42	.	.	.	309
60	.	13	6	52	17	37	55	18	17	.	1	.	216
61	32	15	6	11	3	75	125	5	47	1	11	1	332
62	85	9	7	52	12	42	57	23	23	8	11	.	329
63	75	18	12	25	5	22	36	5	8	12	11	.	229
64	125	4	6	57	4	38	55	12	8	4	18	.	331
65	150	20	33	102	44	28	27	13	24	18	9	.	468
66	.	25	88	76	34	132	135	21	24	13	12	1	561
67	.	34	66	90	72	37	140	30	76	47	4	.	596
68	.	97	65	490	105	160	160	98	46	8	.	.	1259
69	.	111	36	357	119	89	83	13	100	40	30	.	978
70	17	334	6	656	127	212	113	25	10	24	.	.	1524
71	2	238	3	82	25	97	96	28	123	4	41	.	739
72	.	293	25	116	39	78	107	22	135	11	14	1	841
73	.	262	33	205	35	81	217	43	121	.	70	.	1067
74	21	195	13	290	65	22	116	13	135	8	25	2	905
75	3	150	19	49	56	92	53	18	130	4	33	.	607
76	13	77	12	50	104	721	73	5	72	.	48	.	1175
77	14	240	49	50	58	217	32	22	43	13	65	.	803
78	20	104	44	100	131	106	109	6	77	5	17	.	719
79	25	250	22	100	95	98	85	1	35	12	18	.	741
80	30	191	100	100	110	44	148	10	109	45	1	.	888
81	76	343	95	83	115	60	66	16	62	23	78	.	1017
82	127	329	17	80	120	48	55	10	95	13	0	0	894
83	53	233	19	50	50	47	37	10	99	2	1	0	601
84	21	333	15	120	38	111	67	16	25	16	1	0	763
85	190	188	6	50	0	46	55	26	25	17	8	0	611
86	.	240	4	78	.	.	36	.	0	2	0	.	360
87	.	550	13	.	.	.	29	.	0	8	6	.n	606

Districts: TH - Thule; UP - Upernavik; UM - Umanaq; JA - Jakobshavn; CH - Christianshab; GD - Godhavn; EG - Egedesminde, KA - Kangaatsiaq; HO - Holsteinborg; SU - Sukkertoppen; GT - Gothab; Fr - Frederikshab.

Sources: Born (1986, 1987), Kapel (1977, 1983, 1985), Kapel and Larsen (1984).

The killing power of rifles used in Beluga hunts is more related to bullet jacket type than calibre (Doidge, personal observation). Many bullet types and calibres are used. Soft-point ammunition, regardless of calibre, expands and has its energy absorbed in the blubber layer. Bullets may become encapsulated in the blubber (Doidge, personal observation) indicating that wounding does not always result in death. The associated mortality rate however, remains unknown.

Habitat

Estuaries are presumed to be critical habitat for Belugas based on their repeated seasonal occupation (Finley 1982). Site fidelity in spite of harassment (Finley et al. 1982; Caron 1987; Caron and Smith 1990), thermal benefits of warm estuarine waters to the young (Sergeant 1973; Sergeant and Brodie 1975; Breton-Provencher 1979) and all age classes (Fraker et al. 1979), physiological factors such as the moulting of skin (Finley et al. 1982; St. Aubin and Geraci 1989), and the predictably ice-free habitat offered by estuaries in spring (Breton-Provencher 1979) are considered as the reasons estuaries are important habitat for Belugas.

The function of estuaries as calving grounds suggested by Sergeant (1973), was dismissed by Caron (1987) since her observations over two summers in eastern Hudson Bay did not show a pronounced seasonal increase in the number of neonates. However, at Creswell Bay in early August Finley (1976) documented a marked increase in the number of neonates present. Calves may be born outside estuaries then later congregate within them.

The thermal benefit of estuaries is directly proportional to the temperature gradient between the environment and the body of the whale. Beluga body temperatures are in the region of 35°C. In summer, stream channel temperatures at Cunningham Inlet approach 8°C (Hay and McClung 1976) whereas surface waters in Barrow Strait are 0 to 2°C, so estuaries confer some thermal advantage, especially to young. Doidge (1990c) found that the young of Narwhal and Beluga possess similar insulation, yet only Beluga have an estuarine habit. The Inuit belief that warm, flowing, fresh water and sand banks on which to rub enhances the moulting process has been shown to have a physiological basis (St. Aubin and Geraci 1989).

The feeding habitat of Lancaster Sound Belugas is not well known. Recently, Belugas tagged with satellite transmitters were found to dive into, and presumably be feeding in deep holes (350 m) in Barrow Strait (Martin and Smith 1992). Pits on the seafloor, found in Baffin Island Fjords at depths of 40 to 326 m, are believed to have been made by Narwhals or Belugas foraging for food (Hein and Syvitski 1989). Groups of Belugas, thought to be feeding on concentrations of Arctic Cod, have been observed in September along the southeast coasts of Devon and Ellesmere Islands (Bradstreet et al. 1986).

The majority of Belugas overwinter in the waters of Davis Strait, but some occupy the flow leads at the eastern entrances to Lancaster and Jones Sounds (Finley and Renaud 1980).

General Biology

Reproductive Capability

Vital rates are usually determined on an age-specific basis by examining a large number of reproductive tracts from harvested animals. For the Lancaster Sound population and other Beluga populations, vital rates are poorly known and are likely to remain so in Canada, given the small harvest available for scientific examination. The harvest at Grise Fiord has been examined, but is biased by hunter selection of grey (young) animals (R. E. A. Stewart, Department of Fisheries and Oceans, Winnipeg, Manitoba; personal communication) which further reduces the sample size of mature animals. The small sample size (n < 500) associated with studies of Beluga demography (Brodie 1971; Sergeant 1973; Braham 1984; Burns and Seaman 1985; Doidge 1990a) prevents useful comparisons between Beluga populations and are not precise enough to detect changes in population status (Doidge 1990a, d). The general range of these values though, is useful in assessing the relative importance of demographic parameters in the growth of Beluga populations, but are not precise enough to derive meaningful estimates of rate of increase.

Breeding Cycle

Heidi-Jorgensen and Teilmann (*in press*) examined the reproductive cycle of 167 female and 205 male Belugas harvested in West Greenland during 1985 to 1992. Males were found to attain sexual maturity at age 6 to 7 years and females at age 4 to 7 years. Tooth wear, which prevents the estimation of true age for some samples, may have biased these estimates of age-at-maturity downwards (Heidi-Jorgensen and Teilmann *in press*). Implantation occurs in May with a single calf being born the following April or May. Neonatal Belugas have been observed between March (Degerbol and Freuchen 1935; Heidi-Jorgensen and Teilmann *in press*) and late November (Freeman 1968). Others report a more limited period of births from the end of May (Cosens and Dueck 1990) until August (Braham 1984; Greendale and Greendale-Brousseau 1976; Hay and McClung 1976).

The ratios of pregnant and lactating animals in harvests elsewhere (Kleinenberg et al. 1969; Burns and Seaman 1985; Sergeant 1973; Doidge 1990a, d) indicate that the breeding cycle is three years in Hudson Bay and the Russian Far East, but may be two years in the Russian North (Doidge 1990a). The duration of gestation is 12 to 14.5 months (Laws

1959; Sergeant 1962, 1973; Kleinenberg et al. 1969; Brodie 1971; Doidge 1990a), including an average overlap of pregnancy and lactation of 0.3 years (Doidge 1990a). Based on the ratio of lactating to pregnant animals in the harvest, the duration of lactation ranges from 1.4 to 2.6 years in the Russian North and 2.0 to 2.7 years in Hudson Bay (Doidge 1990a). Harvest bias between lactating and pregnant animals directly affects these estimates.

Heidi-Jorgensen and Teilmann (*in press*) argue that fetal growth rates in Beluga warrant closer attention. The 330 day duration of gestation that they calculated for West Greenland animals is shorter than that found elsewhere.

Sex Ratio

Freeman (1968) found a 1:1 sex ratio in a sample of 98 Belugas from Grise Fiord. Similarly, the 381 Belugas examined by Heidi-Jorgensen and Teilmann (*in press*) had an overall sex ratio of unity. Differences between the sex ratios of Belugas harvested at Disko Bay (18 females:43 males) and Upernavik (169 females:117 males) indicate segregation of sexes among groups does occur (Heidi-Jorgensen and Teilmann, *in press*).

Population Age and Length Frequencies

The sample sizes of length frequency data from harvests at Grise Fiord (Freeman 1968), Creswell Bay (Finley 1976) and West Greenland (Heidi-Jorgensen and Teilmann *in press*) are too small to be used in detailed demographic analyses. Comparison of length frequencies from aerial photographs of high Arctic surveys with those of other stocks may yield some useful demographic information, but are likely to be limited by their short time series.

Theoretical stable age and length distributions, based on survivorship and fecundity data from relatively small sample sizes from sites other than the high Arctic, predict that young of the year comprise about 10% of the population at the end of the birth pulse (Burns and Seaman 1985; Béland et al. 1988; Doidge 1990a). During aerial surveys of Creswell Bay, Finley (1976) found the proportion of neonatal Belugas in the herd peaked at 12% in August, a figure similar to Sergeant's (1973) estimate of crude birth rate of 12.0 to 12.5%. In aerial photographs taken at Cunningham Inlet on 30 July 1973, 17.9% of the 1614 Belugas were classified as neonates (Heyland 1974).

Age and length distributions of Belugas harvested in West Greenland differ by site and season (Heidi-Jorgensen and Teilmann, *in press*). The age distribution of animals caught in Disko Bay during spring contains older animals and shows no clear mode. The distribution of ages in the autumn harvest at Upernavik shows a clear mode at age three years for both sexes, but lacks the older ages found in the Disko Bay distribution.

Population Growth Rate

Based on the stabilization of catch-effort and modal length of males during the commercial harvest of Belugas in western Hudson Bay, Sergeant (1981) considered a catch of up to 5% of the population to be sustainable. From simulation models, Béland et al. (1988) concluded the potential for growth of Beluga populations was 2 to 3% or less. The actual rate may lie within these limits, but both estimates are imprecise because they are based either on crude estimates of population size or have been calculated using incorrect assumptions about mortality rates (Doidge 1990a). While the 2.5% rate of population increase used by the Department of Fisheries and Oceans' Arctic Fisheries Scientific Advisory Committee (DFO 1990) might be based on the correct mathematics, the estimates of the demographic parameters used in the calculations do not support such precise estimates of growth rate that are likely to be stock specific.

Cooperative Research and Management

The primary management question is whether the Lancaster Sound population of Beluga can sustain the current combined harvest by Canadian and Greenlandic Inuit. Heide-Jorgensen (1990) summarised the management situation in Greenland:

> "Our present knowledge about the size and biology of small cetaceans in Greenland is insufficient for proper management of the resource".

In particular, he states:

> "lack of precise data on catches of white whales... makes it impossible to evaluate what the presumed changes in hunting patterns might have been on populations".

The question of whether or not the Beluga population which summers in the Canadian High Arctic is shared by the two countries awaits definitive evidence from mark-recapture or genetic studies, but present knowledge of migratory patterns indicates the resource is shared. Efforts, therefore, should be concentrated on determining the most critical issues: the size of the population and catch.

Systematic strip-transect aerial surveys are considered the most effective means of censusing Beluga populations (Heide-Jorgensen 1990; Smith et al. 1985). However, Smith et al. (1985) question the cost effectiveness of large scale systematic surveys of the summering range of Baffin Bay Belugas. Because of the present trend in government spending, the series of surveys required to detect a trend in population number are unlikely to be conducted. Aerial photographic surveys, in combination with shore-based observations along the autumn migration corridor of the south coast of Devon Island (Koski and Davis 1979), likely provide the best estimate of population size at the least cost.

Until better estimates from aerial surveys become available, and satellite telemetry reveals the proportion of whales missed by these surveys, a conservative estimate of population size, based on surface counts, is 12 000 animals. The estimated catch of 600 to 1000 indicates that 3 to 8% (depending on if corrections for submerged animals are made) of the population is harvested annually. The current exploitation rate is viewed as exceeding safe levels (IWC 1980; Reeves and Mitchell 1987; Heide-Jorgensen 1990). Since the values of vital rates are poorly known (Doidge 1990a), arguments concerning estimates of sustainable yield (eg., Béland et al. 1988; AFSAC *in* DFO 1990) become mathematical excercises that are counterproductive to wise management. The data base simply does not exist for such estimates and their application in management serves only to reduce what little confidence the resource users place in such "scientific" arguments concerning allowable catch. Now the issue must not centre on catch exceeding production since neither of these parameters is known with any certainty, but rather efforts should be channelled towards ascertaining stock identity, population and catches size, loss rates and improving estimates of vital rates (especially juvenile mortality). Proper management will depend entirely on the willingness of hunters to cooperate with resource managers (Heide-Jorgensen 1990) and vice-versa, as has been shown in the successful co-management of Polar Bear stocks.

Behaviour/Adaptability

Belugas are a gregarious species, often forming large herds during migration or when gathered at certain estuaries in summer. They are found primarily in coastal waters, although much of their winter range is in deep offshore waters where pack-ice is present (Finley et al. 1980, 1990). Their preference for shallow waters may have evolved in response to Killer Whale (*Orinus orca*) predation, a behaviour that is used to advantage by modern Inuit hunters who often drive Belugas into shallow water where capture is easier (Finley et al. 1990).

Belugas have a wide range of calls (Sjare and Smith 1986a). They possess a sophisticated echolocation system that they use to forage and navigate (Au et al. 1987; Turl et al. 1987). To some extent, their acoustic system is adapted to high levels of ambient noise, but high levels of artificial noise may interfere with their acoustic discrimination. Belugas in Lancaster Sound are sensitive to vessel noise, reacting to ships approaching at distances of 35 to 50 km (Finley et al. 1990). The sensitivity of Baffin Bay Belugas may be explained by their low exposure to vessel traffic in the past. Other populations of Belugas, such as that in the St. Lawrence River, appear to tolerate vessel activity (Finley 1990).

Most Beluga populations show strong site fidelity to estuaries (Caron and Smith 1990). Whatever benefits estuaries bestow, the repeated occupation of estuaries suggests that estuaries are critical habitat for Beluga (Finley 1982). In eastern Hudson Bay, the decline of some estuarine populations while adjacent ones remain stable, suggests that Belugas do not appear to switch to other similar habitat in spite of harassment from hunters and vessel traffic (Caron and Smith 1990; Finley 1990).

Limiting Factors

The response of Beluga populations to exploitation is inherently limited by their slow rate of reproduction. They mature at 5 to 6 years of age, are long lived (30+ years), but produce few young annually (1 per 2 to 3 years) (Brodie 1971; Sergeant 1973; Burns and Seaman 1985; Doidge 1990a). Mortality factors include predation and ice-entrapment.

Besides man, two other predators of Belugas, Killer Whales and Polar Bears (*Ursus maritimus*), are thought to have insignificant effect on Beluga populations (Davis et al. 1980). Some aspects of Beluga behaviour appear to have evolved in response to predation by Killer Whales (Finley et al. 1990). However, few Killer Whales have been observed on the summer range of Belugas leading Davis et al. (1980) to suggest that predation by Killer Whales is not high. Belugas are vulnerable to Polar Bear predation when trapped by ice (Kleinenberg et al. 1969; Freeman 1973; Lowry et al. 1987), but have also been taken by bears in open water (Smith 1985).

Ice-entrapments or "savsatts" are infrequent events, but can result in large scale mortality of Belugas, particularly if the entrapments are found by hunters (Porsild 1918; Freeman 1968; Kapel 1973). The occurrence of savsatts is a well known phenomenon in West Greenland, particularly in Disko Bay which periodically freezes over rapidly, trapping large numbers of Narwhals and Beluga (Porsild 1918). These savsatts may be only short-term entrapments from which the whales later escape.

The habit of Belugas of continuing to congregate in estuaries despite harassment from vessel traffic and hunting makes them susceptible to over-hunting (Finley et al. 1980; Caron and Smith 1990). In the Canadian High Arctic, hunting at estuaries has been limited to Creswell Bay, Somerset Island. The small, subsistence harvest there does not threaten the stock.

As with many Arctic marine mammal populations, the availability of food ultimately controls population size. Knowledge of the feeding ecology and energy budget of Belugas is limited. In late summer, Belugas feed heavily on Arctic cod. An overlap in diet between Belugas, the growing population of Harp Seals (*Phoca groenlandica*) and other piscivores may lead to increased competition for food between these species (Finley et al. 1990). In addition, Greenland's major fishing grounds, and an international shrimp fishery developing in Davis

Strait include the winter range of Belugas. Thus, the carrying capacity of both summer and winter feeding habitats may be decreasing.

Environmental Factors

PCBs: Studies of organochlorine pollutants in Beluga whales show that the Arctic is no longer a pristine environment. Blubber samples from juvenile Belugas (8 males, 7 females) from Grise Fiord contained 2 to 3 ug/g wet weight (ppm) PCBs, 1 to 3 ug/g DDT, 2 to 4 ug/g toxaphene and 1 to 2 ug/g chlordane residues (Muir 1990). Compared to the high levels reported for St. Lawrence River Belugas, these High Arctic samples contained 25 times less PCBs, 20 to 30 times less DDT, 6 times less toxaphene, but only 3 times less chlordane (Muir 1990).

Oil: The exploitation of oil reserves in the deep water of Lancaster Sound poses the risk of a large scale oil spill. The utilization of coastal shallows, estuaries, bays and ice-edges make Belugas vulnerable to oil spills because their ability to avoid slicks would be reduced in such enclosed areas (Wursig 1990). In a qualitative assessment of vulnerability to oil, Wursig (1990) rates Belugas in the mid-range because: (1) their diet includes both animals that concentrate hydrocarbons (benthos) and those that eliminate them (fish and crustacea), (2) Beluga show a degree of adaptation to stress and (3) the size of the population is moderate.

Heavy Metals: The level of heavy metal contamination has been examined in Belugas from West Greenland (n = 41, Hansen et al. 1990) and from Grise Fiord (n = 16+, Wagemann et al. 1990). The range of ages of the whales sampled were similar; West Greenland: 0 to 14 yrs, Grise Fiord: 1 to 21 yrs. When adjusted for moisture content, the maximum contamination levels in muscle tissue from West Greenland were 1.2 times that of cadmium and selenium, and 1.3 times that of mercury in the Grise Fiord animals. In kidney tissue, these factors were 1.2, 1.4 and 2.1 for cadmium, selenium and mercury respectively. Maximum levels in liver tissue from West Greenland were 5.5 those from Grise Fiord for selenium and 4.2 times those for mercury. Conversely, cadmium levels in liver from Grise Fiord were 1.9 times those of West Greenland. This large difference in contaminant levels in liver implies at least some spatial separation between Beluga from West Greenland and Grise Fiord. At both sites, the maximum level of mercury in muscle exceeded that recommended for human consumption (0.5ppm) by Health and Welfare Canada.

Noise: The acoustic system of the Beluga is adapted for communication, navigation and foraging in ice-covered waters. Belugas apparently use passive listening to low-level, low-frequency ambient sounds of moving and solid ice to obtain information critical to their survival (Sjare and Smith 1986a, 1986b; Finley et al. 1990). Although adapted to dealing with high levels of ambient noise, their acoustic system may be susceptible to interference from noises produced by ice-breakers or other large vessels (Mansfield 1983; Cosens and Dueck 1990). Near Inuit settlements, Belugas are subjected to noise from outboard motors, which have increased both in size and number during the past two decades (Riewe and Amsden 1979).

Special Significance of the Species

The Beluga is one of three species of whale in Canadian Arctic waters; the others are the Narwhal and the Bowhead Whale (*Balaena mysticetus*). The publicity associated with the high PCB levels in Belugas in the St. Lawrence River has made this species a symbol of marine conservation and habitat protection. Belugas are of special significance to the Inuit who regard Beluga hunting part of an important cultural tradition. Beluga muktuk is considered a local delicacy. Well managed stocks of white whales provide a renewable resource of lipid, protein and vitamins (Sergeant and Brodie 1975).

International Trade

The Convention on International Trade in Endangered Species of Flora and Fauna (CITES) dictates that permits are required for the international trade of Beluga products, but the trade is not restricted (Reeves and Mitchell 1989). No international trade exists in Beluga products. In Canada, live capture of Belugas for public display is centred at Churchill, Manitoba (Sergeant and Brodie 1975). These animals are not part of the high Arctic stock. In December 1992, the Minister of the Department of Fisheries and Oceans announced a ban on the live cature of Beluga Whales for export.

National Trade

National trade in muktuk is limited by law to sale between Indians, Inuit or beneficiaries of land claim settlements in the Yukon, Northwest Territories, Quebec, and Newfoundland (Marine Mammal Regulations 1993).

Evaluation

Available information on catch size (particularly that in West Greenland) relative to population size, raises concern that Baffin Bay Belugas are being exploited at a rate exceeding productivity. There are, however, uncertainities in both indices of catch and population size that must be urgently addressed.

Migration patterns indicate a single stock, but differences in contaminant levels between Canadian and Greenlandic Belugas raise the question of stock discreteness. This question should be resolved.

Commercial fisheries development in Davis Strait and increasing interspecific competition for food may be degrading the carrying capacity of the summer and winter range of Belugas. Although international and cross-cultural communication has been initiated, conservation strategies for this population cannot be implemented until resource users at the community level agree that management measures are in their own self interest.

Estimates of population size indicate that the species is not rare or endangered, but there are sufficient concerns to warrant close attention to the population's trend. On this basis, we consider the population to be vulnerable.

Acknowledgments

Discussions with T. G. Smith provided the basis for this paper. We thank World Wildlife Fund Canada for funding the report. Over the years, Inuit hunters have shared their knowledge of Beluga life-history and conveyed the practical problems of Beluga management. Members of AFSAC and Fisheries and Oceans Winnipeg, including S. Cosens, H. Cleator, P. Richard, R. Stewart, S. Innes, and T. Strong, provided useful critics of the 1991 version of this manuscript. Thanks to R. Reeves and M. P. Heide-Jorgensen for their comments and for keeping us current with the literature. R. Campbell demonstrated much editorial patience.

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Accepted 27 September 1993

Book Reviews

ZOOLOGY

The Birds of British Columbia Volumes 1 and 2

By R. Wayne Campbell, Neil K. Dawe, Ian McTaggart-Cowan, John M. Cooper, Gary W. Kaiser, and Michael C. E. McNall. 1990. Royal British Columbia Museum, Victoria. Volume 1: xvii + 514 pp., Volume 2: 636 pp., illus. $150.00.

As pointed out by W. Earl Godfrey in his foreword, "British Columbia is an ornithological delight" long overdue for an avifaunal review, the last being published by J.A. Munro and the same Ian McTaggart Cowan in 1947. In a province noted for outstanding nature books by dynamic naturalists, one might expect an excellent tome by the likes of Cowan, the indefatigable R. Wayne Campbell, and four of their renowned colleagues. The first two volumes of this work exceed expectations.

Volume 1 starts with a brief preface by the authors and three pages of acknowledgements, followed by 151 pages of introductory material. This introduction starts with general remarks on British Columbia and the national and international significance of its avifauna, along with comments on changes in bird distribution and populations, and a brief history of the books. A brief, but comprehensive discourse follows on ornithological history of the province, including numerous mini-biographies and sections on the contributions of explorers, collectors and museums, oologists, general naturalists, university studies, and wildlife management agencies (government and non-government). D. A. Demarchi, R. D. Marsh, A. P. Harcombe, and E. C. Lea then present a 90-page overview of the "environment," featuring reviews of each ecoregion and a very brief summary of environmental changes. The introduction ends with comments on taxonomy and several details on coverage of the books.

The rest of Volume 1 and all of Volume 2 are devoted to non-passerine birds. Each volume contains three sets of species accounts, followed by appendices, addenda, references, and index, and "about the authors." The species accounts (loons to waterfowl in Volume 1, vultures to woodpeckers in Volume 2) start with species of regular occurrence (two to eight pages per account), species considered casual, accidental, extirpated, or extinct (one page each), and hypothetical, here considered as published records that either require verification or involve specimens of questionable origin (one paragraph to one-half page). Seventeen additional species for which detailed field notes are on file are mentioned without further details. One race, the Cackling Canada Goose, receives a partially distinctive account under the main species account and a separate range map. Hybrids are also covered under several species. Appendices consist of migration charts, Christmas bird counts (1957–1981), and a list of 4629 (!) contributors (identical in both volumes). Except for spacing differences resulting from a couple of printing errors on one page, the reference list for the two volumes are also identical. The addenda consist of species added between the cut-off date of 31 December 1987 and late 1989, two of which (Red-faced Cormorant and Parakeet Auklet) were earlier listed as hypothetical.

Unlike several "birds of" books of recent times, these volumes are very thorough, being based on 4700 publications and over two million observations, many not published previously. Regular species accounts receive coverage on range (general and British Columbia), status, non-breeding and breeding biology, and "noteworthy records," often with a postscript adding significant new information at the end of the account. Biographical data are primarily from British Columbia, but range farther afield when appropriate. Captions to photos sometimes add information not in the text.

Although I filled about three pages with minor errors, I did not find any significant errors in the book. Some people's names were spelled incorrectly (Copeland for Copland, Decker for Dekker, Chandy for Chaundy, Mossip for Mossop, Myers for Myres), some of whom were spelled correctly at other points in the text. Major Brooks was born in Etawah, not Etawok, India. Hamilton Laing was from Manitoba as stated correctly on page 25, not Saskatchewan as indicated on page 23 of Volume 1. Breeding of Wilson's Phalarope in the Fraser Delta was first documented in 1965 (R.W. Campbell. 1969. *Condor* 71: 434), not 1968.

A few statements are slightly misleading. For example, although Cattle and Great egrets and Black-necked Stilts have all nested in the prairie provinces, nesting there is less regular than implied, and although Baird's Sandpipers are regular prairie migrants, they are far from common. In such a large work, the authors could not possibly include all relevant publications, but I found four omissions unfortunate. Theed Pearse's 1968 book on bird observations of early Pacific explorers was oddly lacking from the account of explorers (although mentioned in his mini-biography). Taverner's 1934 *Birds of Canada* should have been listed among significant museum contributions and the works of Barry Leach and Wilma Robinson on the nearly extirpated lower mainland population of Sandhill Cranes are conspicuous by their absence.

Most of the many illustrations in the book add to its value, but I thought the large photograph of a location where a Rough-legged Hawk had once been seen (Figure 28 of Volume 2) unnecessary.

My only real quibble is with the inclusion of four-letter species codes. As similar or identical codes can logically be derived for very different species, their routine use can lead to errors, and it would be preferable for each observer to use his/her own codes in the field and report full names when submitting records. As pointed out by C. S. Houston, there are different codes for 85 species on two North American species code lists issued for two cooperative schemes (bird-banding and breeding bird surveys) co-odinated by the same Canadian and U.S. government agencies (M.K. McNicholl. 1989. North American Bird Bander 14: 49–50, 54). Listing such codes in provincial and state bird books can only add to the confusion.

Space does not permit even a short summary of the volume of new (or newly accessible) information made available in these books. Although readers will obviously turn to them for distributional and status information, there is also plenty of biological material not readily found elsewhere or found only in scattered reports, here brought together. Corrections are also made, most significantly the revelation that both Arctic Loon specimens attributed to British Columbia in Godfrey's revised (1986) *Birds of Canada* were found on re-examination to be Pacific Loons.

In short, these two volumes are worth every penny of their somewhat steep price. I understand that the first of the passerine volumes is well underway, and await it eagerly.

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The Bats of Texas

By David J. Schmidly. 1991. Texas A&M University Press, College Station. xviii + 188 pp., illus. Cloth U.S. $34.50, paper U.S. $19.95.

As stated in the preface, this book presents "a synopsis of current knowledge about Texas bats" by a professional mammalogist with over 25 years of experience on this subject. It is separated into four chapters including an introduction to bats, identification keys, species accounts, and references. The introduction is further divided into short sections covering a wide array of topics on bat biology such as evolution, flight, echolocation, and conservation. The second chapter is in the format of an illustrated identification key presented for both external and cranial characters. The bulk of the book is composed of the third chapter, comprised of species accounts which are organized in taxonomic fashion and grouped by family. The accounts begin with the scientific and common name followed by biological information including external descriptions, distribution, subspecies designation, and life history. Each account ends with a list of specimens examined, additional records, and references. Black-and-white photographs accompany all 32 species found in Texas with distribution maps for all but a few poorly represented species. The final chapter lists references in three sections covering general works, "Mammalian Species" accounts, and technical papers.

Although a variety of subjects are included in the introduction, none of them are treated exhaustively and few citations are provided for more detailed information on these diverse topics. For example, there are books and chapters devoted to echolocation but there is only one very general publication mentioned for those wanting to delve further into a subject that has fascinated both the general public and scientists alike. Other sections (e.g., reproduction and life expectancy) in the introduction have no citations, which is unfortunate because many readers will not be familiar with the appropriate literature.

The identification keys provide dichotomous choices with usually more than one diagnostic character. The external key is designed for identification of live bats with further verification from a cranial key. If available, skulls provide a confirmation of species identification because many differences are seen in cranial structures or the teeth. Excellent figures by Christine Stetter serve to illustrate diagnostic characters used to distinguish species. This is always useful for comparative purposes because pictures can often convey more than a written description.

The species accounts contain a wealth of information with many examples observed directly from Texas bats. Distributions and habitats are detailed in the text, with county records depicted on maps. Lists of specimens examined contain precise locality information supplemented by additional literature records. Numerous references are given at the end of each account for further information on the species. Photographs are of either the head or full body and are of excellent quality and detail. There are also colour plates for half of the bats covered in this book.

References are separated into three parts, two of which are small sections on general works and "Mammalian Species" accounts. The latter publications are concise summaries of all known biological information on a particular species and include 27 of the 32 species found in Texas. The much larger section for technical papers has citations up to the year 1989. Although the breakdown into three parts is useful for scanning general works or "Mammalian Species" accounts, it is often awkward when searching for the full citation.

A few mistakes have crept in, such as typographical and citation errors (e.g., Jones et al. (1986), on the last page of the preface is not in the bibliography) but these are minor. This book has been well researched as indicated by the extensive specimen examined sections for each species and the 428 references listed. Information is presented in a consistent and readable format with good photographs and helpful illustrations. Those with a general interest in bats or the natural fauna of Texas will find this book an important addition to their library.

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The Ostrich Communal Nesting System

By Brian C. R. Bertram. 1992. Princeton University Press, Princeton. viii + 196 pp., illus. U.S. $35.

The breeding system of ostriches is peculiar. After establishing a nest in a male's territory, a female lays about 11 eggs at 2-day intervals. Surprisingly, she also allows other females to lay in her nest. This doubles the number of eggs in the nest, but not all of these eggs are incubated. A certain number are pushed out of the nest, and eventually rot. Such an intriguing breeding strategy raises many questions: what is the advantage of letting other females lay in one's own nest? Why then does the incubating female reject some of the eggs, and whose eggs are rejected? Do male and female benefit in the same way? And what determines whether a female should lay in her own nest or in another?

From July through October 1977–1979, Brian Bertram and his wife Kate studied the breeding behaviour of ostriches and attempted to answer such questions. Their work, which took place in Tsavo West National Park, Kenya, relied on simple methods: observation, time-lapse photography, and egg-marking. This book presents the results and conclusions of their research.

The first half of the book is a general description of the species, site, methodology used, population studied, breeding parameters, and ecological setting (in particular, the predators present and their impact). This part lays the groundwork for the second half of the book, in which the author presents his analysis of the breeding data and the evidence of how such a system can be maintained by natural selection.

The book is clearly written and is a pleasure to read. I was particularly impressed by the balanced treatment the author gave to his results. Observational field work often yields data that are based on biased sampling or open to alternative interpretations. Bertram never fails to acknowledge the possible biases and to discuss all possible explanations for the results. Although his goal is obviously to explain the evolutionary maintenance of the system (an endeavor where speculation is tempting) he does not overextend his interpretation. I would not hesitate to recommend the book to biology students as an example of how field data should be treated.

Field work has another characteristic: it often generates more questions than it answers, and these new questions usually can only be addressed by a more rigorous approach than simple observation. Reasonable answers can be extracted from observational data, and Bertram does an excellent job of providing such answers in his book. However, a higher level of certainty could only be obtained from further, more experimental work which remains to be done. Some readers will find this state of affairs normal and intellectually stimulating, but others may find it frustrating not to have all the definite answers at once.

I think this book will be greatly appreciated by people interested in the evolution of odd breeding systems or the conduct of field work on large African animals. Also, if some readers feel slightly annoyed by the fact that I started this review with a few questions and then failed to give any hint as to what the answers are, then this book is definitely for them.

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BOTANY

Atlas of Ontario Mosses

By Robert R. Ireland and Linda M. Ley. 1992. Syllogeus Number 70. Canadian Museum of Nature, Ottawa. v + 138 pp. Free.

Over the past decade or so, atlas projects have become popular among Canadian field biologists. Such projects can provide excellent ways for both amateur naturalists and professional biologists to contribute to the knowledge of the distributions of species. Atlases of breeding birds have been most popular, but other recent atlas projects in Ontario have involved herpetofauna, mammals, butterflies, and now, mosses. Admittedly, this *Atlas of Ontario Mosses* was not generated through the same sort of concerted volunteer effort that was used in some of the other atlasses. Nevertheless, a perusal of the list of collectors of mosses contained in this atlas indicates that a good number of naturalists and biologists with non-bryological backgrounds have contributed to the information base from which this atlas was compiled. One of the many benefits of an atlas such as this can be the stimulation of more collecting activity by field biologists and naturalists. This should generate new records that will further elucidate the distributions of Ontario's mosses. It should also make it possible to produce a list of the rare mosses of Ontario in the future.

This atlas is a valuable complement to the earlier *Checklist of the Mosses of Ontario* (R. R. Ireland and R. F. Cain. 1975. National Museums of Canada Publications in Botany Number 5). At the time of publication of the *Checklist*, 464 taxa of mosses were known from Ontario. The *Atlas* now contains distribution maps for 490 taxa, all of which are supported by herbarium specimens.

The bulk of this atlas (122 pages) is comprised of the distribution maps, with taxa arranged in alphabetical order. However, there are also several introductory sections containing information on the herbaria examined, nomenclature used, physiography, geology, climate, and vegetation of Ontario, major collectors of mosses, and general biogeographic interpretations of distribution patterns of Ontario mosses. Some of the sources used to describe the physiography and vegetation of Ontario are somewhat out-dated, but the interpretations provided are adequate for the purposes of this atlas. It is especially nice to see a preliminary analysis of the biogeographic patterns exhibited by Ontario's mosses. The categories used in this publication include: widespread (throughout, southern bias, northern bias), southern, northern, eastern, western, and unknown. As more information becomes available, this chapter could be enhanced, and the distribution patterns of species now placed in the "Unknown" category (68 taxa) should become more fully resolved. Some of the species placed in the "Widespread" category also require better resolution of their distributional affinities (e.g., *Amblystegium riparium*, listed as widespread with southern bias, has three stations in the Hudson Bay Lowlands).

There is very little to criticize in this publication. The value of the range maps should be obvious; additional interest and collecting activity, undoubtedly will be stimulated, with a concomitant increase in the knowledge of these plants. Several excellent guides and monographs are available (one of these by Dr. Ireland) to assist budding bryologists with moss identification. A valuable addition in a future revision would be a list of the rare mosses of Ontario. Such a list would be useful for resource managers and conservation agencies responsible for conserving the elements of the biodiversity of the province. In my perusal of the distribution maps, I found that almost 36% of the taxa (137) known to occur in Ontario are found in five or fewer locations. Fifty-four (54) taxa presently are known from only single locations.

All active field biologists and naturalists should obtain this atlas. Although few of us can claim to have more than a basic knowledge of moss identification, this atlas should stimulate us to learn more about these (often overlooked) plants.

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The Sorediate and Isidiate, Corticolous, Crustose Lichens in Norway

By T. Tønsberg. Sommerfeltia 14: 1–331. University of Oslo, Norway. Prince (including shipping) 380 N Kr ($70.38 Can.).

Lichens are not among the best known organisms, but most naturalists are aware of at least some of the more conspicuous types, the leafy "foliose" and shrubby or hairy "fruticose" lichens. The crustose species are considered to be the realm of the die-hard specialists since one usually needs to examine their fruiting bodies with a compound microscope to name them even to genus. It takes a zealous lichenologist indeed to tackle the crustose lichens that *lack*fruiting bodies, such as most sorediate and isidiate species, and few have ever attempted to do so systematically. Tor Tønsberg is one of this select few, and fortunately for us, he has done a superb job.

The title of this volume gives the impression of a very esoteric study that would be of interest to a small number of specialists, mainly in Scandinavia. Quite the contrary, the sorediate and isidiate crustose lichens are often extremely widespread, and can be important indicators of old growth forests and air quality. Most North American lichenologists have sadly neglected these crusts, especially the ones usually sterile, and so an accurate estimation of the percent of the 148 species documented by Tønsberg that also occur in North America cannot yet be given. An indication of the large overlap can be appreciated from the fact that Tønsberg himself, on several trips to North America, has already found many of his Norwegian "endemics" on this continent, and he and others will undoubtedly find many more.

In the opening sections of the book, the author describes his methods of collecting and preserving the lichens, often sharing his interesting innovations (e.g., he presses the crusts found on thin bark to prevent them from curling into unmanageable tubes!). His section on chemistry is lengthy and detailed, reflecting his reliance on chemical characters for distinguishing the species. (Fortunately, only six or seven taxa out of 148 were found to be totally deficient in lichen substances, the organic compounds unique to lichens and often used in their taxonomy.) To make things especially clear, Tønsberg presents schematic drawings of actual TLC plates showing groups of related compounds run side by side. I have found the drawings to be accurate in the cases I had time to test. Equally detailed and very useful are his descriptions of soralia and soredia (vegetative propagules of lichens) explaining the development of each type and the different pigmentation patterns, and suggesting ways of classifying them. On the other hand, he entirely excludes any discussion of ascocarps, not surprising considering that his keys are based entirely on thalline characters.

I was pleased to see so much new information presented on the substrate ecology of the lichens, even discussing "substrate switches" in which a lichen that is normally associated with one tree or other substrate will switch over to another. The section on phytogeography within Norway will also be of interest to Canadian naturalists since the rainforest flora of the southern, and especially central Norwegian coast is very much like the oceanic east and west coasts of Canada, and many disjunctions occur. The various reproductive "strategies" (a term I don't like because of its anthropomorphism) receive an interesting treatment, and this leads into the taxonomic sections, which form the bulk of the book.

The key to species works well if the user is prepared to do some serious chemical determinations using TLC. It is not intended for the novice with only a few bottles of spot test reagents (K0H, hypochlorite, and para-phenylenediamine). Anyone ready to tackle sterile crustose lichens is generally aware of the need for reliable information on the chemistry of the unknown specimen, so this should not come as a surprise. Still, I would have liked to have seen a few more spot tests included, just to speed things along. The author also takes for granted that users will know that if "xanthones present" is given as one choice and "gyrophoric acid present" is given in the second, that he does not have to state the alternatives ("xanthones absent" and "gyrophoric absent"). This saves space, but can leave a question in the user's mind. The full chemical information is, however, given in the species descriptions, which are thorough and clear.

The discussions following most of the species entries demonstrate the large amount of work that went into each determination. The notes under *Ochrolechia androgyna*, for example, represent a mini-revision of the group, although Tønsberg stops short of giving the populations he circumscribes new names. Under his discussion *Loxospora elatinum*, Tønsberg places the American endemic *L. pustulatum* (Brodo & Culb.) R. C. Harris into synonymy. His arguments are well formulated and documented, but do not yet convince me, based on my experience with both taxa in the field.

The amount of new information in this extraordinary book is too voluminous to summarize here. Suffice it to say that Tønsberg has made it impossible to ever overlook sterile corticolous lichens again. This is a book that every serious student of lichens, whether amateur or professional, Canadian or Scandinavian, must have.

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Seaweed Flora of the Maritimes: 1. Rhodophyta — the Red Algae

By C. J. Bird and J. L. McLachlan. 1992. Biopress, "The Orchard", Clanage Road, Bristol, BS3 2JX, England. 177 pp. + 65 plates. $99.

This flora provides detailed accounts of the common species of red algae in the Maritime Provinces. As such, it is applicable to the adjacent waters of New England, north of Cape Cod, and Newfoundland. The volume is not comprehensive and treats only 73 of the ca. 130 species listed for the region. Many of the omitted species are of questionable status in the region and/or rare; thus their omission will not detract from the usefulness of the work except for the taxonomic specialist.

This is a beautiful book that is a pleasure to handle. The format is particularly clear with species accounts and figures on opposing pages. The photographs are of the highest quality, in many species comprising full page plates of habit and microscopic details. Although many figures have been taken from previously published works (all from publications dealing with algae in the region), there are numerous new photographs, and these comprise a major scientific contribution. The dichotomous key to genera is functional, and although the key requires microscopic study for most taxa, this barrier for the non-specialist is partly overcome with an extensive glossary. It is difficult to escape the fact that identification of many of these organisms requires evaluation of microscopic features of anatomy and reproduction. Descriptions are quite detailed and provide excellent summaries of each species with sections on morphology, ecology, distribution, taxonomy, and life histories. There are also discussions of how to distinguish each species from externally similar (though not necessarily related) species with which they might be confused. It may be frustrating for the specialist that none of this is referenced to the primary literature, however, the absence of citations may make the text more readable for students and naturalists.

This volume is simply too expensive to be considered a popular work that could function as a field guide or as a text for marine phycology students. On the other hand, as a teaching aid it is excellent; this is the first place I will turn to give students an understanding of most of the species covered. The volume should be in any general library dealing with marine biology or phycology. Completion of the companion volumes for the brown and green algae would be a major contribution to the natural history and biology of seaweeds in northeastern North America, and go a long way to promoting interest in seaweeds at all levels.

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ENVIRONMENT

Battle Against Extinction: Native Fish Management in the American West

Edited by W. L. Minckley and James E. Deacon. 1991. The University of Arizona Press, Tucson. xviii + 518 pp., illus. U.S. $40.

Out of sight, out of mind. What else can explain the relative indifference of an otherwise enlightened public towards the demise of native fishes everywhere? While appeals to save terrestrial habitats continue to draw popular attention and funding, entire aquatic ecosystems are collapsing without much of a splash. This is why *Battle Against Extinction* is timely and important.

Before diving into the book, it is necessary to ponder the apparent paradox of the subjects. This book is about desert fishes! More specifically, it concerns fishes native to the four great North American deserts found west of the Rockies. Not exactly the kind of habitat where one would expect fish to thrive, but that's the point. These areas support a great number of endemic species and subspecies. Unfortunately, the same characteristics that led to rapid speciation — genetic isolation, small population size, extreme selection pressures — also render these fish vulnerable to extinction. The writing is on the wall for nearly three-quarters of these unique forms, owing to pollution, competition with humans for limited water resources, and the introduction of non-native species for anglers.

In this edited volume, Minckley and Deacon's aims are threefold. First, they summarize the biology of native fishes, highlighting gaps in our knowledge. Second, they review past and present management programs and show the importance of preserving ecosystems as a whole. Finally, they hope that contributions to this volume will bolster the battle against extinction, which has been faltering for the past two decades. On the first two counts, I think Minckley and Deacon have succeeded admirably. Only time will tell whether they will succeed in the third.

The book's 20 chapters are divided into seven sections, each of which stands as a self-contained whole. The topics range widely, from a historical account of the discovery of desert fishes to a description of their spiral towards extinction. Management techniques considered include stream reclamation, transplantations, and reintroductions. These methods are tailored for preserving long- or short-lived species. The last chapter, by the editors, identifies the factors responsible for the failure to protect desert fishes over the last 25 years. They point out that in spite of all that has been learned, at least eight fish taxa have gone extinct since 1967, and many others have declined.

This book is highly readable and interesting throughout, whether dealing with conceptually difficult issues, such as the ethics of conservation, or potentially very dull ones, such as legislation. The book is full of data and references concerning the natural history of many of the species, especially suckers, squawfish, pupfish, goodeids, killifish, and live-bearers. I was particularly fascinated by the historical accounts. The chapter on the infamous Green River poisoning, where native species were intentionally wiped out and replaced by non-native game fish, presents a harrowing story of "management" at its worst. Such lows in the history of native fish conservation are fortunately offset by some highs, such as the conservation victory at Ash Meadows, which preserved the Devils Hole Pupfish. Both accounts make gripping reading and show the potential power of science and politics in determining the fate of the environment.

The only improvement I can think of would have been the addition of a table or appendix listing all the species found in the region, whether they are native or introduced, and their present status. Such a table is provided only for cyprinodontoid fishes, of which 76 species and subspecies are listed. There are summary statistics, but these are buried in the introductory chapters, which makes it difficult to assess quickly the extent of the problem.

Overall, *Battle Against Extinction* is an excellent book. The editors have drawn together an impressive array of experts to chronicle the problems of a major segment of our North American fauna. Out of sight, out of mind? Not anymore. This fine book deserves a wide audience.

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Messages from Earth: Nature and the Human Prospect in Alaska

By Robert B. Weeden. 1992. The University of Alaska Press, Fairbanks. xiv + 185 pp., illus. U.S. $16.95.

I was intrigued by the title of the book, and the credits on the back cover seemed to indicate a spirituality of relating to the earth and plotting a gentle course for our association with the planet. The focus of the work is Alaska and in the global factors influencing the geographical regions of Alaska. The text did eventually get to the whole idea of how we examine the global structures influencing a region like Alaska, and the final part of the book which contained the last chapter and the epilogue were really directed toward how one lives within the means of the land's capability of production and regeneration. I found the text before that chapter to be rather like a course on the biology and development history of Alaska. Though probably necessary for the argument which was to come, the chapters read like a series of lectures imparting information and background on the state of Alaska.

Weeden has a definite interest in the adaptation of the development to suit the land and the fragility of the biosystem is a consideration in everything that he writes. His writing style is more of the lecture to impart information than of one who will invoke the spirituality of the reader into his arguments. In some places in the book, Weeden gives a vignette of a specific place and situation and how that place is affected by direct intervention by human beings. These vignettes are the most memorable parts of the book and serve to show why the book was written in the first place.

To an ecologist, the strategies of problem solving which Weeden illustrates give some idea of hope as well as illustrating the progress which has been made over the past few decades. For instance the agreement on conservation of goose flocks between the Yupik people on the Yukon-Kuskokwim River Delta and the residents of Southern California is a message of hope though necessitated by a crisis situation. Weeden's review of recent policy decisions in Canada and Alaska shows that there are carefully considered policies being generated at present. The entire chapter *An Ethic for Development* is a message of hope for those who mistrust developers, government decision-making bodies, or even their neighbours' ability to keep their back yards clean. There are people around who have as much interest in the environment as ourselves: work is necessary, trust is implicit. Weeden seems to say that the grace is that we have to recognize our inability to know it all while at the same time trusting the unseen care around us. Weeden did not use the word trust and what he describes is not a blind trust but a policy of minimal disturbance of the area under investigation for development, mineral extraction, or harvest of other resources.

I liked the book better the further I read. I recommend it to people who are looking for strategies of integrated development, since it points out so many misconceptions which have been operative and compares these with older and newer decisions which realize production from the land within the limitations of the land. I think that Weeden's philosophy of living within limitations has a good and necessary message for developers, agriculturalists, and nature enthusiasts for any area and not just Alaska.

If you have the idea of running out to buy the book, plan your strategy carefully. Cole's Books do not have a price, nor were they able to order it for me. They suggested that I write to the publisher or phone them at the University of Alaska (907) 474-6389 to place an order. Neither the University of Toronto Bookstore nor WH Smith Books had the book available to order either.

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Looking Ahead: A Wildlife Strategy for Ontario

By The Ontario Wildlife Working Group. 1991. Wildlife Policy Branch, Ontario Ministry of Natural Resources, Toronto. 172 pages. Free.

This document was prepared by the working group of Ministry of Natural Resources professionals as well as wildlife biologists and other academics who are engaged in wildlife and ecosystem research. In their preparation they listened to different presentations across the Province to get as wide representation of the interests of the public as possible. The document which resulted consists of four objectives, eight guiding concepts on the nature of wild life existing in the province as well as sixty-two strategies of proposed action which might be taken. Preamble and comments on each strategy formed the bulk of the text. The document was distributed to wildlife professionals, community organizations, naturalists, and members of naturalist clubs. A few thousand copies of the document were prepared and only a few hundred remain in the office, I was told by a worker there.

The goal of the project and the objectives were generally to protect the wildlife from hazards of changing conditions and threats from human influence. I was able to agree with the guiding concepts which look at wildlife from the ecosystem approach and the nature of human contact with wildlife. The ecosystem concepts explained how the whole question of wildlife is one which is dynamic and dependant upon many factors which keep changing. These changes may be influenced by human factors but are not exclusively human disturbances. The human principles relate to direct intervention changing the environment and limiting wildlife in captivity situations. The guiding principles were the basis of creating the strategies to follow.

A note in the Forward section of the book lamented the underfunding and understaffing of the agencies who were entrusted with the tasks of conservation and wildlife management. Many of the comments and strategies reflect on this comment and perhaps it should have been stated as one of the guiding principles. Within the sixty-two strategies enumerated, twenty-three different strategies involved research on different aspects of wildlife management, with two other strategies involving professional researchers sitting on review boards. It is natural, however, for a group of reviewers to find that they have only scratched the surface of ongoing problems and to recommend that further work by themselves or a group of like-minded individuals would be beneficial.

Other strategies involved legislation, and indeed the group wanted to emphasize that the existing legislation needed to be cleaned up a lot. There are six different Ontario government ministries as well as the Canadian government all making policies and legislation affecting wildlife in the province. The existing acts have many conflicting parts as well as redundant interests. Thirty-four strategies in the document involve new legislation which should be necessary for an ongoing management project.

I am glad that the Ontario Ministry of Natural Resources is trying to get a comprehensive program dealing with wildlife in the Province. I do not agree that every strategy in the document should have the same weight, and I think that a few of them should be dropped for lack of good logic. I applaud the effort though, and I am in favour of the goals of the project. If you are interested in Ontario wildlife, I suggest that you look at this document and get an idea of the issues involved.

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Australian Ecosystems: 200 Years of Utilization, Degradation and Reconstruction

Proceedings of a Symposium held in Geraldton, Western Australia 28 August – 2 September, 1988. Edited by D. A. Saunders, A. J. M. Hopkins, and R. A. How. 1990. Surrey Beatty, Chipping Norton, NSW, Australia. 602 pp., illus. A$130.

Forest Management in Australia

Edited by F. H. McKinnell, E. R. Hopkins, and J. E. D. Fox. 1991. Surrey Beatty, Chipping Norton, NSW, Australia. 380 pp., illus. A $72 + postage.

When many in Canada think of Australia, they think of the outback, the Sydney Opera House, tropical rainforests, beaches, koalas, kangaroos, and strange egg laying animals. To many this is an idyllic land meant for vacations, perhaps even a largely undeveloped land with few worries. The reality is that Australia is an industrialized country which must deal with many of the same environmental problems found in Canada. Natural resources are a prime focus for the economy of the land down under. Logging, mining, livestock, and tourism are major industries in Australia; its unique flora and fauna are vulnerable to the impacts of these industries and modern society, just as ecosystems in Canada are.

The two books under consideration are both collections of papers from symposia held in the late 1980's. Each provides insight into the use of Australia's natural resources. *Australian Ecosystems* contains 52 papers, *Forest Management* 25. Management is a word used by many for the extraction and "development" of natural resources for human consumption. In the latter volume this is clear as forests are essentially considered in terms of fibre with conservation and recreational issues secondary. *Australian Ecosystems* looks at not only the use (i.e. management) of many ecosystems but considers the impact of use, the "costs" of use (which economists and business executives have traditional deemed "nonquantifiable"), and rehabilitation efforts.

Forest Management is specific in its focus and most papers will have little equivalency in North America due to the very different forests and the emphasis on specific management rather than general principles. Consideration of the process needed to meet various needs (i.e., resource extraction, conservation, and recreation) and theoretical principles involved, receive little discussion. The specifics of managing forests comprised of species such as eucalypts, radiata pine, and others is the main theme. Far more useful volumes on general management principles in various countries are available for the truly interested land manager, ecologist, or naturalist.

Australian Ecosystems is a far more interesting volume. The wide range of topics, theoretical discussions and Australia-specific examples are informative and provide many examples of problems with parallels in North America. General considerations are discussed as are specific topics. Large sections are devoted to the management of aquatic ecosystems, vegetation, arid zones, and fauna as well as planning, land use, and management. Specific topics such as use of coral reefs, the state of the numbat (*Myrmecobius fasciatus*), bauxite mine rehabilitation, and the impact of agriculture and pastoral industries on birds add to general discussions. Papers discussing topics such as interactions of native and introduced species, effects of grazing, state forests and their role in conservation, and conservation of gene pools are in some cases general and contain theoretical information. Though this volume is informative it offers only limited information directly useful to the Canadian reader. The Australian-specific examples are interesting in their own right, though, and some basic concepts may be applicable to other situations. The primary reason to read this volume is to see how another country with a different set of ecosystems has damaged them and the considerations for saving and restoring them. The fact that man has so highly altered much of a country in 200 years is startling and provides much food for thought.

I recommend neither book to the general reader of *The Canadian Field-Naturalist*. The tourist or visiting naturalist will gain little as this is not a field guide. Ecologists and land managers with no ties to Australia will find little professional benefit in the pages. Those that may gain useful knowledge are individuals that wish to obtain a worldwide prospective on ecosystem use, abuse, and restoration and how another country "manages" its forests.

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A Naturalist in New Guinea

By Bruce M. Beehler. University of Texas Press. 251 pp., illus. U.S. $26.95.

Drawing on travels to New Guinea that span over a decade, Bruce Beehler has written a book that beautifully combines scientific study, travel writing, and story-telling into one enjoyable presentation. By relating his experiences of exploration and research in the mountainous regions, jungle habitats, and on outlying islands, readers are introduced to the natural history of the area with an emphasis on the diverse bird life.

The author's writing style and detailed coverage demonstrate an unquenchable enthusiasm and an enviable love of his work. He possesses a highly educated use of the English language and clearly describes the purpose and implementation of all activities that he carried out. Much of the material documents long hours spent observing bird behaviour, netting, banding, and on occasion collecting specimens for the Smithsonian Institute. There is not only provided a broad scope of coverage, but also insight into the organization and methodology of fieldwork that is not often covered in other books of this genre.

During the periods 1978 to 1980 Beehler returned to New Guinea to begin his doctoral field research on the birds of paradise "focusing on the evolution of reproductive behaviour and its relationship to ecology". He chose to centre on four species namely the Trumpet Manucode, Buff-tailed Sicklebill, Magnificent Bird of Paradise, and the Raggiana Bird of Paradise. The author also studied five species of honeyeaters, the largest bird family on the island, focusing on the question "how do foragers of different species manage amicably to share a single food resource". The above are just two examples of the types of study Beehler carried out.

A Naturalist in New Guinea provides a satisfying journey of a western scientist to the South Pacific. Included throughout are detailed pen-and-ink drawings as well as a collection of colour photographs. The extensive documentation of fieldwork is fascinating, the personal anecdotes entertaining, and the work as a whole makes an absorbing reading.

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Quaternary Ecology: A Paleoecological Perspective

By Hazel R. Delcourt and Paul A. Delcourt. 1991. Chapman & Hall, London. x + 242 pp., illus. U.S. $19.95.

Hazel and Paul Delcourt's purpose in writing this book is to "bridge the communication gap between Quaternary ecologists and other ecologists" by "examining important issues and controversies in ecology that can be approached fruitfully using paleoecological methods." They accomplish this by examining major themes in ecology, such as dispersal, population dynamics, plant succession, response to disturbance, community composition and structure, and the spatial pattern of vegetation. In five thematic chapters, they demonstrate how palaeoecology can contribute to an understanding of modern plant ecology. In the first chapter, they examine links between ecology and palaeoecology and examine the validity of the "space for time" substitution in ecology. Throughout the text, scale, both temporal and spatial, and data resolution are important concerns. The final chapter deals with a topical issue — the potential contribution of palaeoecology to assessment of vegetation response given various scenarios of climate warming with global change, using the mid-Holocene Hypsithermal Interval as a partial analogue.

The text highlights plant ecology and more particularly inferences based on pollen analysis. Contributions from the investigation of other biotic components, for example, diatoms and palaeolimnology and vertebrate faunas are also mentioned. The authors focus on North America and specifically on eastern (temperate) United States and the Great Lakes region, with occasional excursions to other areas, such as western Europe, Australia, or Switzerland. This territorial bias reflects the research areas studied by some pre-eminent theoreticians in the discipline, such as Margaret B. Davis and T. Webb III and their colleagues. Topics are discussed by case studies and detailed examples from the palaeoecological literature. Each chapter concludes with a list of four to six short points summarizing the major ideas. The authors feature their own work; for example, I counted 68 references, mainly in the first few chapters, to Delcourt and Delcourt (1987a, *Long-term Forest Dynamics of the Temperate Zone*). This concentration is understandable but these abundant references give the impression that portions of this book are reworked from their other texts.

Much of the research discussed dates from the 1980s, with the most recent citations from 1991. The reference list is extensive. The survey demonstrates that palaeoecology has changed from being mostly descriptive to heavily analytical, relying extensively on numerical methods. Pollen analysis generates vast quantities of numerical data. Among the techniques used to analyze it today are multivariate statistical methods, such as principal components analysis or PCA, time series analysis, and Detrended Correspondence Analysis or DCA. Modelling, such as forest succession simulations, using palaeoecological data for verification, is another growing area of research.

The production of the book is generally good. The text is comparatively clean with few errors (Kurtén is rendered Kurten, for example). The examples are illustrated with plentiful maps and diagrams. Many diagrams are derived from other sources; in a few cases (e.g., Figures 2.5 and 2.6, Figure 7.7) the reproduction is not good.

This book presupposes considerable background knowledge of Quaternary environmental change and palaeoecology and as such has more value as a course text than for general reading. The detailed case studies provide a useful summary of a large amount of information in a convenient format. In my view, this volume is most useful as a sourcebook, a starting point to guide a thematic exploration of a large and growing field. As such, it forms a useful addition to the palaeoecological literature. Its comparatively low price, at least for the paperback version, means that it should be in reach of a wide readership.

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The Animal Rights/Environmental Ethics Debate

Edited by Eugene C. Hargrove. 1992. State University of New York, Albany. xxviii + 273 pp. Cloth U.S. $44.50; paper U.S. $14.95.

Animal rights and environmental ethics are each major areas of contact between the domains of biology and ethics, and prominent on the contemporary intellectual landscape. The differences in orientation of these two areas are significant and worthy of careful consideration because of the issues that they raise. The present volume deliberately sequences 11 key papers appearing over the past 13 years in the exploration and resolution of these differences. In an informative preface Hargrove provides the historical approach to the material. Under a framework of reciprocal rights and duties, Richard Watson argues for self-consciousness (curiously of unclear phyletic distribution and conceived as not admitting of degrees), rather than sentience, as a basis for nonhuman rights. John Fisher emphasizes the importance of sympathy, often rejected by animal liberationists, while recognizing the related issue of anthropomorphism. Both of these chapters share similarities with cognitive ethology *sensu* Donald Griffin (see review of his *Animal Minds* in *The Canadian Field-Naturalist* 107 (2): 258–259) including persistent epistemological problems. In a high moral tone demanding human humility Paul Taylor advocates a life- rather than human-centered basis for environmental ethics involving dispositional respect for good and worth. With large saltations amid the history of ideas Hargrove traces the development of attitudes toward the protection of wildlife in the United States based on aesthetic motives.

Basing human ethics on rights is notoriously difficult, and Bryan Norton cogently argues that advocating individualistic animal rights only worsens the conflicting contentions in community-oriented environmental ethics. By contrast, Mary Warren carefully builds a case for limited animal rights by comparison with humans and uses it to address various disagreements between animal liberationists and land ethicists such as the moral status of predators. Two contributions by Mary Midgley critically interpret empirical observation on speciesism versus racism, and the importance of bonds between humans and other species. Among three key papers by Baird Callicott, one is a titillating excursion into the moral considerability of extra-terrestrials *vis à vis* principles such as a land ethic or Schweitzerian reverence for life. A second, and very influential one, contrasts human ethics, animal liberation, and land ethics on such issues as domestic species (the object of concern by animal liberationists and of dispute by land ethicists). In the third Callicott builds on the discussions of Warren and Midgley to outline a unifying biosocial moral theory.

The intellectual lineage including Descartes, Hume, Bentham, Darwin, Leopold (famous for his land ethic, biography by C. Meine reviewed in the *Canadian Field-Naturalist* 103: 467), Singer, and Regan provides a powerful background to the material, and as in any work on ethics, longstanding fundamental problems such as free will, other minds, the naturalistic fallacy, and the existence of value beyond the eye of the beholder must each at least be acknowledged. The presentation of conflicting views on such central issues as criteria for membership in a moral community, over the course of the articles usefully demands critical reflection by the reader. The differing levels regarded by animal liberationists (individuals) and land ethicists (ecological communities) parallel those examined by evolutionary biologists as levels of selection. The rate of typographical errors seems above average. Especially with royalties committed to an Environmental Ethics Endowment Fund, this book is a worthwhile investment.

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Biological Control by Natural Enemies

By Paul Debach and David Rosen. 1991. Second edition. Cambridge University Press, Cambridge. 440 pp., illus. Cloth U.S.$44.50; paper U.S.$17.95.

This is the second and updated edition of a successful text released in 1974. A number of important references have been added with a larger section on Integrated Pest Management programs. Even though the text has been updated the main purpose as stated in the first edition still applies: "to outline workings and potentialities of biological control of pests for the general reader and student interested in environmental phenomena." The book continues to advocate "the first step of pest control should be aimed at classical biological control..."

This edition continues to rely heavily on case studies. For a good number of these case studies the authors provide an economic impact value, a much required value in these economically depressed times. The book deals mainly with biological control of arthropod pests and unfortunately few examples are provided of weed control efforts.

Biological control by natural enemies is well written with examples taken from the global community. Debach and Rosen do outline workings and potentialities of biological control of pests. They also strongly advocate classical biological control over pesticide use. I believe this text will find a useful place on many shelves of future students of environmental phenomena.

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MISCELLANEOUS

William Diller Matthew: The Splendid Drama Observed

By Edwin H. Colbert. 1992. Columbia University Press, New York. xii + 275 pp.

William Diller Matthew (1871-1930), vertebrate paleontologist, was born and raised in Canada. His research, based mostly at the American Museum of Natural History, New York, had a global impact, and his work on Cenozoic mammals is still extensively cited, several decades after his death. Edwin Colbert's biographical sketch is illustrative, not just of Matthew's life but of his time as well.

The first third of the book is an account of Matthew's upbringing in the late 1800s in New Brunswick. This period was at times harsh. His early association with fossils and geology was fuelled by his father's interest in the subject (*see* Miller and Buhay. 1990. *Life and letters of George Frederic Matthew: geologist and palaeontologist*. The New Brunswick Museum, Publications in Natural Science number 8). A common theme throughout Matthew's life and throughout the text is his feelings of duty and his relations with his family. His higher schooling in New York was possible only with the help of relatives who gave him room and board. It is probably in appreciation for his family's support and sacrifices that Matthew continued this tradition throughout his life. It is also here that we get a vivid picture of life at the turn of the century, when a penny saved meant a lot.

The bulk of the remainder of the book (the last section being a bibliography of Matthew) concerns his affiliation with active research at the American Museum of Natural History and, to a lesser extent, at the University of California at Berkeley, in his final years. His achievements were huge, and his bibliography is more than 20 pages long, including many monographs. His work was methodical and expansive. One of his early introductions to full time work was to sort out the mess left by E. D. Cope, an earlier, prolific paleontologist, whose collection the American Museum of Natural History obtained after he passed away. It was Matthew's task to catalogue and pack the material within Cope's two houses. This no doubt strengthened Matthew's resolve on the importance of accurate record keeping.

Colbert vividly describes the early days of paleontological research as well as science in general. In the field, horses, guns, biscuits and bacon, and a gallon of water a week for personal hygiene, were the norm. The introduction of the automobile in the field was a sign of at least some things changing. His early field work pertained to areas of Kansas, collecting large, extinct, marine reptiles called mosasaurs. Later, Nebraska was his summer home, collecting middle and late Cenozoic mammals (the rich quarries he worked in are now a national park).

In research, before air transport, going abroad was a big deal. Matthew was deeply interested in Cenozoic mammalian faunas in Mongolia and India, and visited these places (or at least tried in the case of Mongolia — due to warring factions in China the 1926 Central Asiatic Expedition was cancelled) and the museums in other parts of the world, observing collections and meeting the men who curated them. The museum touring would often take many months, a practise that is seldom sanctioned today.

Colbert's book is a worthwhile read for anyone interested in the atmosphere of science at the turn of the century, and for paleontologists specifically. He treats Matthew with deserved respect, while Matthew's boss, the often pontifical Henry F. Osborn, overseer of paleontology at the American Museum of Natural History, is treated relatively lightly. This probably reflects the personal character of Colbert who at an early stage in his scientific career worked for Osborn. However, he could not escape illustrating the point that one of the reasons Matthew left New York for California was because of the difficulty, at least in paleontological philosophy if not on a personal level, with Osborn. The text includes many letters, primarily between Matthew and his wife Kate, who were devoted to each other.

The reader may find the details of the begets in the early section of the book rather trying. Colbert gives a genealogical chart which is mandatory reading as the Matthew clan, for several generations, had a habit of naming one of their sons George. There are a few typographical errors; Colbert places the Niobrara Chalk of Kansas at 125 million years old, whereas it is more closer to 85 million years, but this is minor.

One aspect I was very impressed with was that Colbert recognized and maintained throughout the book that Matthew, though living his scientific career in America, was a proud Canadian, never giving up his citizenship.

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Evolution and the Myth of Creationism

By T. M. Berra. 1990. Stanford University Press, Stanford, California. xi + 198 pp.

"Copernicus had driven us out of our home; Darwin drove us out of our bodies; and it only remained for Freud to drive us out of minds!". Thus was the religious interpretation on some of the major revolutions in science as summed up by Michael Ruse's look at "Darwin and philosophy today" (in D. Oldroyd and I. Langham (editors), *The Wider Domain of Evolutionary Thought*, 1983). All three men in the above quotation based their theories on observations and hard facts, yet to some their ideas still present a real threat to their foundational beliefs. None more so affected and more vocal than the individuals who not only believe in the literal interpretation of the biblical creation, but claim that science proves it. These are the "creation scientist" (by most standards this is a oxymoron). But why should we pay any attention to them?

A year or so ago I wrote a book review on one of the scientific creationists books and submitted it to a local periodical. It was never published. The editor thought that giving attention to their beliefs would only increase their following. However, regardless of the intended review (and the book was reviewed by other scientists who politely and not so politely slammed the book) people are still buying the book and are swallowing hook, line, and sinker the trash that particular author wrote. Later, I ran into a "creation scientists" while collecting a fossil crocodile in east central Saskatchewan and was amazed at the lack of truth there was to his sermon. This was an awaking for myself and under different circumstances.

Tim Berra had an awakening too. He reviewed a *Biology Curriculum Guide* where about 50% of the contents were creationist beliefs, supported by "scientific reference" from the *National Enquirer*, no less. Instead of writing book reviews, Berra wrote a book, *Evolution and the Myth of Creationism*. The book covers many topics; embryology, fossils (including humans), missing links, radiometric dating, and science education all supported by *real* references and a glossary. Yet for the most part this book is a biology lesson, where pages are spent describing one feature of evolution or another. Though concise and easily readable, there are many other textbooks or popular books better suited for such a task. However, he qualifies his descriptions with epilogue statements directed to the creationist claims and to highlight the significance of this they are often italicised. The reader must keep in mind the intended audience which Berra puts in the form of a question: "what should an educated person know about the theory of evolution?"

Scientists in the true nature of their discipline have to educate whether in a technical or lay vernacular, ideally both. Often, our ivory tower shades us from pressure "creation scientists" put on the schools at the local level or through the legal system and the potential danger this presents — a backwards step (nay, leap), to blind faith, and the smothering of intellectual curiosity. But as often the case, scientists are often noted to say something to the effect that "what reasonable person would believe such unscientific crap that creation scientists preach." Obviously, some people believe. Berra accomplishes his primary task of education — evolution is a fact, the tempo and mode are theoretical and are supported by hard evidence. As for the scientists who live in their ivory towers, Berra has this to say: "for too long, [scientists] treaded too lightly on the creationists, and have thereby fostered the impression that the creationists are a legitimate scientific voice. It is time for candor and clarity".

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NEW TITLES

Zoology

***The amphibians and reptiles of Alberta: a guide and primer of boreal herpetology.** 1993. By Anthony P. Russell. University of Calgary Press, Edmonton, Alberta. $29.95 cloth, 264 pp., illus.

***The amphibians and reptiles of Maine.** 1992. Edited by M.L. Hunter, J. Albright, and J. Arbuckle. Agricultural Experimental Station Bulletin 838. Maine Department of Inland Fisheries and Wildlife, Augusta. 188 pp., illus. U.S.$ 9.95.

***Arena birds: sexual selection and behavior.** 1994. By Paul A. Johnsgard. Smithsonian Institute Press, Washington. 384 pp., illus, U.S.$ 39.95.

Barn owls: predator-prey relationships and conservation. 1994. By Iain Taylor. Cambridge University Press, New York. c310 pp., illus. cU.S.$ 42.95.

†**Bats of British Columbia. 1993.** By David W. Nagorsen and R. Mark Brigham. University of British Columbia Press, Vancouver. 164 pp., illus. $ 15.95.

†**The bee genera of North and Central America (Hymenoptera: Apoidea).** 1994. By Charles D. Michener, Ronald J. McGinley, and Bryan N. Danforth. Smithsonian Institute Press, Washington. 304 pp., illus. U.S.$ 45.

†**The bowhead whale.** 1993. Edited by John J. Burns, J.Jerome Montague, and Cleveland J. Cowels. Special Edition Publication No. 2. Society for Marine Mammalogy, Box 368, Lawrence, Kansas 66044. xxxvi + 787 pp., illus. U.S.$ 75.

The encyclopedia of land invertebrate behavior. 1993. By Rod and Ken Preston-Mafham. MIT Press, Cambridge, Massachusetts. 320 pp., illus. U.S.$ 45.

†**A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland.** 1993. 4th revised edition. By Steven K. Katona, Valerie Rough, and David T. Richardson. Smithsonian Institute Press, Washington. xix + 316 pp., illus. U.S.$ 15.95.

***Fish: an enthusiast's guide.** 1993. By Peter B. Moyle. University of California Press, Berkeley. xii + 272 pp., illus.

***Freshwater marshes: ecology and wildlife management.** 1994. By Milton W. Weller. 3rd edition. University of Minnesota Press, Minneapolis. 192 pp. Cloth U.S.$ 34.95; paper U.S.$ 16.95.

***A history and atlas of the fishes of the Atlantic Ocean.** 1993. By Richard Gordon Miller. Fresta Institute for Ocean and Mountain Studies, Carson City, Nevada. xx + 792 pp., illus.

The hot-blooded insects: strategies and mechanisms of thermoregulation. 1993. By Bernd Heinrich. Harvard University Press, Cambridge, Massachusetts. 601 pp., illus. U.S.$ 75.

Identification guide to the ant genera of the world. 1993. By Barry Bolton. Harvard University Press, Cambridge, Massachusetts. 224 pp., illus. U.S.$ 65.

†**Is it for food? Addressing marine mammal and seabird declines.** 1993. By Alaska Sea Grant College Program, Fairbanks. 65 pp., illus. U.S. $7.

†**Kangaroos: the marvellous mob.** 1993. By Terry Domico and Mark Newman. Facts on File, New York. xix + 202 pp., illus. U.S.$ 39.95; $ 49.95 in Canada.

***The lives of birds: birds of the world and their behavior.** 1993. By Lester L. Short. Henry Holt, New York. xiv + 256 pp., illus. + plates.

***Measuring and monitoring biological diversity: standard methods for amphibians.** 1994. Edited by W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.-A.C. Hayek, and M.S. Foster. Smithsonian Institute Press, Washington. xix + 364 pp., illus. Cloth U.S.$ 49; paper U.S.$ 17.95.

One man's owl. 1994. By Bernd Heinrich. Abridged edition. Princeton University Press, Princeton. 186 pp., illus. U.S.$ 12.95.

†**Quaternary insects and their environments.** 1994. By Scott A. Elias. Smithsonian University Press, Washington. 156 pp., illus. U.S.$ 40.

***In search of arctic birds.** 1992. By Richard Vaughan. T. & A.D. Poyser, London, England. xiv + 431 pp., illus. U.S.$ 39.95.

***Urban wildlife habitats: a landscape perspective.** 1994. By Lowell W. Adams. University of Minnesota Press, Minneapolis. 160 pp., illus. Cloth U.S.$ 34.95; paper U.S.$ 16.95.

Vertebrate zoology: an experimental field approach. 1994. By Nelson G. Hairston, Sr. Cambridge University Press, New York. c280 pp., illus. U.S.$ 44.95.

***White ibis: wetland wanderer.** 1993. By Keith L. Bildstein. Smithsonian Institute Press, Washington. xiii + 242 pp., illus. U.S.$ 26.95.

†**Wildcats of the world.** 1993. By David Alderton. Facts on File, New York. 192 pp., illus. U.S.$ 25.95; $ 32.95 in Canada.

*__A wing in the door: adventures with a red-tailed hawk.__ 1993. By Peri Phillips McQuay. Hounslow Press, Willowdale, Ontario. 205 pp., illus. $ 17.99.

Botany

*__Alaska's wild plants: a guide to Alaska's edible harvest.__ 1993. By Janice J. Schofield. Alaska Northwest (Graphic Arts Center Publishing, Portland, Oregon). 96 pp., illus. U.S.$ 12.95.

Desert and mountain plants of the southwest. 1993. By D.V. Leake, J.B. Leake, and M.L. Roeder. University of Oklahoma Press, Norman. viii + 239 pp., illus. U.S.$ 18.95.

Diversity and evolution of tropical flowers. 1994. By Peter K. Endress. Cambridge University Press, New York. c420 pp., illus. cU.S.$ 84.95.

History of Australian vegetation: Cretaceous to present. 1994. Edited by Robert S. Hill. Cambridge University Press, New York. c360 pp., illus. Cu.S.$ 79.95.

*__The Jepson manual: higher plants of California.__ 1993. Edited by James C. Hickman. University of California Press, Berkeley. xvii + 1400 pp., illus. U.S.$ 65.

The mangoes: their botany, nomenclature, horticulture, and utilization. 1993. By A.J.G.H. Kostermann and J.M. Bompard. Academic Press, San Diego. c352 pp., illus. cU.S.$ 75.

*__Orchids of Indiana.__ 1993. By Michael A. Homoya. Indiana Academy of Science and Indiana University Press, Bloomington and Indianapolis. xix + 276 pp., illus. U.S.$ 34.95.

†**Rare vascular plants in the Canadian Arctic.** 1993. By Cheryl McJannet, George Argus, Sylvia Edlund, and Jacques Cayouette. Syllogeus No. 72. Canadian Museum of Nature, Ottawa. 79 pp., illus.

Seaweed ecology and physiology. 1994. By Christopher S. Lobban and Paul J. Harrison. Cambridge University Press, New York. c416 pp., illus. U.S.$ 69.95.

*__Seaweed flora of the Maritimes: 1. Rhodophyta - the red algae.__ 1992. By C.J. Bird and J.L. McLachlan. Biopress, Bristol, England. 177 pp., illus. $99.

†**La Selva: ecology and natural history of a rain forest.** 1994. Edited by L.A. McDade, K.S. Bawa, H.A. Hespenheide, and G.S. Hartsharm. University of Chicago Press, Chicago. x + 486 pp., illus. Cloth U.S.$ 90; paper U.S.$ 28.95.

Tropical alpine environments: plant form and function. 1994. Edited by P.W. Rundel, A.P. Smith, and E.C. Meinzer. Cambridge University Press, New York. c370 pp., illus. cU.S.$ 84.95.

*__A Utah flora.__ 1994. By S.L. Welsh, N.D. Atwood, L.C. Higgins, and S. Goodrich. Brigham Young University Natural History Publications, Provo, Utah. vii + 986 pp. U.S.$ 65.

*__Vascular plants of Wyoming.__ 1992. By Robert D. Dorn. 2nd edition. Mountain West Publishing, Cheyenne, Wyoming. 340 pp. U.S.$ 13.

Environmental

†**An African savanna: synthesis of the Nylsvley study.** 1993. By R.J. Scholes and B.H. Walker. Cambridge University Press, New York. xii + 306 pp., illus. U.S.$ 69.95.

*__Applied ecology.__ 1993. By Edward L. Newman. Blackwell Scientific Publications, Cambridge, Massachusetts. 328 pp., illus. U.S.$ 31.95.

An approach to improving decision making in wetland restoration and creation. 1993. By M.E. Kentula, R.P. Brooks, S.E. Gwin, C.C. Holland, A.D. Shemran, and J.C. Sifneos. Lewis Publications, Boca Raton, Florida. 192 pp. U.S.$ 39.95 in U.S.A.; U.S.$ 48 elsewhere.

†**Assessing surprises and nonlinearities in greenhouse warming.** 1993. Edited by Joel Darmstadter and Michael A. Toman. Proceedings of a workshop, March, 1992. Resources for the Future, Washington. 158 pp., illus. U.S.$ 25.

*__Biogeography: an ecological and evolutionary approach.__ 1993. By C. Barry Cox and Peter D. Moore. 5th edition. Blackwell Scientific Publications, Cambridge, Massachusetts. x + 326 pp., illus. U.S.$ 34.95.

China's environmental crisis: an inquiry into the limits of national development. 1993. By Vaclav Smil. M.E. Sharp, Armonk, New York. xiii + 257 pp. Cloth U.S.$ 42.50; paper U.S.$ 16.95.

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Science as a way of knowing: the foundations of modern biology. 1993. By John Moore. Harvard University Press, Cambridge Massachusetts. viii + 530 pp., illus. U.S.$ 29.95.

The secret of life: redesigning the living world. 1993. By Joseph Levine and David Suzuki. MGWB Boston, Boston. v + 265 pp. U.S.$ 22.95.

Soil ecology. 1994. By Ken Killham. Cambridge University Press, New York. c250 pp., illus. Cloth cU.S.$ 79.95; paper cU.S.$ 24.95.

Tall grass prairie. 1993. By John Madson. Falcon Press, Helena, Montana. xv + 112 pp., illus. U.S.$ 29.50.

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***Newton rules biology: a physical approach to biological problems.** 1992. By C.J. Pennycuick. Oxford University Press, Don Mills, Ontario. 111 pp., illus. $26.95.

***Restless energy: a bibliography of William Rowan, 1891 - 1957.** 1993. By Marianne Gosztonyi Ainley. Véhicule Press, Montréal. 368 pp., illus. $ 19.95.

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Books for Young Naturalists

Amazing animal babies. 1993. By Laurence Mound. Random House, New York. 32 pp., illus. U.S.$ 10.99.

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Animal science. 1993. By Anita Ganeri. Dillon Press, New York. 46 pp., illus. U.S.$ 13.95.

Arctic summer. 1993. By Downs Matthews. Simon & Schuster, New York. 32 pp., illus. U.S.$ 14.

Compost critters. 1993. By Bianca Lavies. Dutton, New York. 32 pp., illus. U.S.$ 14.99.

Creepy crawlies and the scientific method: over 100 hands-on science experiments for children. 1993. By S.S. Kneidel. Fulcrum, Golden, Colorado. 244 pp., illus. U.S.$ 15.95.

Dogs: the wolf within. 1993. By D.H. Patent. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$ 14.96.

Dragonfly. 1993. By Emery Bernhard. Holiday House, New York. 32 pp., illus. U.S.$ 15.95.

The extinct alphabet book. 1993. By Jerry Pallotta. Charlesbridge, Watertown, Massachusetts. 32 pp., illus. Cloth U.S.$ 14.95; paper U.S.$ 6.95.

The giraffe: a living tower. 1993. By Christine and Michel Denis-Huot. Charlesbridge, Watertown, Massachusetts. 28 pp., illus. U.S.$ 6.95.

If trees could talk. 1993. By Stuart Lallen. Abdo and Daughters, Minneapolis. 32 pp., illus. U.S.$ 14.95.

Janice van Cleave's A+ projects in biology: winning experiments for science fairs and extra credit. 1993. By Janice van Cleave. Wiley, New York. vi + 231 pp., illus. Cloth U.S.$ 22.95; paper U.S.$ 12.95.

Jungles and forests. 1993. By Clint Twist. Gloucester Press, New York. 32 pp., illus. U.S.$ 12.40.

Killer whales. 1993. By D.H. Patent. Holiday House, New York. 32 pp., illus. U.S.$ 15.95.

Lion cubs and their world. 1993. By M. Barbara Brownell. National Geographic Society, Washington. 10 pp., illus. U.S.$ 27.20.

Mammals. 1993. By Jenny Tesar. Blackbirch Press, Woodbridge, Connecticut. 64 pp., illus. U.S.$ 16.95.

Monarchs. 1993. By Kathryn Lasky. Gulliver Green/HBJ, New York. 64 pp., illus. Cloth U.S.$ 16.95; paper U.S.$ 8.95.

Nature's timekeeper - the tree. 1993. By Gaud Morel. Young Discovery Library, Ossining, New York. 37 pp., illus. U.S.$ 4.95.

Night creatures. 1993. By S.S. Whayne, Simon & Schuster, New York. 45 pp., illus. U.S.$ 15.

Once upon a tree: life from treetop to root tips. 1993. By James Nardi. Iowa University Press, Ames. viii + 103 pp., illus. U.S.$ 16.95.

Outside and inside trees. 1993. By Sandra Markle. Bradbury House, New York. 32 pp., illus. U.S.$ 15.95.

Rocks tell stories. 1993. By Sidney Horenstein. Millbrook Press, Brookfield, Connecticut. 72 pp., illus. U.S.$ 14.90.

Quack and honk. 1993. By Allan Fowler. Childrens Press, Chicago. 32 pp., illus. U.S.$ 12.60.

Salamanders. 1993. By Cherie Winner. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$ 14.96.

Seal journey. 1993. By Richard and Jonah Sobol. Cobblehill Books, New York. 32 pp., illus. U.S.$ 14.95.

Sea otter, river otter. 1993. By S.C. Robinson. Roberts Rinehart, Niwot, Colorado. 64 pp., illus. U.S.$ 7.95.

The search for the right whale. 1993. By Scott Kraus and Kenneth Mallory. Crown, New York. 36 pp., illus. U.S.$ 14.99.

Of things natural, wild, and free: a story about Aldo Leopold. 1993. By M. Lorbiecki. Carolrhoda, Minneapolis. 64 pp., illus. U.S.$ 14.95.

Vultures. 1993. By Lynn M. Stone. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$ 19.95.

What you can do for the environment. 1993. By Mike Wald. Chelsea House, New York. 109 pp., illus. U.S.$ 19.95.

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† available for review

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Compiled by Leslie Cody

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Advice to Contributors

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The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

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ISSN 0008-3550