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CONTENTS

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THE BREEDING BIOLOGY OF BROAD-WINGED AND RED-SHOULDERED HAWKS IN WESTERN NEW YORK

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ABSTRACT.—Nesting Red-shouldered (*Buteo lineatus*; RSH) and Broad-winged Hawks (*Buteo platypterus*; BWH) were studied in 1978–1980 in Chautauqua County, New York. Both species nested predominantly in upland maple-beech-hemlock associations. Six of 18 BWH nests were in larch (*Larix decidua*); 7 of 18 RSH nests were in American beech (*Fagus grandifolia*). BWH nested closer to woodland openings and lower in a tree than RSH although neither difference was statistically significant. RSH began nesting about a month before BWH. In general, BWH produced more young and were more successful than RSH. Both species suffered similar types of mortality, and Great Horned Owls (*Bubo virginianus*; GHO) were the largest cause of nest failure for both species. A comparison of our data with other studies indicated that for many criteria, BWH and RSH were less productive in western New York than elsewhere. Reasons for this were not clear for RSH, although nest predation was an important factor. Our more extensive data for BWH explain in part their lower productivity in western New York as a function of habitat, clutch size, age of nesters, predation and reuse of nest. BWH nesting success was greater for new nests than rebuilt ones; greater for adult/adult pairs compared to adult/yearling pairs, greater in deciduous-mixed woodlands compared to conifer plantations, and greater for nests more distant from woodland openings. Three-egg clutches produced more fledglings than 2-egg clutches, but 2-egg clutches produced more fledglings per egg. We interpreted the BWH as an r-selection strategist over its lifetime, compared to many larger buteos, but the species seems capable of optimizing its reproductive effort in New York in any given year by employing brood reduction and possibly clutch adjustment reproductive strategies.

Although the natural history (Burns 1911), nesting ecology (Matray 1974), and nesting habitat (Keran 1976) of the Broad-winged Hawk (*Buteo platypterus*; BWH) have been studied, only a few studies included in-depth quantitative analysis of reproductive success (Rusch and Doerr 1972; Keran 1976; Armstrong and Euler 1982; Janik and Mosher 1982; Rosenfield 1984). There is documentation of the nesting density of the species in Wisconsin, Minnesota and Alberta (Rusch and Doerr 1972; Keran 1978; Rosenfield 1984), but not in the Northeastern United States. BWH populations appear healthy, but many researchers have suggested a general decline in Red-shouldered Hawk (*Buteo lineatus*; RSH) populations (Bent 1937; Brown 1971; Henny et al. 1973; Mason 1980; Bednarz and Dinsmore 1981), and the species appears on several state endangered and threatened species lists (i.e., Illinois, Iowa, Michigan, Minnesota, New York, Wisconsin; Anon.

1984). Bent (1937) and Stewart (1949) suggested that BWH and RSH select different nesting habitats, and Titus and Mosher (1981) and Armstrong and Euler (1982) quantified differential habitat utilization of both species. However, preliminary field work in western New York indicated that these species were locally sympatric and could be studied simultaneously.

Because the BWH's 1–4 eggs hatch asynchronously (Lyons and Mosher 1987), the species appears to be a simple brood reduction strategist (O'Connor 1977). However, Howe (1976) showed that the Common Grackle (*Quiscalus quiscula*) can combine this strategy with a resource storage strategy (see O'Connor 1977) in which eggs are provisioned with extra lipids so that young may survive short periods of food shortage. If a food shortage is lengthy, then brood reduction will occur. We looked for the presence of a second reproductive strategy in

the BWH by assessing clutch size differences between years and marking and measuring eggs and monitoring the hatching sequence within clutches. Egg size/hatching sequence data will be the subject of a future paper.

Specific objectives of our study were: To document ecological nesting densities of both species; to characterize and compare breeding habitats of both; and to compare quantitatively rates of reproductive success during 2 or more breeding seasons, looking especially for nest success in relation to clutch size.

STUDY AREA

Our study area was in central and northern Chautauqua County, New York, a characteristically flat plain along Lake Erie bordered by hilly terrain a few miles from the lake. Chautauqua County is bordered by Pennsylvania to the south, Lake Erie to the northwest, and Cattaraugus County to the east. Historically, land along the lake has been used largely for grape production. Upland areas have been farmed or logged. Some farmland has returned fallow and some was used by the Civilian Conservation Corps in the 1930s for monocultural plantings of Scotch pine (*Pinus sylvestris*), red pine (*P. resinosa*) and tamarac or European larch (*Larix decidua*). Overstory was comprised of approximately 45-yr-old individuals of these species, and the understory was dominated by sugar maple (*Acer saccharum*). Much acreage resembled or was succeeding to a typical maple-beech-hemlock (*Acer-Fagus-Tsuga*) association (Shelford 1963).

Although most of the study area was forested by a maple-beech-hemlock association or a prior sere, some acreage supported oak-hickory (*Quercus-Carya* spp.) or aspen-black cherry (*Populus* spp.-*Prunus serotina*). In a few areas larch was the dominant species with sugar maple (*A. saccharum*) understory. Topography was very hilly with numerous deep ravines. Water in some form (stream, pond, swamp) was present within 0.4 km of all the study sites.

The principal study site was the New York State Canadaway Creek Wildlife Management Area (approximately 875 ha) and adjoining land, a broad, deeply dissected upland plateau predominantly covered with deciduous forest, but also with conifer plantings. The area is managed primarily to ensure quality habitat for wildlife, especially game species, and secondarily is available for recreational use.

METHODS

This study was conducted from 1978 through 1980. Thorough ground censuses for old stick nests were conducted during late winter and early spring before nesting hawks returned. All old nest sites were revisited after hawks returned, and other areas where BWH and RSH were observed were also censused.

Nests being used (active) were revisited approximately once/wk until hatching to document clutch size and egg survival. Use of a pole and mirror device (Parker 1972) minimized nest disturbance. Eggs were measured and weighed approximately 1 wk prior to hatching. Nest height (measured using the pole and mirror device or carefully

estimated from sightings on a person of known height standing at the tree base), distance of nest tree from a roadway or woodland opening (measured by pacing), and the number of limbs supporting a nest were also recorded. Once eggs hatched, nests were visited every 2-4 d and nestlings were marked, weighed, and measured. Culmen, tarsal length, and lengths of the sixth primary (conventional numbering) of the right wing and the right central rectrice were measured. Young were banded with U S Fish and Wildlife Service bands prior to fledgling. In 1979 plumages of breeding Broad-wings were used as a basis for age determination. Naphthalene crystals were placed at the base of active nest trees to deter terrestrial predators. Addled eggs and prey remains were collected at nests whenever possible, and behavior of the nesting hawks was observed. Predation was detected by observing Great Horned Owls (*Bubo virginianus*, GHO) near nests, presence of GHO feathers in nests, or at 1 nest noticing the strong odor of Striped Skunk (*Mephitis mephitis*) in the nest (Striped Skunks are not known to climb trees [R. Cole pers. comm.] and GHO often prey on Striped Skunks).

Nestlings were aged by observing hatching dates. Statistical analyses followed Sokal and Rohlf (1969).

RESULTS

Nesting Habitat. Both BWH and RSH nested in approximately the same type of upland woods, but with specific differences in nest sites. Each species used a variety of tree species, but each showed a preference (Table 1). BWH used larch (*Larix decidua*) most often (33%), whereas RSH apparently preferred American beech (*Fagus grandifolia* 39%). BWH showed a tendency to nest on slopes, but RSH chose relatively level terrain. Both species nested <1 km from streams, ponds, or swamps. BWH seemed to nest closer to woodland openings (road cuts, field, etc.) and lower in trees than RSH, respectively: 90 ± 54 m [N = 17] versus 182 ± 164 m [N = 6]; and, 11.8 ± 3.2 m [N = 18] versus 13.4 ± 2.4 m [N = 11], although neither comparison was statistically significant (distance to woodland opening F = 2.15, P > 0.1, single classification analysis of variance (ANOVA) and nest height F = 1.85, P > 0.1, ANOVA). Both species seemed to prefer the first substantial crotch in a tree except in larch where nests were placed on a platform of horizontal branches against the trunk, and both used approximately the same number of limbs for nest support (BWH, 4.3 ± 1.1 [N = 16] and RSH, 4.2 ± 0.7 [N = 12]).

Nesting Density. We could measure ecological density only on the 1200 ha of the Canadaway Creek Wildlife Management Area and adjoining private land. In 1978, 6 RSH pairs and 5 BWH pairs were found. Additionally, we suspected the presence of 1 additional pair of each species based on sightings

Table 1. Species of trees used for nest sites by Broad-winged and Red-shouldered Hawks in western New York. Only active nests were counted.

	FREQUENCY OF USE	
TREE SPECIES	BROAD-WING	RED-SHOUL-DER
Scotch Pine (*Pinus sylvestris*)	1	0
European Larch (*Larix decidua*)	6	1
Quaking Aspen (*Populus tremuloides*)	1	1
Yellow Birch (*Betula alleghaniensis*)	1	2
American Beech (*Fagus grandifolia*)	0	7
Northern Red Oak (*Quercus rubra*)	2	0
Sweet Crab Apple (*Malus coronaria*)	1	0
Black Cherry (*Prunus serotina*)	3	1
Sugar Maple (*Acer saccharum*)	2	0
Red Maple (*Acer rubrum*)	0	2
Maple sp. (*Acer* sp.)	0	2
American Basswood (*Tilia americana*)	1	0
White Ash (*Fraxinus americana*)	0	2
Total number of tree species	9	8
Total nests	18	18

Table 2. Raptor species occurring in the 1200 ha Canadaway Creek Wildlife Management Area and adjacent woodlands and probable densities in 1978.

SPECIES	OCCURRENCE
Cathartes aura	1 or 2 pairs
Circus cyaneus	1 pair
Accipiter striatus	1 pair
Buteo jamaicensis	1 pair
Buteo lineatus	6 or 7 pairs
Buteo platypterus	5 or 6 pairs
Falco sparverius	1 pair
Asio otus	1 pair
Bubo virginianus	1 pair
Strix varia	1 pair

and calls of hawks. Including suspected pairs, nesting densities of RSH and BWH were 1 pair/171 ha and 1 pair/200 ha, respectively, of forested land. BWH and RSH more often nested adjacent to each other than to conspecifics. Nearest neighbor distances were 877 ± 422 m (N = 12) for BWH/RSH, 1441 ± 331 (N = 11) for BWH/BWH, and 1271 ± 640 (N = 4) for RSH/RSH. A single active Barred Owl (*Strix varia*) nest was 120 m from a RSH nest and 578 m from a BWH nest.

Several other species of raptors were present during the breeding season in the Canadaway Creek area (Crocoll and Parker 1986; Table 2) but were not carefully censused, and some nesting pairs were probably overlooked. Nevertheless, overall raptor density was conservatively estimated at 1 pair/63.2 ha.

Nesting Chronology. BWH. Broad-winged Hawks were first seen on the study area on 12 April in 1978, on 23 April in 1979, and on 19 April in 1980. These were probably local breeding birds because active nests were subsequently found near sightings. Migrant BWHs were also observed in the study area in April. Nest building or rebuilding began soon after occupying nesting territories. Active

nests were verified by the presence of green sprigs or down, or a bird on the nest. Nests were found as early as 24 April, and partially constructed nests were found as late as 14 May, suggesting a nest construction period of approximately 3 wks. Backdating from hatching dates, and assuming 30 days for incubation as did Matray (1974), egg laying occurred mainly during the second and third wks of May.

Eleven of 12 BWH eggs hatched in the first 2 wks of June (Fig. 1). Variation in hatching date seemed unrelated to year or clutch size. Mean first egg hatching dates for 1978, 1979, and 1980 were 16 June, 7 June, and 10 June, respectively. Mean first egg hatching date for the 3-yr period was 10 June.

Average interval ($\bar{x}$ ± S.D.) between any 2 eggs hatching for any size clutch was 1.87 ± 1.36 d (N = 31). Eggs hatched 1 d apart (N = 4) in all 2-egg clutches (N = 4). In 3-egg clutches the average time between any 2 eggs hatching was 2.00 ± 1.41 d (N = 24). The second egg hatched an average of 0.38 ± 0.52 d (N = 8) after the first, and the third egg hatched an average of 2.62 ± 0.74 d (N = 8) after the second. In a single 4-egg clutch, the second egg hatched <24 hr after the first, the third egg failed to hatch, and the fourth hatched 3 d after the second.

First flights of nestlings, usually in response to disturbance, occurred at 31.4 d of age ($\bar{X}$; N = 11, range 29–39). There was little variation in the age of first flight among individuals from broods of different sizes. In this study fledging was defined as the ability of an individual to sustain horizontal flight and occurred when the nestlings were 5–6 wks old.
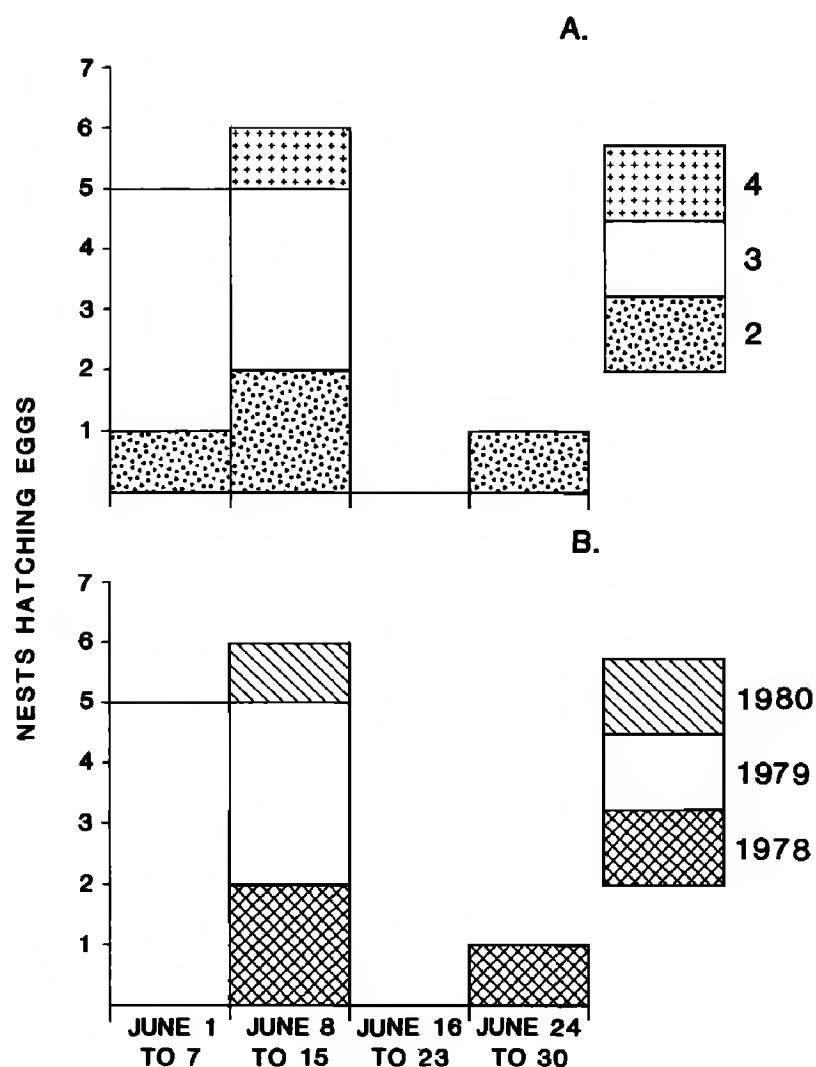
Figure 1. Hatching dates for the first egg in clutches of Broad-winged Hawks. The numbers show clutch sizes in A and years in B.

lyzed for each of 3 time periods. The egg period encompassed the time from laying of the first egg until its hatching, the nestling period was the time from the hatching of the first egg until the fledging of the first young, and the fledging period was the time from the fledging of the first young until migratory departure.

In most respects the BWH seemed more successful in 1979 than in 1978 (Table 3), but sample sizes were small and statistical significance could seldom be shown. Clutch size was significantly larger (F = 4.92, P < 0.05, ANOVA) in 1979 than 1978. Most notably, overall productivity of the fledglings per nesting attempt in 1979 was nearly twice that of 1978.

Ten of 18 BWH nesting attempts suffered some mortality. Total nest loss occurred more often during the egg period in both years, but only for 1979 was the difference statistically significant ($t_s = 1.96$, P < 0.05, arcsine test). In 1979 more nests hatching eggs survived the nestling period than in 1978 ($t_s = 1.71$, P < 0.05). In 1979 the overall percentage of successful nests seemed higher than 1978, but the difference was not statistically significant ($t_s = 1.25$, P ~ 0.10).

Because records for some RSH nests are incomplete, only limited generalizations are possible. RSH clutch size was larger than BWH (Table 3), but RSH fledged fewer young, which probably reflects largely the lower hatching success for RSH. A third egg which failed to hatch was suspected for two 2-egg clutches because of the presence of egg shell fragments beneath the nest early in the egg period. Therefore, data presented in Table 3 represents the minimum percentage of eggs hatched. Discounting the observed shell fragments would have resulted in a hatching percentage of 77%. Rates of nest success for RSH and BWH were similar during the egg period, but BWH nests seemed more successful during the nestling period.

Success and Clutch Size. Only 1 BWH clutch each of 1 egg and 4 eggs was found. Therefore, comparisons of success (Table 4) were made only between clutches that were originally of 2 or 3 eggs. The average number of fledglings per nest was not statistically greater with larger clutch size, but a larger sample size might well establish statistical significance. Two-egg clutches produced more fledglings/egg hatched than did 3-egg clutches ($t = 2.45$, P < 0.01), but a similar comparison for fledglings/egg laid was not statistically significant. Percentages

Earliest fledging date was 4 July and the latest was 2 August. Most young (88.9%) fledged during the second and third wks of July. BWH were last seen on the study area on 5 September in 1978 and on 3 September in 1979.

RSH. Twenty active RSH nests were found during our 3-yr study but were intensively studied only during 1979. The following schedule was constructed primarily from data obtained in 1979.

RSH were first seen during the second and third wks of March when nest relining was also observed. Adults were sitting on nests as early as the first wk in April and may have been incubating eggs. Most eggs hatched during the second and third wks of May, which suggests a minimum incubation period of 4–5 wks in western New York. Fledging occurred during the third and fourth wks of June, with the exception of 1 nest at which a single young fledged on 11 July, suggesting a nestling period of approximately 5 wks.

Reproductive output and nest success were ana-

Table 3. Productivity and nest success of Broad-winged and Red-shouldered Hawks in western New York. Sample sizes are in parentheses.

PARAMETER	BROAD-WINGED HAWK			RED-SHOULDERED HAWK
	1978	1979	TOTAL	ALL YEARS
Total nests found	6	10	18[a]	9
Average clutch size	2.00 ± 0.82 (4)	2.89 ± 0.60 (9)	2.60 ± 1.09 (15)[a]	3.00 ± 1.00 (5)
Average no. of eggs hatching	1.40 ± 1.34 (5)	2.30 ± 1.25 (10)	1.88 ± 1.32 (17)[a]	2.00 ± 1.58 (5)
Percentage of eggs hatching	90.9 (11)	88.5 (26)	83.3 (42)[a]	66.7 (15)
Percentage of fledglings per egg laid	75.0 (8)	73.1 (26)	69.2 (39)[a]	—
Percentage of fledglings per egg hatched	85.7 (7)	82.6 (23)	84.4 (32)[a]	—
Avg. fledglings per nest	1.00 ± 1.10 (6)	1.90 ± 1.20 (10)	1.50 ± 1.20 (18)[a]	1.11 ± 1.17 (9)
Avg. fledglings per successful nest	2.00 ± 0 (3)	2.38 ± 0.74 (8)	2.25 ± 0.62 (12)[a]	2.00 ± 0.71 (5)
% Nests successful in:				
Egg period	66.7 (6)	80.0 (10)	72.2 (18)[a]	75.0 (8)
Nestling period	75.0 (4)	100 (8)	92.3 (13)[a]	83.3 (6)
Overall	50.0 (6)	80.0 (10)	66.7 (18)[a]	55.6 (9)

[a] Total includes 2 nests found in 1980.

of successful nests in both the egg and nestling periods were very similar between 2-egg and 3-egg clutches.

Success and Age of BWH. BWH yearlings were first observed paired and breeding with adults in 1979. Age of both parents was known for only 1 pair in 1978 and 1980. All breeding yearlings were males. Adult/adult pairs were more successful than adult/yearling pairs for most criteria in Table 5. However, only the percentage of eggs hatching

showed a significant difference (t_s = 2.31, P ≃ 0.01) favoring the adult/yearling pairs. Clutch size of 1 mixed pair was unknown and was excluded from some of the calculations.

Success and Reuse of Nests by Broad-wings. Of fifteen BWH nests of known age, 5 (33%) had been rebuilt (Table 6). Clutch size was not statistically different between the 2 ages of nests, but nest success appeared greater in all criteria for newly constructed nests compared to reused nests, although

Table 4. Productivity of different clutch sizes[a] in the Broad-winged Hawk in western New York. Sample sizes are in parentheses.

	CLUTCH SIZE			
	1	2	3	4
Number of nests	1	5	8	1
Average No. of eggs hatching	0 (1)	1.60 ± 0.89 (5)	2.62 ± 1.06 (8)	3.00 (1)
Percentage of eggs hatching	0 (1)	80.0 (10)	87.5 (24)	75.0 (4)
Percentage of fledglings per egg laid	0 (1)	80.0 (10)	66.7 (24)	75.0 (4)
Percentage of fledglings per egg hatched	—	100 (8)	76.2 (21)	100 (3)
Average fledglings per nest	0 (1)	1.60 ± 0.89 (5)	2.00 ± 1.06 (8)	3.00 (1)
Average fledglings per successful nest	—	2.00 ± 0 (4)	2.28 ± 0.76 (7)	3.00 (1)
% Nests successful in:				
Egg period	0 (1)	80.0 (5)	87.5 (8)	100 (1)
Nestling period	—	100 (4)	100 (7)	100 (1)
Overall	0 (1)	80 (5)	87.5 (8)	100 (1)

[a] Clutch size was not determined at 2 nests and one pair did not lay eggs.

Table 5.   Reproductive output and nest success by age composition of pairs of breeding Broad-winged Hawks. Sample sizes in parentheses.

	PAIR COMPOSITION	
	ADULT/ADULT	ADULT/SUBADULT
Total number of nests	6	4
Average clutch size	3.00 ± 0.63 (6)	2.67 ± 0.58 (3)
Average No. of eggs hatching	2.33 ± 1.21 (6)	2.00 ± 1.41 (4)
Percentage of eggs hatching	77.8 (18)	100 (8)
Percentage of fledglings per egg laid	72.2 (18)	75.0 (8)
Percentage of fledglings per egg hatched	92.9 (14)	75.0 (8)
Average fledglings per nest	2.17 ± 1.17 (6)	1.50 ± 1.39 (4)
Average fledglings per successful nest	2.60 ± 0.55 (5)	2.00 ± 1.00 (3)
% Nests successful in:		
Egg period	83.3 (6)	75.0 (4)
Nestling period	100 (5)	100 (3)
Overall	83.3 (6)	75.0 (4)

the difference showed statistical significance only in the cases of percentage of eggs hatching (t_s = 2.22, P < 0.05) and percentage of fledglings/egg laid (t_s = 2.27, P < 0.05).

Success and BWH Nest Sites. Fledging success of BWH was not related to the number of limbs supporting nests (F_s = 0.62, P > 0.5, ANOVA) or nest elevation (F_s = 0.81, P > 0.25, ANOVA) (Fig. 2A and 2B). A trend toward increased success was indicated for nests farther from woodland openings but was not statistically significant (F_s = 2.1, P > 0 1, ANOVA; Fig. 2C).

Essentially, BWH nested in 2 habitat types: de-

ciduous mixed woodland, and small-stand conifer plantations (approximately 1 ha) contiguous with beech-maple-hemlock forest. Average clutch size and average number of fledglings/nest were similar between different habitats (Table 7). However, approximately 1 less egg/nest hatched from nests in conifer plantations than from those in the mixed deciduous-conifer habitat, apparently the result of greater loss of nests in plantations during the egg period (t_s = 1.59, P ≃ 0.06). A larger percentage of eggs hatching in deciduous mixed habitat as compared with plantations (t_s = 2.72, P < 0.01) was associated with a higher percentage of fledglings/

Table 6.   Nest success of new versus rebuilt Broad-winged Hawk nests in western New York. Sample sizes in parentheses.

	NEW NESTS	REBUILT NESTS
Total number of nests	10	5
Average clutch size	2.44 ± 1.13 (9)	2.40 ± 0.39 (5)
Average No. of eggs hatching	2.10 ± 1.20 (10)	1.60 ± 1.52 (5)
Percentage of eggs hatching	95.4 (22)	66.7 (12)
Percentage of fledglings per egg laid	86.4 (22)	50.0 (12)
Percentage of fledglings per egg hatched	90.5 (21)	75.0 (8)
Average fledglings per nest	1.90 ± 1.00 (10)	1.20 ± 1.30 (5)
Average fledglings per successful nest	2.38 ± 0.52 (8)	2.00 ± 1.00 (3)
% Nests successful in:		
Egg period	80.0 (10)	60.0 (5)
Nestling period	100 (8)	100 (3)
Overall	80.0 (10)	60.0 (3)

egg laid, although the only nest that failed during the nestling period was in mixed habitat. Percentage of successful nests was essentially the same during the egg and nestling periods in the mixed habitat, but a greater percentage of nests failed in the egg period than in the nestling period in conifer plantations ($t_s = 2.28$, $P < 0.05$).

Mortality Factors. Four mortality factors reduced BWH reproductive success. Nest desertion caused only the loss of 1 egg and 1 nest attempt, and egg failure was known to cause only the loss of 1 egg. Predation accounted for half the loss of Broad-wing nests (5 of 10), and most occurred prior to hatching. Five eggs and 4 nestlings were known to be lost to predators, and GHO were judged responsible at 4 nests. During the 3 yrs of the study, 4 adults were killed by predators, all at different nests, and 3 of those by GHO (see Methods). The remaining adult died from an unknown cause. Four yearlings were recruited into the breeding population in 1979, indicating that at least 3 additional adults in the local population probably suffered some form of mortality prior to the breeding season. Starvation was secondary to predation by causing the loss of 4 nestlings (2 in 1 nest, 1 in each of 2 others).

RSH mortality showed a roughly similar pattern. Predation eliminated 3 nests (1 egg, 1 nestling known lost). Starvation impacted 2 nesting attempts (3 nestlings at 2 nests) but resulted in no complete nest failures. It was not possible to determine if predation on Red-shoulder nests was more prevalent during the egg period than the nestling period, but Great Horned Owls were the responsible predator in all cases judging by the presence of feathers and other observations similar to failed BWH nests.

Food Habits. BWH in Chautauqua County, New York were generalized predators bringing at least 14 species of vertebrates to nests (Table 8). Because invertebrate remains were rarely found in the nests, their importance in the BWH diet is unclear. Clearly, mammals (chipmunks, moles, shrews) and miscellaneous birds predominated, but toads and garter snakes were taken also. The percent composition of different vertebrates in the Broad-wing's diet changed considerably between 1978 and 1979 with the greatest shift being to birds. Of 20 prey items found in 1978, 12 (60%) were mammals, 4 (20%) were reptiles, and only 2 each (10%) were birds and amphibians. In 1979, 14 (33%) of 42 prey items were birds, mammals fell to 40% (17), while reptiles and amphibians 4 (10%) and 7 (17%), respectively, re-
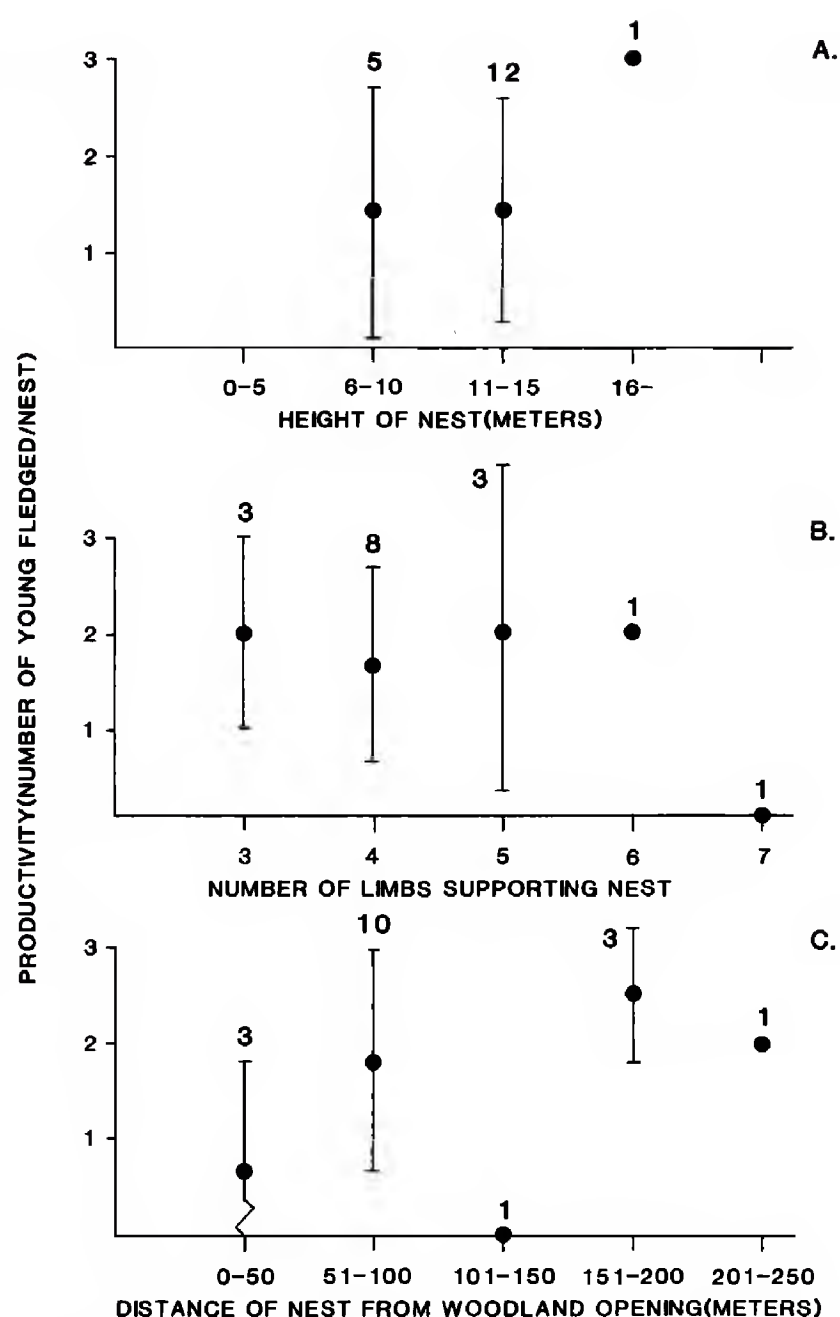
Figure 2.   Production of BWH fledglings associated with A, nest height; B, number of supporting limbs, and C, distance of nest from a woodland opening. Each point represents the mean and the bars represent the S.D. Nest sample size appears above each bar.

mained uncommon. In 1978 an average of 0.35 vertebrate prey items were found during each nest visit (N = 57) in comparison to 0.54 prey items found per visit (N = 78) in 1979. Prey items [2 Eastern Chipmunks; 1 Shorttail Shrew; 1 Masked Shrew (*Sorex cinereus*)] were found at only 2 RSH nests.

DISCUSSION

Nesting Characteristics and Densities of BWH and RSH. BWH. In most parts of its range, BWH associates with dense forests (Burns 1911; Bent 1937). However, forest type is quite variable [e.g., maple-beech-hemlock in this study, oak-aspen in Wisconsin-Minnesota (Keran 1978), hemlock-yellow birch

Table 7. Reproductive success of Broad-winged Hawks in two habitat types in western New York. Sample sizes in parentheses.

	DECIDUOUS MIXED WOODLANDS	CONIFER PLANTATIONS
Total number of nests	11	7
Average clutch size	2.56 ± 1.13 (9)	2.28 ± 0.76 (7)
Average No. of eggs hatching	2.44 ± 1.01 (9)	1.43 ± 1.40 (7)
Percentage of eggs hatching	95.6 (23)	62.5 (16)
Percentage of fledglings per egg laid	73.9 (23)	62.5 (16)
Percentage of fledglings per egg hatched	77.3 (22)	100 (10)
Average fledglings per nest	1.54 ± 1.13 (11)	1.43 ± 1.40 (7)
Average fledglings per successful nest	2.12 ± 0.64 (8)	2.50 ± 0.58 (4)
% Nests successful in:		
Egg period	90.0 (10)	57.1 (7)
Nestling period	88.9 (9)	100 (4)
Overall	80.0 (10)	57.1 (7)

in the Adirondack Mountains (Matray 1974)]. Only in this study has BWH been observed nesting in conifer plantations. Other studies reported nesting close to some type of forest opening (Table 9), but BWH in western New York unaccountably nested farther from forest openings than other populations. Nest heights appeared to be similar among different regions except for Wisconsin where nests were substantially lower (Keran 1978). Clearly, BWH displays a degree of adaptability in choice of nesting habitat, but no detailed patterns are apparent.

Few comparative data exist on BWH nesting densities. Rusch and Doerr (1972) reported about 1 pair/23.3 km², which is much less dense than the Chautauqua study area (approximately 1 pair/2 km²), probably because the Alberta study site was on the western edge of the species' range. Keran (1978) and Rosenfield (1984) reported breeding densities of 1 pair/5.2 km² and 1 pair/2.4 km², respectively, for Minnesota and Wisconsin. In Chautauqua County the BWH appeared subjectively to be about the third or fourth most common raptor, behind RSH and Red-tailed Hawks (*Buteo jamaicensis*) and possibly GHO.

We know of only 3 other studies that reported on densities of raptor communities: Craighead and Craighead (1956) in Michigan (1 pair/144.7 ha), Brown (1966) in Kenya (1 pair/84 ha), and U.S.D.I. (1979) in the Snake River Birds of Prey study area, Idaho (1 pair/91.7 ha). Clearly, total raptor density in the Canadaway Creek (1 pair/63.2 ha) ranks with others as a very dense raptor community,

whether or not birds forage outside the study area (as do the birds at Snake River).

Breeding schedule of BWH in western New York seems to coincide most closely with Wisconsin-Minnesota (Keran 1976) and the central Appalachians (Janik and Mosher 1982). Egg laying and hatching occurred from early May to early June and fledging from mid to late July in both the Wisconsin-Minnesota and central Appalachian populations.

RSH. Although several studies (Stewart 1949; Wiley 1975; Preston et al. 1989) indicate an association between Red-shouldered Hawk nesting and low floodplain forests, only 1 of our 20 active RSH nests was in floodplain forest. Most were in upland hills, but all were close to some form of surface water which is in agreement with other studies. Forest habitat used by RSH in this study was most similar to that used by populations in the Waterloo region of Ontario (Sharp and Campbell 1982) and in southwestern Quebec (Morris et al. 1982). The Canadian studies as well as Titus and Mosher (1987) also indicated preference for the American beech as a nest tree.

A comparison of several studies (Table 10) suggests that RSH use nest sites with similar characteristics throughout much of their geographic range However, few estimates of nesting densities are available. Craighead and Craighead (1956) computed only crude density for an entire township, which included unsuitable cropland as well as suitable woodland habitat. Consequently, their nesting density is not directly comparable to western New

York. Stewart (1949) documented a nesting density in central Maryland that was very similar to western New York even though habitats were much different. In central Maryland, RSH nested only in low river floodplains where the only other nesting raptor was the Barred Owl.

Interestingly, the RSH was the most common nesting raptor in Chautauqua County during the study despite the fact that numbers appear to be declining in many parts of the range (Crocoll and Parker 1988). Most studies (Bednarz and Dinsmore 1981; Kimmel and Fredrickson 1981; Sharp and Campbell 1982) indicate that the primary cause of decline is loss of extensive forested habitat. Currently, habitat does not appear to be limiting in western New York (Crocoll and Parker, pers. obs.) and may in fact be increasing due to a reversion of farm land and old timber harvest areas to woodlands.

Several other studies have reported on RSH nesting chronology (Craighead and Craighead 1956; Henny et al. 1973; Wiley 1975; Portnoy and Dodge 1979; Kimmel and Fredrickson 1981). Chronology in Michigan (Craighead and Craighead 1956) was more similar to western New York than other areas, where some showed earlier (Henny et al. 1973; Wiley 1975; Kimmel and Fredrickson 1981) and some later (Portnoy and Dodge 1979) schedules.

Other studies (Stewart 1949; Titus and Mosher 1981) indicated that BWH and RSH do not usually nest in close proximity. However, we found the opposite true in western New York as did Armstrong and Euler (1982) in central Ontario. Though the general nesting habitats of each species are similar, there probably exist subtle habitat differences similar to those reported in Titus and Mosher (1981), such as distance to nearest forest opening, topography, tree density, ground cover, and percent coniferous trees (Armstrong and Euler 1982) that help reduce potential competition for nest sites. Also, as Fuller (1979) suggested, two species may use overlapping home ranges at different times of the day or week to reduce potential competition for space.

Comparative Reproductive Success of Different BWH and RSH Populations. BWH. Table 11 presents reproductive data for BWH populations from 6 studies. They permit few statistical comparisons and only one comparison among all six populations (% nests successful overall). Only for the population in western New York has the relationship between habitat, age of nesters, clutch size, nest reuse, productivity, and reproductive success been

Table 8. Food items in 13 Broad-winged Hawk nests 1978–1980 in Chautauqua County, New York.

SPECIES	N	% OCCURRENCE
Mammals		
Blarina brevicauda	9	13.0
Condylura cristata	6	8.7
Parascalops breweri	2	3.0
Tamias striatus	10	14.5
Microtus pennsylvanicus	2	3.0
Unidentified	3	4.3
Total mammals	32	46.4
Birds		
Colaptes auratus	2	3.0
Cyanocitta cristata	3	4.3
Bombycilla cedrorum	1	1.4
Junco hyemalis	2	3.0
Unidentified	10	14.5
Total birds	18	26.1
Reptiles		
Storeria dekayi	1	1.4
S. occipitomaculata	1	1.4
Thamnophis sirtalis	5	7.2
Unidentified	2	3.0
Total reptiles	9	13.0
Amphibians		
Bufo americanus	7	10.1
Rana pipiens	2	3.0
Total amphibians	9	13.0
Unidentified vertebrate	1	1.4
Total vertebrates	69	100
Invertebrates		
Crustacea (Crayfish)	2	?
Insecta (grasshoppers and caterpillars)	?	?

reported. Some measures of productivity were roughly similar among different populations, but the western New York population with a high average clutch size had one of the lowest average numbers of young fledged per nest. This study area also seems to have the lowest percentage of successful nests, although the difference was not statistically significant. Lower success in western New York was at least partly due to the statistically lower success of nests in the egg period (G = 7.44, P < 0.025 R x C test of independence).

Surprisingly, causes of mortality and nest failure have received attention in only 1 other study (Ro-

Table 9. Nesting habitat characteristics of several Broad-winged Hawk populations. Sample size in parentheses.

	NEST HEIGHT (M)	NO. SUPPORT LIMBS	DISTANCE TO FOREST OPENING (M)
Wisconsin-Minnesota (Keran 1978)	—	3.8 ± 0.4	42
Central Appalachians (Titus and Mosher 1981)	13.7 ± 3.0 (24)	—	63 ± 61 (24)
Western New York (this study)	11.8 ± 3.2 (18)	4.3 ± 1.1	90 ± 54 (17)
Adirondack Mountains, NY (Matray 1974)	13.3 ± 1.36 (14)	—	—
Wisconsin (Rosenfield 1984)	8.2 ± 2.7 (72)	—	—
Central Ontario (Armstrong and Euler 1982)	11.8 ± 2.8 (27)	—	42.1 ± 30.2 (27)

senfield 1984) which reported that almost twice as many eggs as nestlings were lost, concluding that major impacts occurred during the egg period, as we observed. Rosenfield (1984) also observed the same types of mortality, except starvation of nestlings was not detected. He did record a significantly higher incidence of eggs that failed to hatch (9.1%) compared to our western New York study (2.4%) (t_s = 1 75, P ≃ 0.04 arcsine transformation, test of equality of 2 percentages) and suspected that predation was due to Raccoon (*Procyon lotor*) and American Crow (*Corvus brachyrhynchos*). Ours is the first study to report predation by GHO, which clearly can have a substantial impact on a local BWH population (also see Parker 1974).

Several raptors are known to reuse nests (Brown and Amadon 1968). Rosenfield (1984) reported reuse of nests both in the year after and 2 yrs after construction. To reuse nests is probably energetically

more advantageous than building anew (Weeks 1978). In addition nest reuse is most likely to occur if the nest was successful the previous year (Craighead and Craighead 1956). In our study, however, reuse only occurred 2 yrs after construction and most often in pine plantations. In fact, reused nests in New York were less successful than new ones, nests further from woodland openings appeared more productive than nests relatively close to openings (Fig. 2), and reused nests were much closer to openings than newly constructed nests. We suggest reuse of a nest, placement nearer open areas, or both increases the likelihood of nests being noticed by GHO One possible pressure for nest reuse in pine plantations was the lack of suitable nest trees (Crocoll and Parker, pers. obs.).

Although *Buteo* species usually start breeding at 2 or 3 yrs (Newton 1977) in adult plumage, there have been some reports of breeding subadults (Red-

Table 10. Red-shouldered Hawk nest site characteristics. Sample size in parentheses.

	NEST HEIGHT (M)	NO. SUPPORTING LIMBS	DISTANCE TO FOREST OPENING (M)	BREEDING DENSITY
Western New York (this study)	13.4 ± 2.6 (11)	4.2 ± 0.7 (12)	182 ± 164 (6)	1 pair/171 ha
Southwest Quebec (Morris, et al. 1982)	14.0 ± 3.6 (54)	4.2 (54)	—	—
Waterloo Region (Sharp and Campbell 1982)	14 (9)	—	—	—
Missouri (Kimmel and Fredrickson 1981)	14.4 ± 3.6 (14)	—	—	—
Iowa (Bednarz and Dinsmore 1982)	19.1 ± 4.8 (11)	3.6 ± 0.5 (11)	—	—
Massachusetts (Portnoy and Dodge 1979)	12.0 ± 1.7 (12)	—	—	—
Central Appalachians (Titus and Mosher 1981)	13.4 ± 3.0 (10)	—	—	—
Central Maryland (Stewart 1949)	15 (57)	—	180 ± 141 (10)	1 pair/48.7 ha
Michigan (Craighead and Craighead 1956)	—	—	—	1 pair/645 ha
Central Ontario (Armstrong and Euler 1982)	14.0 ± 3.6 (9)	—	27.8 ± 18.2 (9)	—
Arkansas (Preston et al. 1989)	—	—	173.3 ± 73.1 (19)	—

Table 11.   Comparison of Broad-winged Hawk reproductive output among 6 populations. Sample sizes in parentheses

	CENTRAL ONTARIO (ARMSTRONG AND EULER 1982)	ALBERTA, CANADA (RUSCH AND DOERR 1972)	MINNESOTA AND WISCONSIN (KERAN 1976)	CHAUTAUQUA COUNTY, NY (THIS STUDY)	CENTRAL APPALACHIANS (JANIK AND MOSHER 1982)	WISCONSIN (ROSENFIELD 1984)
Total nests found	16	5	12	18	36	72
Average clutch size	—	2.40 ± 0.55 (5)	2.17 ± 0.39 (12)	2.60 ± 1.09 (15)	2.7 (15)	2.36 (70)
Average no. of eggs hatching	—	2.40 ± 0.55 (5)	2.00 ± 0.60 (12)	1.88 ± 1.32 (17)	2.1 (29)	1.81 (70)
Percentage of eggs hatching	—	100 (12)	92.3 (26)	83.3 (42)	—	77.0 (165)
Percentage of fledglings per egg laid	—	83.3 (12)	84.6 (26)	69.2 (39)	—	64.8 (165)
Percentage of fledglings per egg hatched	—	83.3 (12)	91.7 (24)	84.4 (32)	—	84.3 (127)
Average fledglings per nest	1.5	2.00 (5)	1.83 ± 0.83 (12)	1.50 ± 1.20 (18)	1.74 (34)	1.53 (70)
Average fledglings per successful nest	1.7	2.00 (5)	2.00 ± 0.63 (11)	2.25 ± 0.62 (12)	1.90 (31)	1.94 (55)
% Nests successful:						
Egg period	—	100 (5)	100 (12)	72.2 (18)	—	—
Nestling period	—	100 (5)	91.7 (12)	92.3 (13)	—	—
Overall	87.5 (16)	100 (5)	91.7 (12)	66.7 (18)	86.1 (36)	78.6 (70)

tailed Hawks, Luttich et al. 1971; and Red-shouldered Hawks, Henny et al. 1973; Wiley 1975; Apanius 1977). Yearling Broad-wings have not previously been reported to nest (Newton 1979).

In general young breeders are not as successful as older individuals (Lack 1968; Fisher 1975; Brown 1978). Additionally, Crawford (1977) indicated that subadult female Red-winged Blackbirds (*Agelaius phoeniceus*) and Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) nested in lower quality territories than adults. In our study, BWH pairs that included subadults were apparently less successful than adult/adult pairs (Table 5) even though the former used the habitat (mixed deciduous coniferous forest) producing more young per nest and greater nest success (Table 7).

Male BWH provide all the food during incubation and the early nestling period (Matray 1974). Therefore, mixed pairs in which the male is the subadult should be most successful in years of high food abundance when inexperienced breeding males would have a better chance of obtaining sufficient food.

Subadult breeders of many species start nesting later in the season than more experienced breeders

[Laysan Albatross (*Diomedia immutabilis*), Fisher 1975; European Sparrowhawk (*Accipiter nisus*), Newton 1976; Great Horned Owl, McInvaille and Keith 1974]. However, in our study mixed pairs did not breed later in the season than adult/adult pairs, and overall the population in western New York appeared to breed synchronously, as do BWH in the Adirondacks (Matray 1974).

Several studies showed that nesting habitat has an effect on the nesting success of raptors (Howell et al. 1978; Newton 1976). In western New York, mixed deciduous woodlands were apparently superior to conifer plantations for BWH breeding (Table 7), even though the difference in reproductive success was not large. This situation may be explained (at least in part) by a combination of several factors. First, 67% of the rebuilt nests were found in pine plantations, and reused nests were less productive than new nests. Second, a positive (though statistically non-significant) relationship exists between nest success and distance of nest from a woodland opening (Fig. 2C), and nests in mixed deciduous woodlands were farther from a woodland opening than nests in pine plantations (92.6 m and 85.7 m, respectively). However, mixed pairs were in deciduous-mixed

Table 12. Comparison of Red-shouldered Hawk reproductive output among different populations. Sample sizes in parentheses.

	TOTAL NESTS FOUND	AVERAGE CLUTCH SIZE	AVERAGE NO. OF EGGS HATCHING	AVERAGE FLEDGLINGS PER NEST	AVERAGE FLEDGLINGS PER SUCCESS- FUL NEST	% NESTS SUCCESS- FUL
California (Wiley 1975)	29	2.69 ± 0.54 (29)	2.07 ± 1.03	1.34 ± 1.14 (29)	2.05 (19)	65.5 (19)
Iowa (Bednarz 1979)	8	—	2.9 (8)	2.9 (8)	3.3 ± 0.76 (8)	87.5 (8)
Michigan (Craighead and Craighead 1956)	40	3.42 (40)	2.55 (40)	1.77 (40)	—	—
Missouri (Kimmel and Fredrickson 1981)	9	—	—	2.56 ± 0.53 (9)	2.56 ± 0.53 (9)	100 (9)
New York (this study)	9	3.00 ± 1.00 (5)	2.00 ± 1.58 (5)	1.11 ± 1.17 (9)	2.00 ± 0.71 (5)	55.6 (9)
Maryland—western (Janik and Mosher 1982)	17	3.1 (6)	2.4 (8)	1.8 (10)	—	52.9 (9)
Maryland—central (Henny et al. 1973)	74	—	—	1.58 (74)	2.34 (50)	67.6 (74)
Massachusetts (Portnoy and Dodge 1980)	9	3.33 (9)	2.67 (3)	2.00 (5)	2.50 (4)	80.0 (5)
Central Ontario (Armstrong and Euler 1982)	6	—	—	1.8	2.2	83.3 (6)

habitat, but were less successful than pairs of adults. Consequently, nest success for BWH is less affected by habitat at the nest than by age of nesters. Newton (1976) noted a similar situation in regard to habitat for the European Sparrowhawk and suggested that the higher success observed in the best habitat was due to considerably higher prey availability. We did not quantify prey availability in different hunting habitats.

Many researchers have shown that species diversity and individual species densities are often greater in an ecotone than in adjacent habitats. Our observations agree with Keran (1978) and Titus and Mosher (1981) that BWH hunt the forest edge, particularly near wetlands or ponds in response to higher prey density. Gates and Gysel (1978) documented an increased density of open-nesting passerines in a field-forest ecotone even though there was a concomitant decrease in fledging success, apparently because of predation. In fact, as for passerines, BWH nesting success declined near forest edge, possibly because of the increased likelihood of predation.

RSH. RSH populations in western New York appear uniformly less successful than those in other regions (Table 12), and the species should be considered as threatened in New York. Weather and

human disturbance can be major causes of reproductive failure for RSH (Craighead and Craighead 1956; Henny et al. 1973; Wiley 1975; Sharp and Campbell 1982), and Raccoons and GHO are known predator threats (Craighead and Craighead 1956; Wiley 1975; Bednarz 1979; Portnoy and Dodge 1979). However, only Wiley (1975) recorded GHO predation more than once. In contrast the GHO appears to be the major reason for the low success of RSH in western New York.

Breeding Strategies of the Broad-winged Hawk. Newton (1977) discussed trends in breeding strategy over evolutionary time in small, short-lived raptors having large clutches, high breeding rates, and early maturity ("r-selection," MacArthur and Wilson 1967 and many later references) and in large, long-lived raptors having small clutches, low breeding rates and late maturity ("k-selection"). Although these terms, and the theory associated with them, have undergone considerable discussion and controversy, they still can be validly used to represent two contrasting patterns of reproduction at opposite ends of a continuum. Compared to buteos, BWH in western New York tends toward an "r"-strategy as evidenced by high adult mortality, early maturity, and seeming early recruitment into the breeding population. Relatively high reproductive failure for BWH in some

(lesser-quality) habitats and in years of apparent low food supplies may or may not reinforce an r strategy for BWH reproduction, but would not select against it.

O'Connor (1977) theorized that birds might evolve 1 of 3 breeding strategies by which to maximize reproductive effort within a given year: clutch adjustment, brood reduction, or resource storage. Going further, Hirschfield and Tinkel (1975) suggested that an organism might be flexible, and to maximize contributions to future generations, adjust reproductive strategy from one breeding season to the next, based on environmental constraints. Indeed, Howe (1976) showed that the Common Grackle can simultaneously utilize 2 strategies. Clearly, the BWH often shows brood reduction as do many other raptors (see Newton 1977 for a general review). High adult BWH mortality (Crocoll and Parker, pers. obs.) probably puts an adaptive premium on maximum, annual reproductive output, unlike some other raptors (Newton 1979; Newton et al. 1981; Forsman et al. 1984).

For the BWH it might also be advantageous to have a way to optimize reproductive effort in any year to adjust for unpredictable food variability; to move away from being an extreme r-strategist and use clutch adjustment. O'Connor (1977) predicted clutch adjustment would occur when eventual food supply for young was predictable prior to egg laying and likely to remain stable throughout the nestling period. Lack (1966) noted for the Common Swift (*Apus apus*) that optimal clutch size in one year might not be the optimal clutch size in another year. For our study average BWH clutch size was significantly higher in 1979 ($\sim$3) than 1978 ($\sim$2). Diet analysis indicated that food was not as plentiful in 1978 as 1979, and brood reduction only occurred in clutches of 3 and 4, never for 2. We suggest that a lower food supply in 1978 may have, in part, determined the lower reproductive effort by triggering use of a clutch adjustment strategy. Brood reduction would be the more significant and functioning strategy in years of initially higher food supplies. Although our study is insufficient to confirm this generalization, the BWH appears to be comparatively an r-selectionist, capable of optimizing its reproductive effort in any given year by employing the brood reduction strategy, but with occasional lessening of an r-selection pattern by resort to clutch adjustment. Additional long-term studies of reproduction and prey availability could determine if BWH

or other raptors regularly resort to such complex strategies, and the terms r- and k-selection may prove inadequate to describe some breeding patterns.

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ENVIRONMENTAL CONTAMINANTS IN BLOOD OF WESTERN BALD EAGLES

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ABSTRACT.—Blood samples collected in 1979–81 from wintering Bald Eagles (*Haliaeetus leucocephalus*) in Oregon and northern California, residents in Oregon, migrants in Montana and residents in Washington were analyzed for lead (Pb), mercury (Hg) and organochlorines. Lead was detected infrequently (5%) and at low concentrations (<0.25 ppm) in nestlings from Oregon, more frequently (41%) and at occasionally elevated concentrations (>0.40 ppm) in wintering Bald Eagles in Oregon and northern California and migrants in Montana, and most frequently (56%) in nestlings from Washington but at low concentrations (<0.40 ppm). Mercury concentrations were low (<0.70 ppm) in samples from Washington nestlings and higher in samples from Oregon and northern California birds and in Montana migrants. Adults tended to have higher concentrations of Hg than hatch year birds or nestlings. Two Bald Eagles from Montana had clearly elevated Hg concentrations (7.0 and 9.5 ppm). DDE and polychlorinated biphenyl (PCB) concentrations were generally low (most means <0.20 ppm) with adults having higher concentrations than subadults or nestlings. A few resident adult Bald Eagles from Oregon had elevated concentrations of DDE.

Bald Eagle (*Haliaeetus leucocephalus*) populations in the United States and Canada have been adversely impacted by environmental contaminants. DDE has been strongly implicated in reduced reproductive success (Grier 1982; Wiemeyer et al. 1984a), and birds have died of dieldrin and endrin poisoning (Kaiser et al. 1980; Reichel et al. 1984). Bald Eagles also have died of lead (Pb) poisoning (Kaiser et al. 1980; Reichel et al. 1984), primarily caused by ingesting Pb shot from hunter-crippled and killed waterfowl (Pattee and Hennes 1983). Although some Bald Eagles have been exposed to mercury (Hg) contamination, most populations do not appear to have been affected (Belisle et al. 1972; Wiemeyer et al. 1984a).

Environmental contaminants in Bald Eagle populations have been monitored through analysis of tissues of birds found dead (Reichel et al. 1984), eggs (Wiemeyer et al. 1984a) and blood, including plasma (Henny et al. 1981; Pattee and Hennes 1983). We collected blood samples for contaminant analyses from Bald Eagles in Oregon, northern California, Montana and Washington. Our objectives were to determine contaminant concentrations in the birds, to compare concentrations among areas, age classes and residency status, and relate concentrations to sources of exposure and possible effects on populations.

METHODS

Sample Collection. Blood samples (6–12 cc) were collected in 1979–81 during the breeding season from resident (including 7–11-wk-old nestlings and adults) and subadult

Bald Eagles from the Klamath Basin and Cascade Lakes areas of Oregon, and from wintering Bald Eagles from the Klamath Basin, Oregon and northern California (Frenzel 1985). Blood samples were taken with heparinized glass syringes (washed with detergent and rinsed with residue grade acetone) then frozen.

Blood samples (ca. 10 cc) were collected from migrant Bald Eagles in Glacier National Park (GNP), Montana (McClelland et al. 1982) during October–December 1980 and October–November 1981 using disposable syringes. Samples collected in 1980 were preserved with formalin (1 part/20 parts blood; Wiemeyer et al. 1984b); those collected in 1981 were preserved by freezing. Some birds were equipped with patagial markers and radio transmitters to monitor movements (Young 1983).

Blood samples (6 cc) were collected from 7–9-wk-old nestling Bald Eagles in San Juan Island County, Washington during June 1980 with heparinized disposable syringes. Samples were preserved with formalin. A sample of formaldehyde from the lot used in preserving blood samples was also submitted for chemical analysis.

Blood samples (5 cc) were collected from 5 captive Bald Eagles at the Patuxent Wildlife Research Center, Laurel, Maryland on 19 October 1983 for comparative purposes, using disposable syringes. Birds had been in captivity for 1–13 yrs. Samples were frozen. Two unused syringes from the same lot used in collecting blood samples were also submitted for chemical analysis.

Blood samples were placed in glass jars that had been cleaned with nitric acid and rinsed with deionized water, acetone and hexane, and capped with lids equipped with teflon liners.

Bald Eagles, except for nestlings, were aged on the basis of plumage characteristics. Eagles with white heads were classified as adults. In Oregon and California, all eagles lacking a white head were classified as subadults. In Montana, nonadult eagles were classified as hatch year birds or as subadults. Birds having the "dark immature" plum-

age (with dark brown eye and completely dark brown or black bill) as described by Clark (1983) were classified as hatch year; older nonadult birds (with varying degrees of lighter plumage, eye and bill coloration) were classified as subadults. Ages of nestlings were estimated by development of plumage (Stalmaster 1987), size and nesting chronology.

Chemical Analysis. Samples were homogenized and subsampled for various analyses. A 0.5 g aliquot was used for Pb analysis, 2.0 g for Hg and 5.0 g for organochlorines.

Organochlorines were analyzed by the methods of Cromartie et al. (1975) and Kaiser et al. (1980), except that fractions I and II were combined. Glassware was rinsed with 15% ethyl ether in hexane prior to use. Contaminants in each fraction were identified and quantitated by electron capture gas chromatography using a 1.5/1.95% SP-2250/SP-2401 packed column. The lower limit of reportable residues was 0.01 ppm for pesticides and 0.05 ppm for polychlorinated biphenyls (PCBs) in Oregon and northern California samples, and 0.05 ppm for pesticides and 0.10 ppm for PCBs in Montana samples. A gas chromatograph-mass spectrometer was used to confirm the identity of contaminants in about 10% of samples containing detectable concentrations.

Samples were analyzed for Hg by cold vapor atomic absorption spectrophotometry using previously described methods (Monk 1961; Hatch and Ott 1968). The lower limit of reportable residues was 0.02 ppm. Lead was analyzed by graphite furnace atomic absorption spectrophotometry using a wet ash procedure (Hinderberger et al. 1981). The lower limit of reportable residues was 0.05 ppm.

Frozen duck blood samples stored for 2 and 8 mo lost 35% of their DDE concentrations compared to those analyzed fresh, whereas no DDE was lost from samples preserved with formalin and stored for the same periods (Wiemeyer et al. 1984b). Data on the stability of PCBs under these preservation methods are not available. Freezing and formalin preservation of blood were equally suitable when dealing with Pb and Hg residues (Wiemeyer et al. 1984b). Only samples from Montana in 1980 and from Washington nestlings in this study were preserved with formalin.

Samples from Oregon and California were stored frozen for 8–24 mo before chemical analysis. Samples from Montana that were collected in 1980 were analyzed for organochlorines in August 1981 and for Pb and Hg in February 1983. Montana samples collected in 1981 were analyzed for organochlorines and metals in July and November 1982, respectively. Samples from Washington were analyzed in September 1982. Samples from captive birds were analyzed within 3 wk of collection.

Lead or Hg was not detected in a sample of formalin from the lot used to preserve samples from Washington. Mercury was not detected in solutions used to rinse syringes from the same lot as those used in collecting blood samples from captive Bald Eagles.

Statistical Analysis. Geometric means are reported throughout when ≥50% of samples contained a detectable concentration of a given contaminant. Samples containing nondetectable residues were assigned values equal to one-half the detection limit in computing means. T-tests were used to determine if significant differences occurred between means of log transformed values.

RESULTS

Lead was detected infrequently (5%) and at low concentrations in nestling Bald Eagles from Oregon (Table 1), but more frequently in Washington nestlings (x^2; $P < 0.001$). Forty-one percent of samples from wintering Bald Eagles in Klamath Basin and also in migrants from Montana had detectable Pb concentrations. Only 3 samples from all areas contained >0.4 ppm Pb, 2 migrants from Montana and 1 wintering subadult from Klamath Basin.

All but 1 sample contained detectable Hg concentrations (Table 1). Concentrations ranged widely, with the lowest mean concentration found in nestlings from Washington and the highest in subadults and adults from Oregon and northern California. Oregon nestlings had significantly higher ($P < 0.0001$) concentrations than Washington nestlings. Subadults and adults tended to have higher Hg concentrations than nestlings or hatch year birds. Concentrations in Oregon resident adults were significantly higher ($P = 0.019$) than in Oregon nestlings. Blood samples from 5 captive Bald Eagles contained a mean of 0.23 ppm Hg (range 0.17–0.31 ppm).

The primary organochlorines detected were DDE and PCBs (Table 2); however, DDD, *trans*-nonachlor and *cis*-nonachlor were detected in a few samples from Oregon (Frenzel 1985). DDE was detected in 61% of samples from Oregon nestlings and 100% of samples from subadults and resident adults. DDE was detected in 95% of samples from subadults and adults wintering in Oregon and northern California. Polychlorinated biphenyls were detected much less frequently than DDE in samples from Oregon and northern California; only 15% of samples from nestlings and 59% of samples from subadults and adults contained detectable concentrations. Samples from resident adults in Oregon contained significantly ($P < 0.0001$) higher DDE and PCB concentrations than did nestlings from the same area. Resident adults from Oregon had significantly ($P < 0.0001$) higher DDE and PCB concentrations than those of wintering adults from the Klamath Basin. Few samples from migrant Bald Eagles from Montana contained detectable DDE and PCB concentrations, although the lower limits of reportable residues were higher than for Oregon and northern California samples. DDE was detected most frequently in adults.

Table 1. Frequency of occurrence and concentrations (ppm wet weight) of lead (Pb) and mercury (Hg) in blood samples from western Bald Eagles.

STATE, STATUS AND AGE	Pb				Hg		
	NUMBER		GEO- METRIC MEAN	RANGE	NUMBER SAMPLED[b]	GEOMETRIC MEAN	RANGE
	SAMPLED	WITH DETECT- ABLE[a]					
Oregon							
Resident							
Nestling	58	3	—	nd[c]–0.22	82[d]	1.2	nd–4.2
Subadult[e]	2	0	—	—	2	3.0	2.8–3.2
Adult	5	1	—	nd–0.25	7	2.3	1.1–4.8
Oregon and northern California							
Wintering[f]							
Subadult	4	3	0.129	nd–0.62	5	2.2	1.6–2.7
Adult	13	4	—	nd–0.25	15	2.3	1.1–5.4
Montana							
Migrant							
Hatch year	12	4	—	nd–0.23	12	1.5	0.94–3.2
Subadult	14	7	0.072	nd–1.9	14	1.8	0.89–9.5
Adult	3	1	—	nd–1.9	3	2.0	0.85–4.5
Washington							
Resident							
Nestling	9	5	0.066	nd–0.36	9	0.23	0.075–0.65

[a] Lower limit of reportable residues 0.05 ppm.
[b] All samples contained Hg except as noted in footnote d.
[c] nd = none detected.
[d] One sample contained no detectable Hg.
[e] These birds were probably nomadic and not true residents even though they were sampled during the breeding season.
[f] Data from Frenzel and Anthony (1989).

DISCUSSION

Lead. Only 3 eagles in our study had recent significant exposure (>0.40 ppm Pb in blood) to Pb. Although a number of additional eagles had detectable Pb concentrations in blood (evidence of Pb exposure), their exposure appeared minimal. Bald Eagles that were experimentally dosed with 10 pellets of No. 4 Pb shot had a mean of 0.8 ppm Pb in blood 1 d after dosage and 2.8 ppm 3 d after dosage, whereas unexposed Bald Eagles had no detectable Pb concentrations (<0.1 ppm) in their blood (Hoffman et al. 1981).

Bald Eagles wintering in Klamath Basin fed mostly on waterfowl (Frenzel and Anthony 1989), whereas fish were predominant in the diet of resident eagles during spring and summer (Frenzel 1985). Detectable Pb concentrations were found more fre-

quently in adult and subadult Bald Eagles wintering in Klamath Basin (41%) than in subadults and resident adults from Oregon (14%); however, the difference was not significant (χ^2; P = 0.20). Seasonal shifts in food habits and the possible entry of birds into the wintering population that could have been previously exposed to Pb may explain these differences; however, larger samples would be required to examine this issue. Most Bald Eagle food items from Oregon had low concentrations of Pb in carcass, except for grebes, gulls and Belding's Ground Squirrels (*Spermophilus beldingi*) (Frenzel 1985). The most likely source of Pb exposure to Bald Eagles is ingestion of Pb shot from hunter-killed or crippled waterfowl (Pattee and Hennes 1983).

Migrant Bald Eagles in GNP fed on fish (McClelland et al. 1982). Lead was detected in none

Table 2. Frequency of occurrence and concentrations (ppm wet weight) of organochlorines in blood samples from western Bald Eagles.

STATE, STATUS, AGE AND COLLECTION YEAR	N	DDE			PCB		
		NO. WITH DETECTABLE[a]	GEOMETRIC MEAN	RANGE	NO. WITH DETECTABLE[b]	GEOMETRIC MEAN	RANGE
Oregon[c]							
Resident							
Nestling	75	46	0.015	nd[d]–0.15	11	—	nd–0.29
Subadult[e]	3	3	0.12	0.06–0.20	1	—	nd–0.08
Adult	8	8	0.50	0.08–1.4	8	0.25	0.05–0.71
Oregon and northern California[c]							
Wintering[f]							
Subadult	5	5	0.030	0.01–0.14	2	—	nd–0.08
Adult	16	15	0.042	nd–0.13	8	0.018	nd–0.12
Montana							
Migrant							
Hatch year							
1980[g]	5	0	—	—	0	—	—
1981[c]	6	0	—	—	0	—	—
Subadult							
1980[g]	5	2	—	nd–0.06	0	—	—
1981[c]	5	0	—	—	0	—	—
Adult							
1980[g]	7	7	0.19	0.07–0.71	4	0.28	nd–0.71
1981[c]	3	3	0.086	0.05–0.13	0	—	—

[a] Lower limit of reportable residues 0.01 ppm for Oregon and northern California samples and 0.05 ppm for Montana samples.
[b] Lower limit of reportable residues 0.05 ppm for Oregon and northern California samples and 0.10 ppm for Montana samples.
[c] Samples preserved by freezing.
[d] nd = none detected.
[e] These birds were probably nomadic and not true residents even though they were sampled during the breeding season.
[f] Data from Frenzel and Anthony (1989).
[g] Samples preserved with formalin.

of 8 samples collected on or before 25 October, whereas 12 of 21 (57%) samples collected after that date had detectable concentrations (x^2; $P = 0.005$). Samples from subadults and adults ($N = 2$ and 0, respectively) were poorly represented in the earlier time period. For hatch year birds only, none of 6 samples collected on or before 25 October had detectable Pb concentrations, whereas 4 of 6 collected later had detectable concentrations (x^2; $P < 0.025$). Exposure to Pb shot would be expected to increase after the start of the waterfowl hunting season and may have occurred before arrival in GNP.

One adult female Bald Eagle found dead in Klamath Basin in 1982 died of Pb poisoning; liver contained 27 ppm Pb (Frenzel and Anthony 1989). Lead concentrations in livers of 11 other adult and subadult Bald Eagles from Oregon and northern California that died in 1979–82 were <6 ppm; 7 were <2 ppm (Frenzel 1985). Twenty-two Bald Eagles dying in Oregon, Montana, and Washington were necropsied during 1978–81; none died of Pb poisoning (Reichel et al. 1984). Bald Eagles dosed with Pb shot all had >10 ppm Pb in liver at death (Pattee et al. 1981).

Although the exposure of Bald Eagles to Pb in our study areas generally appeared low, even some nestlings were exposed. A few migrant and wintering Bald Eagles were at risk from Pb poisoning. Additional information relating known Pb concentrations in blood of Bald Eagles to effects on health and risk of poisoning would be helpful in interpreting data from field studies. The eventual ban on use of

Pb shot in waterfowl hunting in the 1991–92 hunting season (U.S. Fish and Wildlife Service 1986) should greatly reduce the risk of Bald Eagles dying of Pb poisoning. Studies on exposure of wild Bald Eagles to Pb following the ban should be conducted to determine impact on populations.

Mercury. Bald Eagles appear to routinely have higher concentrations of Hg in their blood than other species of birds. For example, nearly all untreated Mallards (*Anas platyrhynchos*) had <0.07 ppm in blood (Heinz 1980), whereas wild Rock Doves (*Columba livia*) from Mississippi had 0.005–0.012 ppm Hg in blood (Knight and Harvey 1974). Nestling Bald Eagles from Washington and captive Bald Eagles both had means of 0.23 ppm Hg in blood. Young Common Terns (*Sterna hirundo*) from Long Island, New York that may have been exposed to minor Hg contamination and were classified as normal with regard to feather development had 0.37 $\mu g/ml$ Hg in blood (Gochfeld 1980). Mallards fed 0.5 ppm (dry weight) methylmercury for 7 mo had blood levels of 0.5 to 0.6 ppm Hg (Heinz 1980).

Wild Bald Eagles, except for Washington nestlings, in our study had far higher Hg concentrations in blood. Fifteen eagles had >3 ppm Hg in blood (11 from Oregon or northern California and 4 from Montana). Two Montana eagles, both subadults, had >6 ppm in blood (7.0 and 9.5 ppm). Higher concentrations in blood samples of adults than in those from nestlings and hatch year birds correspond with the known accumulative nature of Hg.

Although Bald Eagle blood samples from Oregon and northern California had higher concentrations than other species or captive Bald Eagles, there is no evidence that Hg was having an adverse impact on the population. Reproductive success appeared normal (Frenzel 1985). Eight clutches of Oregon Bald Eagle eggs from the Klamath Basin and Cascade Lakes regions collected during 1979–81 contained <0.26 ppm Hg (clutch means) (Frenzel 1985). Eight of 9 Bald Eagles found dead in the same area during 1979–82 had <3 ppm Hg in liver, with 1 bird having 8 ppm (Frenzel 1985). These concentrations are far below those associated with effects on reproduction (0.5 to 1.5 ppm in eggs; Wiemeyer et al. 1984a) or survival (>20 ppm in liver; Finley et al. 1979). Mercury residues in prey of Oregon Bald Eagles also tended to be low (Frenzel 1985).

Some Bald Eagles migrating through GNP may have been exposed to Hg contamination in Canada. Transmitter-equipped Bald Eagles migrating through GNP were tracked to summering areas in Northwest Territories (NWT) and northeastern Alberta, Canada (Young 1983). Elevated Hg concentrations in fish have been reported for several Canadian areas within the migratory corridor of some Bald Eagles passing through GNP, to include: Giauque and Thompson Lakes, 100–125 km north of Great Slave Lake, NWT (Moore and Sutherland 1980); the North Saskatchewan River, near Edmonton, Alberta (Ramamoorthy et al. 1985); and some lakes in northern Saskatchewan, especially Cumberland Lake on the Saskatchewan River (Murray 1978). A Bald Eagle found dead in Montana south of GNP in March 1985 had 35 ppm (wet weight) Hg in liver, a concentration suggesting Hg poisoning.

The western states and British Columbia lie in a mercuriferous belt where underlying rock contains elevated Hg levels (Jonasson and Boyle 1971). This naturally occurring source of Hg in the region may contribute to Hg in food chains and subsequently in Bald Eagles. However, this source should contribute little to Hg found in hatch year Bald Eagles migrating through GNP, their origin in Canada being outside the mercuriferous belt. Mercury residues in blood of hatch year Bald Eagles sampled in GNP were not correlated (P > 0.05) with date of collection.

Lack of information relating known exposures of Hg to concentrations in blood and effects on health of Bald Eagles prevents adequate interpretation of our data. Therefore, risk cannot be assessed. The presence of highly elevated concentrations in a few birds is cause for concern. Data on sources of exposure could lead to control thus reducing risk to Bald Eagles.

Organochlorines. Direct comparisons of DDE concentrations between samples that were preserved by freezing and those that were preserved with formalin should be conducted with caution (see Methods).

Organochlorine concentrations in plasma or serum of birds have been significantly correlated with concentrations in tissues, making possible the monitoring of contamination in wild populations without sacrifice of birds (Capen and Leiker 1979; Friend et al. 1979; Henny and Meeker 1981). The nature of the relationship between organochlorine concentrations in whole blood and that in carcass or other tissues is unknown for Bald Eagles. Henny and Meeker (1981) predicted DDE burdens in eggs based

on residues in plasma of laying females for American Kestrels (*Falco sparverius*) and accipiters. Application of predictive equations to our data is questionable because of differences in residue concentrations between plasma and whole blood and possible species differences. Plasma should contain about twice the concentration in whole blood. Relative DDE concentrations in blood from resident adult Bald Eagles from Oregon were similar to the relative DDE concentrations in eggs (Frenzel 1985). Concentrations of DDE in eggs from the southern Oregon population were high enough to be associated with eggshell thinning and reproductive failure for a few breeding pairs (Wiemeyer et al. 1984a; Frenzel 1985). A few resident adult Bald Eagles from Oregon had clearly elevated DDE concentrations in blood. Henny et al. (1981) found low Σ DDT (almost all DDE) concentrations ($\bar{x} = 0.06$–0.14 ppm) in plasma of Bald Eagles wintering in Colorado and Missouri in 1977–78. Organochlorine concentrations in the environment have declined following bans and restrictions on usage which should result in continuation of reduced risks to Bald Eagles.

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HAZARDS TO RAPTORS FROM STRYCHNINE POISONED GROUND SQUIRRELS

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Abstract.—To evaluate the potential for secondary poisoning of raptors from poisoning campaigns for ground squirrels, we placed eviscerated, strychnine-poisoned Richardson's Ground Squirrels (*Spermophilus richardsonii*) into Swainson's Hawk (*Buteo swainsoni*) nests and monitored nestling survival. Of 52 nestlings which consumed 67 poisoned ground squirrels, 49 nestlings survived the treatment period. We could not detect a difference in growth rates between treated and control nestlings, nor a difference in survival after the treatment period. We present evidence to suggest that raptors eviscerate ground squirrels prior to consumption. This evisceration probably has a profound influence on the survival of raptors scavenging poisoned ground squirrels.

Use of poisons to control unwanted wildlife poses potential threats to predators and other non-target species (Mendenhall and Pank 1980; Townsend et al. 1981; Holler and Schafer 1982; Merson et al. 1984; Marsh et al. 1987; Hegdal and Colvin 1988). Strychnine, the active ingredient in several forms of ground squirrel poison (e.g., "Gopher Cop"® or "Strychnine Gopher-kill Liquid"®), is highly toxic to birds; LD_{50}s for most species tested ranged from 2–25 mg/kg (Hudson et al. 1984). Strychnine has been implicated in the mortality of several species of raptors (Reidinger and Crabtree 1974; Cromartie et al. 1975; Kaiser et al. 1980; Redig et al. 1982; Bortolotti 1984; Reichel et al. 1984). Strychnine is used throughout prairie Canada each year to poison Richardson's Ground Squirrels (*Spermophilus richardsonii*), and usage will probably continue until alternative, biological methods of control become available (e.g. Wodzicki 1973).

In this study we attempted to determine the potential threat to young hawks that are fed poisoned ground squirrels. Nestling hawks may be more subject to secondary poisoning because they, unlike adults (e.g., Brett et al. 1976), have less opportunity to reject poisoned prey. Cheney et al. (1987) found that even some adults did not learn to avoid strychnine-laced mice in captivity. We examined the survival and growth rate of nestling Swainson's Hawks (*Buteo swainsoni*) into whose nests we placed poisoned ground squirrels. We selected Swainson's Hawks for this study because >65% of their prey biomass was comprised of ground squirrels (Schmutz et al. 1980), and because Swainson's Hawks nested preferentially in cultivated areas (Schmutz 1987, 1989) where ground squirrels are poisoned. We also studied the frequency with which poisoned ground squirrels died above ground and were available to scavenging hawks. Rather than examining the effect of known amounts of poison on hawks, we simulated field conditions in an attempt to determine the magnitude of the threat under current poisoning practices.

Study Area and Methods

This work was carried out adjacent to a study area near Hanna, Alberta (Schmutz et al. 1980). The area consisted of mixed-grass prairie in a semi-arid climate. The primary land use was grazing of cattle with 14% of the land under dry-land cultivation for cereal production.

To evaluate the potential impact of poisoning of ground squirrels on raptors, we offered poisoned ground squirrels to nestling Swainson's Hawks. Ground squirrels were captured locally using live traps (#102 and #103; Tomahawk Live Trap Co., Tomahawk, Wisconsin). Squirrels were held, one to a trap, in a ventilated room and offered water and approximately 200 g of poison-coated grain immediately after capture. "Strychnine Gopher-kill Liquid"® (Sanex Inc., Mississauga, Ontario; Registration No. 15849) containing 2% strychnine was used to coat oats according to the manufacturer's instructions. Up to 24 hr elapsed until some squirrels died, but most died within 12 hr. After a squirrel's death, we removed stomach, large intestine and small intestine, and marked the squirrel with two monel metal tags. One squirrel was deposited into a Swainson's Hawk nest (treated nest) on each of 3 consecutive d unless the nestlings had died. In the evening of the third day we visited the nests a second time to determine the fate of deposited prey and of nestlings. We chose a 3-d period assuming that this would approximate the period during which dead squirrels would be available to hawks during actual poisoning campaigns. All prey items found in treated nests were removed during daily visits. Prey items in control nests were not removed nor was prey added. These "control nests" did not represent a true control because of a net addition of food to treated nests Sixty-nine ground squirrels were added to treated nests but only 23 prey items found were removed.

Nestlings were weighed during daily visits between 9–28 July 1988. To account for varying amounts of crop contents at the time of weighing, we subtracted 10% of a nestling's mass if the crop was judged full and propor-

tionately less if partially full. Age of nestlings at the start of the treatment period varied, as reflected in their body mass (J. K. Schmutz 1977). Mean age of 52 nestlings in "treated" nests was 13 d (range 2–26). Mean age of "control" nestlings was 16 d (range 3–25).

We compared reproductive performance among 3 groups of nests to examine the impact of poisoned food on nestlings. Twenty-five treated nests were selected just outside the eastern edge of a study area which was part of a long-term, ecological study of prairie raptors (e.g., Schmutz et al 1980). Treated nests were interspersed with 13 "control nests." We assumed that the effect of poison on nestlings was independent of the amount of food available to them. We also compared the number of young fledged from treated nests with the success of a large sample of nesting pairs on the adjacent study area. To determine whether Swainson's Hawks actually scavenge dead squirrels, we placed 3 marked, unpoisoned ground squirrels within 30 m of each of 4 nests.

To examine whether placement of poison in or outside a burrow affected whether squirrels die above ground or below, we distributed poison on 9 plots of approximately 0 5 ha each. Poison was placed either inside the burrow (4 plots selected at random) or, contrary to the manufacturer's recommendation, atop a mound adjacent to a burrow entrance (5 plots). We returned the next day and recorded the number of dead ground squirrels outside a burrow. At this time, we plugged 25 burrow entrances with dry vegetation on each of 6 plots (3 plots with poison outside of burrows and 3 within). We recorded the number of plugged burrows that had been opened the following day and compared these proportions in relation to where poison was placed (atop or inside a burrow). We used burrows in the center of a poisoned area to minimize counting dispersing squirrels using the plugged burrows.

RESULTS

Observations of Raptor Feeding Behavior. Swainson's Hawks and other raptors may be subject to secondary poisoning if they scavenge dead or take dying squirrels. We did not visit those nests where ground squirrels were placed on the ground frequently enough to document the fate of all squirrels. One marked squirrel was taken to the nest by a Swainson's Hawk. All other marked squirrels had disappeared. On 5 other occasions we have observed Swainson's Hawks attempt to or actually retrieve road-killed Richardson's Ground Squirrels. In addition, 2 crushed ground squirrels, evidently road killed, were found in nests during a study of food habits (Schmutz et al. 1980).

The impact of secondary poisoning on raptors could be much reduced if raptors rejected viscera. Some of our ground squirrels died only hrs after the consumption of poisoned bait, presumably after sufficient poison had been absorbed into the blood stream. Excess poisoned grain was contained in the squirrels' stomachs. We removed stomach, and large and small intestine as the hawks did. Of 91 whole ground squirrels found in Ferruginous Hawk (*B. regalis*) nests and of 20 in Swainson's Hawk nests, 64 (70%) and 11 (55%) respectively had been eviscerated. Our additional observations of raptors indicate that the viscera are actually rejected. We observed a Northern Harrier (*Circus cyaneus*), a Ferruginous Hawk and 2 Swainson's Hawks kill ground squirrels, pull out the viscera in 2–3 strokes and drop the viscera onto the ground. The Ferruginous Hawk subsequently offered the ground squirrel to nearby fledglings without feeding itself. In 7 additional cases we observed a Northern Harrier, a fledgling Ferruginous Hawk, a Red-tailed Hawk (*B. jamaicensis*), and 4 Swainson's Hawks (1 fledgling) eat a duck, 5 ground squirrels or a mouse, with viscera lying on the ground within 1 m of the carcass. A captive Great Horned Owl (*Bubo virginianus*) rejected viscera when the entire ground squirrel was offered as food. We found mouse viscera discarded at the entrances into the nests of Burrowing Owls (*Athene cunicularia*) at least 8 times. The rejection of viscera may be related to prey size relative to raptor size because we observed a Short-eared Owl (*Asio flammeus*) swallowing viscera of a mouse consumed in pieces. In 29 cases we were able to examine portions of viscera that were found on the ground at kill sites or had been removed from squirrels found otherwise whole in nests (Fig. 1). In these cases the liver was attached to other rejected parts and may have been discarded accidentally.

Of 69 poisoned squirrels placed into treated nests, 6 were seen partially consumed 8–24 hr later. Sixty squirrels had disappeared from the nests and presumably had been consumed. Three squirrels were uneaten. We believe that all poisoned ground squirrels offered to surviving nestlings (67 squirrels) were eaten. In a previous study in which food was supplemented (Schmutz et al. 1980), excess food was reluctantly discarded by the parents if at all. Food began to rot and later dry up in the nests.

Hawk Survival. No adult mortality was evident in this study. Two adults were seen after the treatment period at all nests. We examined the potential impact of poisoning on nestlings in 3 ways, by (1) recording survival during the 3 treatment days, (2) monitoring survival after the treatment period, and (3) by comparing growth. Three of a total of 58 nestlings may have died from secondary poisoning. Three poisoned ground squirrels had disappeared
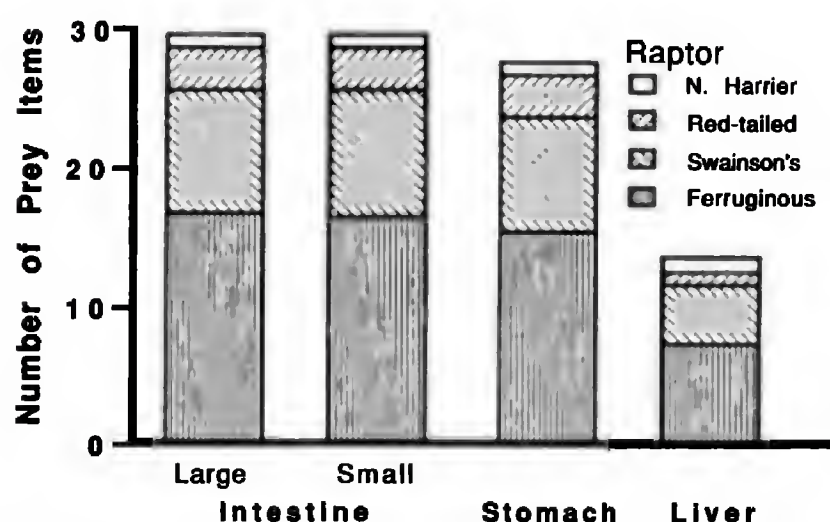
Figure 1.   Portions of the gastrointestinal tract removed by various raptors from a duck, a vole, a songbird and 26 Richardson's Ground Squirrels.
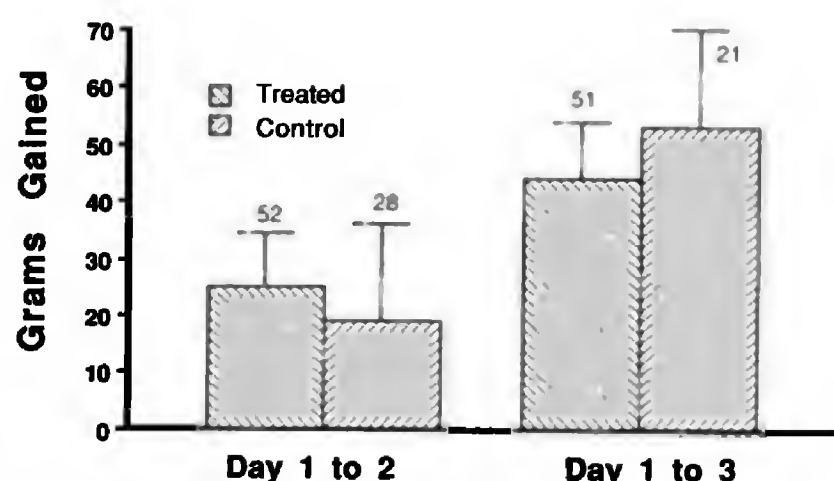

Figure 2.   Growth of control and treated nestling Swainson's hawks which were fed strychnine-poisoned Richardson's ground squirrels over a three day period in southeastern Alberta. Lines represent standard error and numbers = sample size. Seven nestlings in control nests were not weighed on day 3 due to time constraints.

in these nests and had presumably been consumed. One partially eaten squirrel remained. An additional six nestlings died in 2 nests between the first and second visits before actually consuming any of the poisoned ground squirrels. These 2 nests were hence excluded from further analysis. Three of these 6 nestlings were partially consumed, suggesting predation as a possible cause of death. None of 28 nestlings in control nests died during this 3-d period. There was no significant difference in the survival between 52 treated and 28 control nestlings during the treatment period (χ^2 = 1.68, P = 0.195).

All nests were visited a final time for banding. At this time no differences in brood size could be detected. Of the 52 nestlings in treated nests, 42 (72%) survived from the conclusion of the treatment period to the time of banding, an average of 12 d later (range 5–21 d). In control nests 23 of 28 (82%) nestlings survived to banding, an average of 10 d later (range 3–20; χ^2 = 0.97, P = 0.325). Successful, treated pairs raised an average of 2.0, as did successful pairs which were not part of this study on the adjacent study area. Successful control pairs raised an average of 1.8 young.

Nestling Body Mass. Average mass of treated and control nestlings increased throughout the period (Fig. 2). On the third day, at the end of the treatment period, there was no significant difference in the mass gained by treated nestlings compared to controls (Mann-Whitney U = 451, P = 0.794).

Poison Placement. Potential for scavenging by raptors was not reduced by placing poison inside ground squirrel burrows. Eighteen squirrels were found at 606 burrows (3.0/100 burrows) at which poison was placed outside compared to 19 squirrels

near 434 burrows (4.4/100 burrows) where poison was placed within. Whether poison was placed outside or inside the burrow also had no significant influence on squirrel survival based on the frequency with which plugged burrows were opened. Thirty-two of 75 burrows with poison placed above ground were opened a day later, compared to 30 of 75 burrows with poison placed below ground (χ^2 = 0.11, P = 0.740).

DISCUSSION

Absence of a clear indication of reduced survival due to secondary poisoning among treated nestling Swainson's Hawks was unexpected. There was also no evidence that nestling growth was affected by the treatment. If local environmental conditions had any bearing on the outcome of this study, the drought conditions of 1988 may have worsened the impact. We attempted to simulate actual field conditions and conclude that under those conditions, secondary poisoning through ground squirrels is a minor threat for Swainson's Hawks. Other buteonine hawks may be similarly unaffected since it is unlikely that Swainson's Hawks are unique with regard to the threat of secondary poisoning.

We could not control some variables in this field study. Our daily visits may have had a detrimental impact (e.g., White and Thurow 1985). We also did not know how much "clean" food was brought to nestlings by their parents, a factor which may similarly lessen the impact of actual poisoning campaigns.

Population performance of pairs of Ferruginous and Swainson's Hawks monitored during the last 13 years is consistent with a minor (if any) impact from secondary poisoning in the area. In 1986 strychnine use (1782 l of "Gopher Cop" in the Hanna area alone) was greater than during any other year in the last decade (Schmutz and Hungle 1989). Landowners distributed more poison in response to an increase in ground squirrel abundance. Nesting densities on the study area of both species were also higher in 1986 than during the preceding 10 yrs. Brood size among Ferruginous Hawks was greater in 1986 than during years of low strychnine use, while brood size of Swainson's hawks remained unchanged. Hegdal and Gatz (1977) also could not detect a detriment to raptors arising from ground squirrel poisoning. Some mortalities did occur but could not be attributed to the poisoning. Two Great Horned Owls monitored using radiotelemetry in their study, frequented the treatment area and were alive 4 mo after treatment.

Evisceration of poisoned ground squirrels is without doubt an important factor affecting the hazard to raptors. However, even eviscerated squirrels sometimes contained poisoned bait in their cheek pouches which could pose a threat. Our conclusion of a minor impact on raptors presupposes that the gastrointestinal tract of poisoned ground squirrels is not eaten. As soon as strychnine is absorbed into the blood stream, death probably occurs quickly, allowing relatively little strychnine to be present in the flesh. Raptors under food stress, however, may devour parts or all of a poisoned gastrointestinal tract and die.

Evisceration of prey prior to consumption is not unique to the raptors studied. Vatev (1987) found an eviscerated vole in a nest of Long-legged Buzzard (*B. rufinus*) in Bulgaria. Poole and Boag (1988) found that Gyrfalcon (*Falco rusticolus*) in Canada's north eviscerated Rock Ptarmigan (*Lagopus mutus*) and Arctic Ground Squirrel (*Spermophilus parryii*). Falcons frequently left the stomach and intestines of large prey on the nest site but ate small passerines and microtines entirely.

Mammalian predators which may eat ground squirrel viscera face a greater danger from secondary poisoning than do hawks. Marsh et al. (1987) found, however, that Coyotes (*Canis latrans*) rejected viscera from strychnine-poisoned ground squirrels 66% of the time. One coyote died in their study. On our study area, one landowner's dog died after eating ground squirrels from a poisoned area. The potential threat to livestock arising from poison-coated grain is well recognized by landowners.

Efforts to estimate the potential impact from secondary poisoning to wildlife assume that poison users adhere to recommended procedure. Regulatory measures to protect wildlife may have little effect if not widely adhered to. Some landowners canvassed by us deliberately used more than the recommended dose in preparing bait; others used less. The prevailing practice was to spread poison in a given area once and to repeat poisoning 10–14 d later, depending on the degree of Richardson's Ground Squirrel survival and immigration. In some cases poisoned bait was placed inside a tire which resulted in persistent exposure to squirrels and thus to raptors. The influence of these deviations from recommended practice on secondary threats to wildlife is not known.

Because of their characteristic dispersal tendencies, especially by juveniles in July, squirrel populations are resilient to periodic, local eradication (Schmutz et al. 1979). Even adults removed in May–June repopulated a 4 ha plot to near former levels in <1 month (S. M. Schmutz 1977). From our experience, many landowners would attempt to ameliorate secondary impacts if made aware of the threat to non-target wildlife. Granivorous birds apparently face a greater threat from ground squirrel poisoning than do raptors. In a study in south-central Wyoming Hegdal and Gatz (1977) detected strychnine residues in the gastrointestinal tract of dead birds found in the area where poison had been broadcast. Casualty species included Mallard (*Anas platyrhynchos*), Mourning Dove (*Zenaida macroura*), Horned Lark (*Eremophila alpestris*), American Crow (*Corvus brachyrhynchos*), European Starling (*Sturnus vulgaris*), Yellow-headed (*Xanthocephalus xanthocephalus*), Red-winged (*Agelaius phoeniceus*) and Brewer's Blackbird (*Euphagus cyanocephalus*), Brown-headed Cowbird (*Molothrus ater*), and Savannah (*Passerculus sandwichensis*), and Vesper Sparrow (*Pooecetes gramineus*). No strychnine was detected in birds that were collected by various means outside the broadcast area. Horned Larks and Mourning Doves were most vulnerable, galliforms least vulnerable.

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SURVEYS FOR WINTERING BIRDS OF PREY IN SOUTHEASTERN COLORADO: 1983-1988

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ABSTRACT.—From 1983 through 1988 we conducted 45 road surveys for wintering birds of prey on the Piñon Canyon Maneuver Site in southeastern Colorado. Surveys were conducted from January through mid-March along a 75.7 km survey route that passed through pinyon (*Pinus edulis*)-juniper (*Juniperus monosperma*) and shortgrass prairie habitat. Twelve raptor species were sighted on these surveys, with Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*), Golden Eagle (*Aquila chrysaetos*), and Loggerhead Shrike (*Lanius ludovicianus*) together representing over 73% of all sightings. As a group, birds of prey were consistently sighted most frequently (raptors/km) along the limestone breaks/ pinyon-juniper section of the survey route (P < 0.05). Indices to overall raptor abundance varied little among winters, although relative abundance varied significantly during the 6-year period (P < 0.05).

Road surveys have historically been used to index densities of wintering birds of prey (Nice 1934; Leopold 1942; Craig 1978; Fuller and Mosher 1981). These surveys have also been used to estimate density (Andersen et al. 1985), distribution (Gessaman 1982), and total population size (Craighead and Craighead 1956; Woffinden and Murphy 1977; Bildstein 1978), determine perch (Marion and Ryder 1975; Preston 1980) and habitat use (Koplin 1973; Fischer et al. 1984), and make comparisons in relative abundance among years and areas (Johnson and Enderson 1972; Bauer 1982). However, most surveys in open habitats have been conducted where utility poles parallel roads, which potentially bias raptor distribution (Stahlecker 1978). Additionally, many surveys have been conducted for only 1 or 2 consecutive winters in a given location.

Here, we report on the results of road surveys for wintering birds of prey that were conducted for 6 consecutive winters in an area where utility poles were not present along roads. Our objectives were to index wintering populations of birds of prey and to determine which habitats in southeastern Colorado consistently were used by wintering raptors.

STUDY AREA AND METHODS

Road surveys were conducted on the 1040 km² Piñon Canyon Maneuver Site (PCMS), in Las Animas County in southeastern Colorado. Elevation on PCMS ranged from 1300-1700 m, and topography consisted of broad, moderately sloping uplands bordered by the Purgatoire River Canyon on the east, limestone hills on the west, and a basalt hogback on the south (U.S. Dept. Army 1980). Annual precipitation averaged approximately 32 cm, fluctuating widely from year to year and between areas of the parcel (U.S. Dept. Army 1980). Climate was classified as mid-latitude semiarid and mean monthly temperature ranged from −1°C in January to 23°C in July.

Vegetation on PCMS was dominated by shortgrass prairie and pinyon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodland (Costello 1954; Kendeigh 1961). Three major and distinct habitats occurred on PCMS (Fig. 1). sandstone breaks/pinyon-juniper (sandstone) habitat occurred along the Purgatoire River Canyon and associated side canyons, shortgrass prairie (prairie) habitat covered the central, northern, and extreme western portion of PCMS, and limestone breaks/pinyon-juniper habitat (limestone) occurred in the west and northwest portions. Blue grama (*Bouteloua gracilis*), alkali sacaton (*Sporobolus airoides*), galleta (*Hilaria jamesii*), western wheatgrass (*Agropyron smithii*), walking stick cholla (*Opuntia imbricata*), and small soapweed (*Yucca glauca*) dominated shortgrass prairie vegetation. See Shaw and Diersing (in press) for a detailed description of habitat on PCMS.

We conducted road surveys for wintering birds of prey from 1983 through 1988. Surveys were conducted every 10-14 d from January through mid-March in all winters, except in 1983 when surveys were conducted at 6-d intervals. We selected a 75.7 km route that included 24.6 km (32.5%) of sandstone habitat, 36.0 km (47.6%) of prairie, and 15.1 km (19.9%) of limestone (Fig. 1). The route was selected on the basis of distribution of existing roads that were likely to be passable in winter, and so that each major habitat was represented. Utility poles were largely absent from the PCMS and did not parallel the survey route.

Survey methods followed those outlined by Andersen et al. (1985). For each raptor sighted, we recorded species, age, sex, individual description (color morph), time of sighting, perch characteristics, direction of flight, and behavior, where applicable. Starting points were alternated between ends of the route and we began surveys approximately 0.5 hr after sunrise. Surveys were initiated only on days when estimated wind speed was <10 km/hr and cloud cover was <50%. Two observers participated in all surveys and speed was maintained between 25 and 40 km/ hr. Surveys were completed in 3-4 hrs.

Statistical procedures follow those outlined in Ryan et al. (1976), Snedecor and Cochran (1980), and Sokal and Rohlf (1980). Multiple comparisons were made using the protected least significant difference (LSD) method (Snedecor and Cochran 1980:234) with an experiment-wise al-
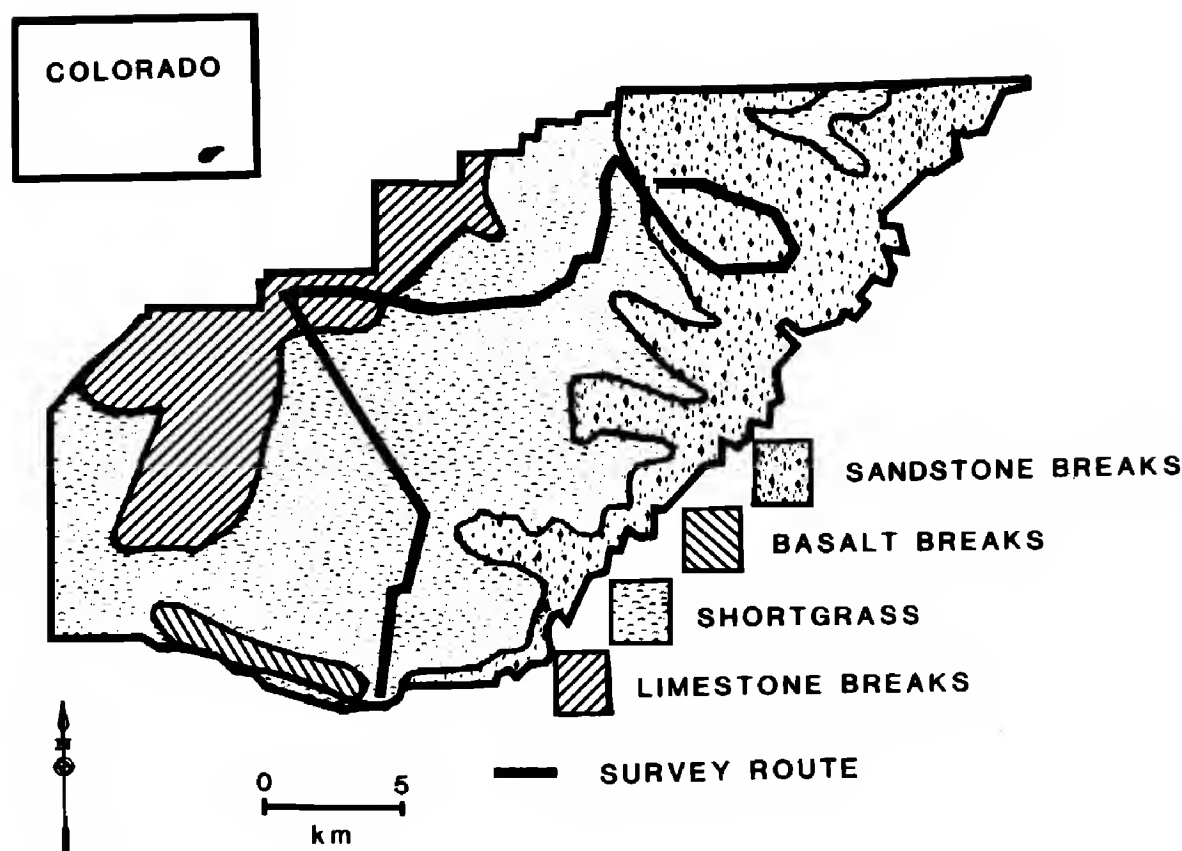
Figure 1. Habitats and survey route for wintering birds of prey on the Piñon Canyon Maneuver Site, Colorado. Sandstone breaks, basalt breaks, and limestone breaks all supported a pinyon-juniper plant association.

pha of 0.05. Surveys were repeated over the same route each winter and we were not able to randomly sample habitats on PCMS. Thus, our analyses do not test for treatment (i.e., habitat) differences (see Hurlbert 1984), only differences among locations in sighting frequency. Years were treated as independent replicates in analysis of variance (ANOVA) procedures.

RESULTS

From 1983 through 1988 we conducted 45 surveys for wintering birds of prey on PCMS. Twelve species of raptorial birds were observed on these surveys (Table 1) with Red-tailed Hawk (48.8%), American Kestrel (13.5%), Golden Eagle (9.4%), and Loggerhead Shrike (9.0%) totalling over 73% of all sightings. Raptors were consistently sighted more frequently in limestone habitats than in either sandstone or prairie habitats (Table 2; 2-way AN-OVA, $F = 5.43$; 2,10 df; $P < 0.05$). Variation among winters in raptor densities on PCMS could be related to factors independent of habitat. We adjusted for annual variation in sighting frequency by subtracting yearly mean sighting frequency (habitats combined) from sighting frequency in each habitat (adjusted sighting frequency). Adjusted sighting frequency was significantly higher in limestone habitats than in either sandstone or prairie habitats (1-way ANOVA, $F = 8.16$; 2,15 df; $P < 0.005$; LSD

procedures), indicating that winter raptor density was also highest along the limestone section of the survey route.

In the winters of 1982–83 ($\chi^2 = 6.22$, 2 df, $P < 0.05$) and 1984–85 ($\chi^2 = 8.14$, 2 df, $P < 0.025$; Table 2) birds of prey were sighted more frequently (unadjusted sighting frequency) than expected in limestone habitats and less frequently than expected in sandstone habitats, based on the proportion of the survey route that passed through each habitat. No significant differences in sighting frequency were found among habitats in the winters of 1983–84, 1985–86, 1986–87, or 1987–88 (χ^2-tests, all Ps > 0.10). Raptors (species combined) were sighted most frequently (sightings/km) in limestone habitats in every winter (N = 6) that surveys were conducted (Exact Randomization Test, $P < 0.005$; Table 2), indicating that raptors were consistently most abundant along the section of the survey route that passed through limestone habitat.

Overall, wintering raptor abundance (species combined) on PCMS was similar among years ($\bar{x} = 14.1$ km/raptor, coefficient of variation = 19.4%). However, counts of individual raptor species sighted on survey routes changed among winters ($\chi^2 = 27.13$, 15 df, $P < 0.05$), indicating that the abundance of different species on PCMS also differed among winters.

Table 1.   Birds of prey sighted on a 75.7 km winter[a] survey route on Piñon Canyon Maneuver Site, Colorado from 1983 through 1988. Number of surveys is given in parentheses.

	WINTER						
SPECIES	82–83 (11)	83–84 (6)	84–85 (8)	85–86 (7)	86–87 (8)	87–88 (5)	TOTAL (45)
Red-tailed Hawk (*Buteo jamaicensis*)	29	16	10	21	20	6	102
American Kestrel (*Falco sparverius*)	4	0	5	10	10	4	33
Golden Eagle (*Aquila chrysaetos*)	6	6	3	1	6	1	23
Loggerhead Shrike (*Lanius ludovicianus*)	2	1	5	7	1	6	22
Prairie Falcon (*Falco mexicanus*)	3	4	2	1	4	3	17
Ferruginous Hawk (*Buteo regalis*)	5	0	0	1	3	1	10
Northern Harrier (*Circus cyaneus*)	0	0	1	0	3	1	5
Rough-legged Hawk (*Buteo lagopus*)	0	2	5	2	2	0	11
Merlin (*Falco columbarius*)	0	0	2	1	1	4	8
Cooper's hawk (*Accipiter cooperii*)	0	1	1	1	0	2	5
Sharp-shinned Hawk (*Accipiter striatus*)	0	2	0	1	1	1	5
Bald Eagle (*Haliaeetus leucocephalus*)	0	0	0	0	2	0	2
Unidentified	0	1	0	0	0	0	1
Total	49	33	34	46	53	29	244
km/sighting	17.0	13.8	17.8	11.5	11.4	13.0	14.1

[a] Surveys were conducted in January, February, and early March.

DISCUSSION

Wintering birds of prey were consistently sighted more frequently in limestone than in any other habitat. Sighting probabilities can differ among habitat types or years (Andersen et al. 1985), although because the number of sightings/habitat/year for each species was small, we were unable to estimate detection functions or raptor densities. However, the probability of detecting a raptor in sandstone and prairie habitats was at least as high as in limestone habitats, based on vegetative characteristics that influence detectability (U.S. Dept. Army 1980; Shaw and Diersing, in press; Millsap and LeFranc 1988). Higher sighting frequencies in limestone habitat indicate that densities of wintering raptors were also highest in limestone habitats.

Local prey abundance (Craighead and Craighead 1956; Enderson 1964; Phelan and Robertson 1977; Newton 1979:289) and availability (Sylvèn 1978; Baker and Brooks 1981) influence winter raptor abundance. On PCMS, we did not have an index to winter prey abundance or availability. However, variation among years in raptor abundance was low, indicating either that prey densities were similar among years, or that factors unrelated to fluctuating prey availability influenced raptor abundance (Bildstein 1978).

As an index to abundance, distance travelled per sighting (habitats combined) ranged from 11.4 km (0.087 raptors/km) in 1983–84 to 17.8 km (0.056 raptors/km) in 1984–85. These indices indicate that winter densities of raptors on PCMS were lower than in similar areas in eastern Colorado in other years: 6.3 km/raptor (Enderson 1965), 5.8 km/raptor (Johnson and Enderson 1972), 8.9 km/raptor (Bauer 1982), and 5.4–8.7 km/raptor (Andersen 1984). Excluding shrikes (to make results comparable with cited studies), distance travelled/sighting on PCMS ranged from 7.7 km in 1983–84 to 20.9 in 1984–85. However, other studies were conducted where utility poles paralleled the survey route (except Andersen 1984) which likely influenced winter raptor distribution (Enderson 1964; Stahlecker 1978) by concentrating raptors along the survey route and increasing the probability of being observed. Thus, winter density on PCMS may be similar to other areas of eastern Colorado where surveys have been conducted and winter sighting frequency on PCMS may be a useful index of winter raptor density in eastern Colorado.

Table 2. Raptors sighted (by habitat) during winter road surveys conducted on Piñon Canyon Maneuver Site, Colorado from 1983 through 1988. The total survey route was 75.7 km, of which 24.6 km (32.5%) was sandstone, 36.0 km (47.6%) was prairie, and 15.1 km (19.9%) was limestone habitats.

		HABITAT					
		SANDSTONE		PRAIRIE		LIMESTONE	
WINTER	NO. OF SURVEYS	N	KM/SIGHTING	N	KM/SIGHTING	N	KM/SIGHTING
82–83	11	10	24.5	23	17.2	16	10.5
83–84	6	12	12.3	12	18.0	9	10.1
84–85	8	6	32.8	15	19.2	13	9.3
85–86	7	15	11.5	17	14.8	14	7.6
86–87	8	13	15.1	26	11.1	14	8.4
87–88	5	11	11.2	9	20.0	9	8.4
$\bar{x}$			17.9		16.7		9.0

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FOOD HABITS OF NESTING PRAIRIE FALCONS IN CAMPBELL COUNTY, WYOMING

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ABSTRACT.—Fifteen species of prey were utilized by nesting Prairie Falcons (*Falco mexicanus*) as determined through pellet analysis. Thirteen-lined Ground Squirrels (*Spermophilus tridecemlineatus*), the most common prey, were present in 91% of the pellets, followed by Western Meadowlarks (*Sturnella neglecta*) which were present in 56% of pellets. Horned Larks (*Eremophila alpestris*) and Lark Buntings (*Calamospiza melanocorys*) were found in 23% and 12% of the pellets, respectively. Additional prey species were present in low frequencies (≤5%). Eighty-nine percent of pellets contained both bird and mammal remains. Four percent of pellets contained only bird remains while 7% contained only mammalian remains.

The Prairie Falcon (*Falco mexicanus*) is an open-country raptor that forages on a diversity of birds and small mammals (Enderson 1962; Denton 1975; Becker 1979; Boyce 1985). Diets of nesting Prairie Falcons depend on local prey abundance. For example, some nesting Prairie Falcons forage primarily on mammalian prey (Porter et al. 1973; Ogden and Hornocker 1977), while others forage primarily on avian prey (Marti and Braun 1975; Becker 1979; Boyce 1985). Therefore, predicting falcon diets based on studies from different areas is difficult.

Our analysis of Prairie Falcon diet was part of a larger study that investigated movements and habitat-use patterns. Our objective was to determine important prey species used by a small population of nesting Prairie Falcons in northeastern Wyoming.

STUDY AREA AND METHODS

The study area located in northcentral Wyoming included the Pumpkin Butte formation, which contains 5 buttes used by a small, isolated population of nesting Prairie Falcons ($\bar{x}$ = 6 pairs/yr). Average distance between occupied territories was 0.56 km, and prairies surrounding the buttes were either sagebrush (*Artemisia tridentata*) steppes or open grasslands.

Pellets and prey remains were collected at falcon eyries from 1982 through 1985. Mammalian prey were identified by examining both internal and external hair characteristics and through comparisons with specimens collected at the study site. Hair identification procedures were conducted according to those outlined by Moore et al. (1974). Avian remains in pellets were identified by comparing characteristic feather, beak, and bone fragments with the University of Wyoming's museum collection.

Pellet analysis cannot be used to directly quantify the number of prey items consumed due to several biases associated with the technique (Craighead and Craighead 1956). For example, adult falcons have been observed removing pellets and uneaten prey remains from their nest site (Fowler 1931; Wayre and Jolly 1958). Therefore, the percentage of prey items in the diet as determined through analysis of pellet and prey remains should be interpreted as an approximation of the falcon's true diet. To supple-

ment data gathered from pellet and prey remain analyses, foraging falcons were observed when possible.

Prey Abundance Indices. During 1984 and 1985, birds and small mammals were sampled on transects that were established in areas frequently used by foraging falcons Transect sampling was used as an index of the relative abundance of prey species and to document changes in prey abundance between years. All prey-sized birds occurring along a 1.6 km, walked, belt-transect were counted. Bird transects (N = 6) were censused twice each summer between July 2 and July 16, at approximately 0.5 hr after sunrise.

Each small mammal transect (N = 4) consisted of 100 Sherman live-traps placed 10 m apart that were trapped for 2 successive days and nights. Traps were baited with a mixture of peanut butter and oats. Traps were checked approximately 1 hr after sunrise and 1 hr before sunset. All transects were sampled between 8 July and 24 July during both years.

Transect data were compared using *t*-Tests [STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES (SPSS), Nie et al. 1975; α = 0.05]. The 2 replicates of the 1984 indices were averaged and then compared to the average of 1985 indices.

RESULTS

Food Habits. A total of 243 pellets, plus prey remains from 9 eyries, were examined. At least 15 prey species were used by this population of Prairie Falcons (Table 1). Four species, Thirteen-lined Ground Squirrels (*Spermophilus tridecemlineatus*), Western Meadowlarks (*Sturnella neglecta*), Horned Larks (*Eremophila alpestris*) and Lark Buntings (*Calamospiza melanocorys*) were important prey species during each year of the study (Table 2). Most of the remaining prey species occurred in pellets in low frequencies (≤5%). Eighty-nine percent of the pellets contained both bird and mammal remains. Four percent of the pellets contained only bird remains while 7% contained only mammalian remains.

Foraging Behavior. Foraging falcons used low, flushing-type flights when hunting. Typically, fal-

Table 1. Food items in pellets of Prairie Falcons nesting in Campbell County, Wyoming, 1982–85.

PREY SPECIES	NUMBER OF PELLETS CONTAINING PREY ITEM	PERCENT PELLETS WITH PREY ITEM
Mammals		
13-lined ground squirrel (*Spermophilus tridecemlineatus*)	221	91
Least Chipmunk (*Eutamias minimus*)	7	3
Leporidae spp.	8	3
Unknown mammal	2	1
Mule Deer (*Odocoileus hemionus*)	1	<1
Birds		
Western Meadowlark (*Sturnella neglecta*)	135	56
Horned Lark (*Eremophila alpestris*)	55	23
Unknown passerine	45	19
Lark Bunting (*Calamospiza melanocorys*)	28	12
McCown's Longspur (*Calcarius mccownii*)	13	5
Brewer's Sparrow (*Spizella breweri*)	4	2
Pinyon Jay (*Gymnorhinus cyanocephalus*)	2	1
Brewer's Blackbird (*Euphagus cyanocephalus*)	1	<1
Northern Flicker (*Colaptes auratus*)	remains*	<1
Anseriform spp.	remains	<1
Mollusks		
Gastropoda spp.	1	<1

* Remains found in eyrie.

cons would attempt to surprise prey by flying approximately 6 m off the ground while traveling rapidly down draws. Falcons using fast, contour-hugging flights have been noted by other researchers (Webster 1944; Dunstan et al. 1978). Foraging falcons were also observed "still hunting" from fence posts, telephone poles, and high-tension power poles.

On 16 June 1984, a male falcon was observed hunting Cliff Swallows (*Hirundo pyrthonota*). He flew rapidly along a cliff face in an apparent effort to capture swallows leaving their nests. On several occasions, the falcon hung upside from the Cliff Swallow nests while reaching inside, presumably to extract nesting swallows or their young. The falcon was unsuccessful though persistent in capturing swallows during these observations, however which suggests that the foraging technique must at times be successful.

A single case of kleptoparasitism was observed when a male falcon forced a Northern Harrier (*Circus cyaneus*) to drop a mouse which the falcon retrieved. Both the methods of hunting cliff swallows and prey piracy from a Northern Harrier were also documented by Holthuijzen et al. (1987).

Prey Abundance Indices—Passerine Birds. Fifteen species of birds were observed on bird transects (Table 3). Lark Buntings, Brewer's Sparrows, Horned Larks, and Vesper Sparrows (*Pooecetes gramineus*) were present on >75% of all transects suggesting an even distribution on falcon foraging areas. Remaining species were observed infrequently (on ≤13% of the transects).

The t-Test statistic was used to test the null hypothesis that both 1984 and 1985 bird transects had equal bird numbers. We failed to accept the null hypothesis (P = 0.019) in favor of the alternate hypothesis which suggested that significantly more prey-sized birds were present on falcon foraging areas in 1985 than in 1984.

Prey Abundance Indices—Small Mammals. During 800 trap days and 800 trap nights, a total of 166 small mammals from 3 species were captured (Table 4). A total of 141 Thirteen-lined Ground Squirrels were captured accounting for 85% of total captures. This was the only species captured during day trapping while all 3 species were captured at night. However, 23 Thirteen-lined Ground Squirrels classified as night captures were probably trapped either early morning or late evening and did not represent nocturnal activities for the species (Murie and Michener 1984).

The only species captured on transect 1 located in a grassland habitat was Thirteen-lined Ground Squirrel while all 3 species were captured on the other transects located in mixed grass-sage habitat types (Table 4). The greatest number of small mammals were captured on transect 4 which was located in a similar habitat type as were transects 2 and 3 but in an area of very sandy soil.

The t-Test statistic was used to test the null hypothesis that the numbers of small mammals cap-

Table 2.   Percent frequency of prey remains found in Prairie Falcon pellets according to year (1982–85), Campbell County, Wyoming.

	1982 (N = 21)	1983 (N = 91)	1984 (N = 57)	1985 (N = 74)	Four Yr. Wt. Ave.
Mammals					
13-lined Ground Squirrel (*Spermophilus tridecemlineatus*)	95	95	75	97	91
Least Chipmunk (*Eutamias minimus*)	5	2	7	—*	3
Leporidae spp.	—	7	2	—	6
Mule Deer (*Odocoileus hemionus*)	—	—	2	—	tr**
Unknown mammal	10	1	—	—	1
Birds					
Western Meadowlark (*Sturnella neglecta*)	81	66	53	38	56
Horned Lark (*Eremophila alpestris*)	24	29	26	10	22
Lark Bunting (*Calamospiza melanocorys*)	14	19	4	11	13
McCown's Longspur (*Calcarius mccownii*)	19	4	7	3	6
Brewer's Sparrow (*Spizella breweri*)	—	4	—	—	1
Brewer's Blackbird (*Euphagus cyanocephalus*)	—	1	—	—	tr
Pinyon Jay (*Gymnorhinus cyanocephalus*)	—	—	—	3	1
American Kestrel (*Falco sparverius*)	—	—	2	—	tr
Unknown passerine	—	10	9	43	19
Mollusks					
Gastropoda spp.	—	1	—	—	tr

* Prey item not present.
** tr = trace.

tured in 1984 and 1985 were equal. We failed to reject this hypothesis (P = 0.785) suggesting that no significant differences in the number of small mammals were present between years.

DISCUSSION

Prairie Falcons at Pumpkin Butte used Thirteen-lined Ground Squirrels as their primary prey species during the nesting season. Thirteen-lined Ground Squirrel litters emerge from their burrows in mid-June (Streubel and Fitzgerald 1978) making them highly available to foraging falcons.

Ninety-three percent of pellets contained some feather remains indicating these falcons frequently foraged on birds. Other studies have documented similar high use of avian prey by nesting Prairie Falcons (Marti and Braun 1975; Denton 1975; Peterson et al. 1977; Voilker, unpublished data cited in Sherrod 1978; Becker 1979). However, Mac-Laren (1986) found that pellets from Prairie Falcons in southeastern Wyoming were dominated by mammalian prey (86.3%) with only 13.7% containing avian remains.

Western Meadowlarks were the primary avian prey found in 56% of the pellets in our study. However, meadowlarks were not the most common prey-sized bird present on the study area according to our bird transects. Prairie Falcons may actively select meadowlarks, even though other avian prey were more abundant. Other researchers have also noted a similar high incidence of meadowlark in Prairie Falcon diets (Fowler 1931; Enderson 1962; Leedy 1969; Platt 1974; Denton 1975; Becker 1979).

Two pellets contained unusual prey remains for Prairie Falcons. One pellet was composed entirely of Mule Deer (*Odocoileus hemionus*) hair. There are at least 2 possible explanations for such an occurrence. The falcon either fed on deer carrion directly or consumed the stomach of a carrion feeding bird (i.e., Pinyon Jay (*Gymnorhinus cyanocephalus*), Clark's Nutcracker (*Nucifraga columbiana*), Brewer's Blackbird (*Euphagus cyanocephalus*)). The first explanation was thought more probable since the pellet did not contain any feather remains. To our knowledge, this is the first documentation of Prairie Falcons possibly consuming carrion.

The second unusual pellet was composed entirely of aquatic snail shells with no trace of feather or fur

Table 3. Abundance and distribution of birds observed on 6 strip transects of 1.6 km each.

Species	Number Observed	Percentage of Transects on Which Species Were Observed
Lark Bunting (*Calamospiza melanocorys*)	284	88
Brewer's Sparrow (*Spizella breweri*)	176	83
Horned Lark (*Eremophila alpestris*)	174	71
Vesper Sparrow (*Pooecetes gramineus*)	133	75
Mourning Dove (*Zenaida macroura*)	66	25
Cliff Swallow (*Petrochelidon pyrrhonota*)	47	8
McCown's Longspur (*Calcarius mccownii*)	43	13
Brewer's Blackbird (*Euphagus cyanocephalus*)	22	13
Western Meadowlark (*Sturnella neglecta*)	14	25
Lark Sparrow (*Chondestes grammacus*)	6	13
Sage Thrasher (*Oreoscoptes montanus*)	2	4
Common Nighthawk (*Chordeiles minor*)	2	4
Chestnut-collared Longspur (*Calcarius ornatus*)	2	4
Red-winged Blackbird (*Agelaius phoeniceus*)	2	4
Killdeer (*Charadrius vociferus*)	1	4

remains. It is difficult to envision how a Prairie Falcon would encounter snails while foraging. Possibly, the falcon ate the stomach of an aquatic-feeding bird (Killdeer (*Charadrius vociferus*) or waterfowl) which contained the shells, but no feather remains were present in the pellet. The falcon might have selectively picked snails from aquatic vegetation while drinking or bathing. Other species of birds do consume snails with shells to help meet their calcium requirements (Krapu and Swanson 1975; Beasom

Table 4. The number of small mammals captured on live-trap transects during 1984–85, Campbell County, Wyoming.

Transect Number (Year)	Thirteen-lined Ground Squirrel		Deer Mouse		Grasshopper Mouse	
	Day	Night	Day	Night	Day	Night
1-(1984)	9	0	0	0	0	0
1-(1985)	14	2	0	0	0	0
2-(1984)	8	0	0	4	0	0
2-(1985)	11	5	0	7	0	1
3-(1984)	2	0	0	0	0	0
3-(1985)	2	1	0	2	0	1
4-(1984)	39	6	0	2	0	5
4-(1985)	33	9	0	1	0	2
Total	118	23	0	16	0	9

and Patte 1978; Ankney and Scott 1980). It is possible that Prairie Falcons also consume snails to compensate for calcium deficiencies incurred during egg production.

In summary, Prairie Falcons at Pumpkin Butte foraged on a diversity of prey that included at least 15 species. However, 4 species, Thirteen-lined Ground Squirrel, Western Meadowlark, Horned Lark, and Lark Bunting comprised the bulk of the diet. Most pellets (93%) contained feather remains suggesting that falcons frequently foraged on avian prey.

ACKNOWLEDGMENTS

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OBSERVATIONS ON THE EVENING DEPARTURE AND ACTIVITY OF WINTERING SHORT-EARED OWLS IN NEW JERSEY

THOMAS BOSAKOWSKI

ABSTRACT.—Wintering Short-eared Owls (*Asio flammeus*) were primarily crepuscular and nocturnal. Roost departure occurred most frequently after sunset (83%) with most exceptions occurring on heavily overcast days. Owls usually departed singly or in tandem and engaged in a steady direct flight, presumably to a predetermined hunting area. Hunting was rarely initiated near the roost site. Night observations up to 5 hr after sunset revealed that owls hunted continuously into the night and were not merely crepuscular. Despite their reputation as an on-the-wing predator, extended periods of perch-hunting were often observed after sunset, particularly on windless nights. Active hunting from perches was evidenced by a continual series of pounces and hunting flights that were launched from the same or nearby perches. Owls responded on 3 of 5 trials to broadcasts of prerecorded Short-eared Owl calls with vocalizations and/or vigorous circling flights over the calling station.

The Short-eared Owl (*Asio flammeus*) is primarily nocturnal during the winter months, and hence relatively few attempts have been made to study activity patterns and behavior of the species on wintering grounds (e.g., Short and Drew 1962; Clark 1975; Marr and McWhirter 1982). In this paper I present information on evening roost departure, social interactions and hunting activities of wintering Short-eared Owls in New Jersey.

STUDY AREA AND METHODS

The primary study site was an inland tidal marsh known as the Hackensack Meadowlands (Lyndhurst, Bergen Co.) previously described in detail (Bosakowski 1984). Briefly, the marshes are dominated by common reed (*Phragmites communis*) and are surrounded by dense urban development. Several active and inactive landfill mounds are present in the marsh as well as many warehouses, rights-of-way, and occasional light industry. Weather data were obtained from the National Weather Service, Newark International Airport, located 13 km south of the study area.

During the winters of 1982 and 1983, 25 hr of observation were made on 22 different evenings. I usually arrived at least 0.5 hr before sunset to make observations at dusk at a known roosting area (Bosakowski 1986). Observations were continued until at least 0.5 hr after sunset and occasionally up to 1.5 hr. From a 3 m mound, I recorded the number, location, activity, flight direction, and time that owls emerged for initial evening flight. During late winter 1988, an additional 22 hr of observation were conducted on 7 evenings from late afternoon up to 5 hr after sunset in this same general study area, plus 5 hr at the "Sod Farms" of Pine Island (Orange Co., NY), 2 hr at Great Swamp National Wildlife Refuge (Morris Co., NJ), and 2 hr at a Hightstown roost (Monmouth Co., NJ). Evening roost arrival times of coexisting Northern Harriers (*Circus cyaneus*) in the Meadowlands site were previously reported (Bosakowski 1983).

On 5 different nights, I played prerecorded Short-eared Owl "barking" calls (A Guide to Bird Songs of Eastern and Central North America, Peterson Field Guide Series Record, Houghton Mifflin Co., Boston) at known Short-eared Owl locations for at least 8 min. Taped calls were broadcast at full volume with a portable 7 watt-output cassette tape-recorder placed on the roof of a parked vehicle with observers inside.

RESULTS AND DISCUSSION

Evening Departure. Short-eared Owls were highly crepuscular and nocturnal in the Meadowlands study area. I observed evening departures on 22 occasions with departures ranging between 28 min before–24 min after sunset, although the majority of owls (45 of 54 = 83.3%) emerged after sunset (Fig. 1) which is very similar to the 81.9% which Clark (1975) observed. On 3 evenings owls departed before sunset, but the sky was heavily overcast (total sky cover rating 10 of 10, National Weather Service). Hendrickson and Swan (1938:585) stated "the birds were observed to hunt on several occasions as early as 3 p.m. on a cloudy day and just before sunset on a clear day."

Despite 8 winters of field work in the Meadowlands area, I have only observed 1 Short-eared Owl flying during mid-day. However, the owl was being mobbed by an American Crow (*Corvus brachyrynchos*) and may have been flushed. The owl quickly dove for cover and was never observed hunting. At the Great Swamp site I observed 2 owls emerge just after sunset while waiting at a known roost site. At the Hightstown roost 1 owl emerged just after sunset. At the Sod Farms site, I observed from 3–6 owls on 3 evenings. On the first observation day, owls were actively hunting and flying at about 90 min before sunset even though the sky was partly sunny. How-
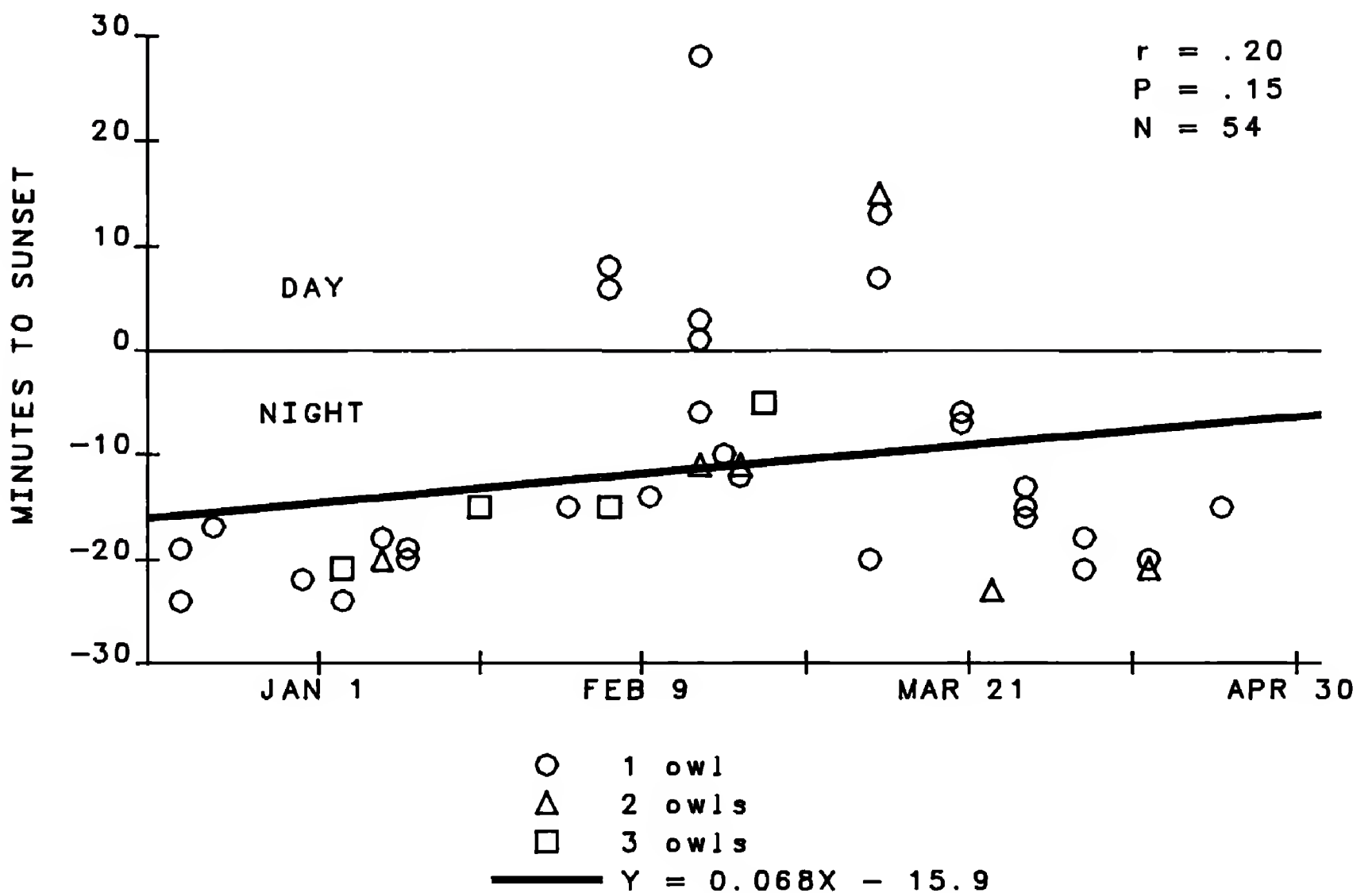
Figure 1. Short-eared Owl roost departure times relative to sunset. Data are combined from the winters 1981–2 and 1982–3. For computation, 12 December was considered day 0 with tic marks displayed at 20-day intervals

ever, on 2 subsequent observation days, owls emerged just at or shortly after sunset.

I observed a slight tendency for roost departures to occur closer to sunset and greater variability as the season progressed toward spring (Fig. 1). This slight change may be due to increasing day length which shortens the available time period for nocturnal activities. Clark (1975) also found a similar tendency, but owls in his study area emerged slightly earlier relative to sunset. In either study, evening departure from winter roosts was usually quite close to sunset. These results are in close agreement with studies in other owl species which show that the initial activity or roost departure is closely correlated with time of sunset (Glass and Nielsen 1967; Smith and Murphy 1973; Fuller 1979; Wijnandts 1984). Light cycle has been clearly demonstrated as the primary synchronizer of circadian rhythms and diel cycles (reviewed by Marler and Hamilton 1966) although Tester (1987) has shown some marked seasonal plasticity in activity periods of several free-

ranging animal species depending on important ecological/ethological events (e.g., care of young, courtship, hut building). While the Short-eared Owl is frequently diurnal during the nesting season (Bent 1938; Pitelka et al. 1955), my studies have shown the species to be primarily nocturnal in winter which generally agrees with the observations of Clark (1975) and the Craigheads (1956). Although winter roost departure times are often closely allied with sunset, Short-eared Owls occasionally showed some plasticity by departing earlier on overcast days (this study) and later during inclement weather (Clark 1975).

Interspecific Interactions. Avoidance of interference interactions with diurnal raptors (Jaksic 1982) could be another factor affecting the emergence time of owls in the Meadowlands study area. The owls I observed were roosting within 100 m of a communal roost of 6–9 Northern Harriers (Bosakowski 1983) and usually emerged just after the last harrier had entered the roost for the night (Fig. 2). It is tempting to speculate that this nearly com-
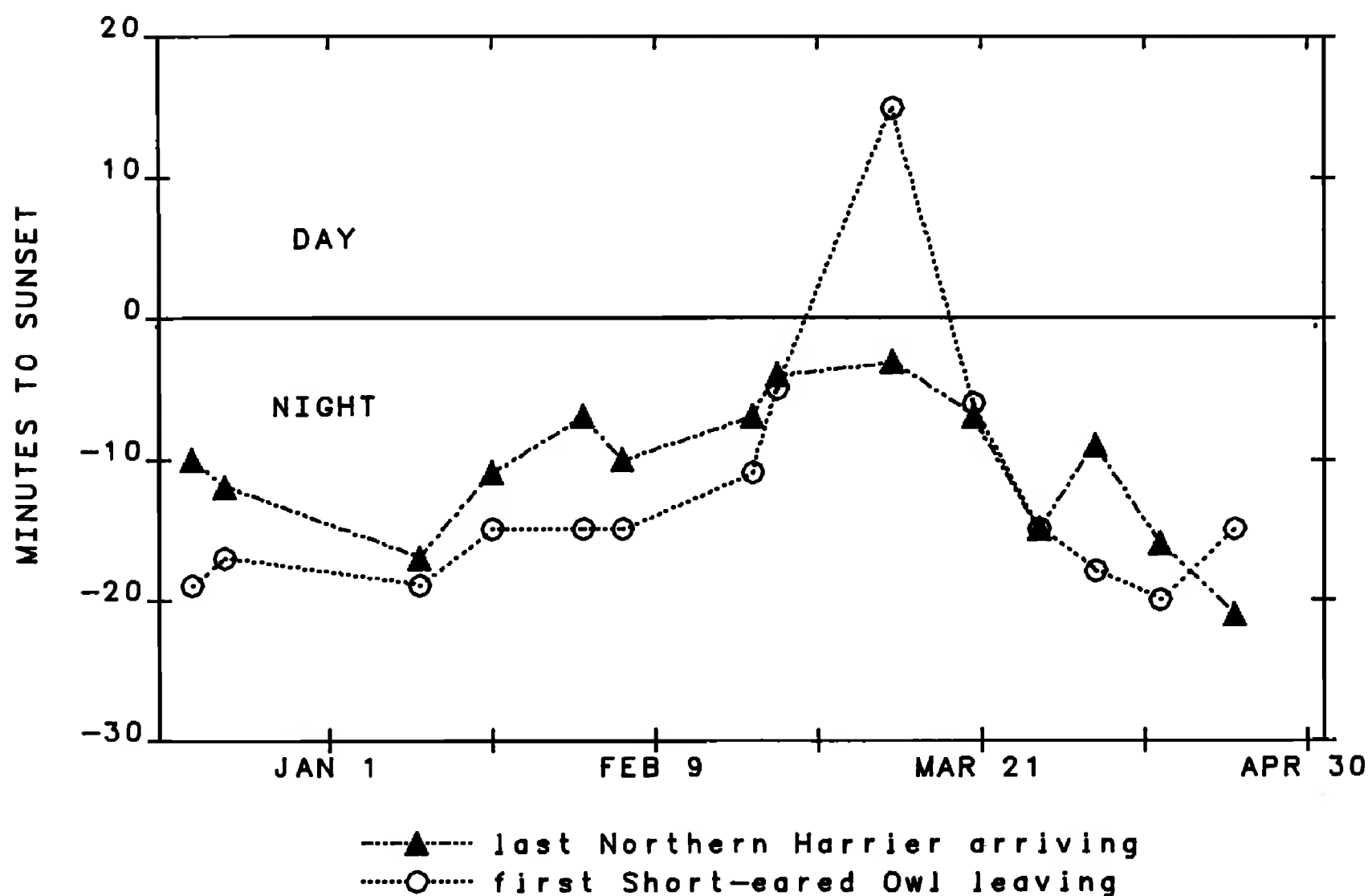
Figure 2.   Minimal temporal overlap between Short-eared Owls and Northern Harriers at nearby winter roosts in 1983.

plete lack of temporal overlap was intentional on the part of the owls. Clark (1975) and Watson (1977) have noted frequent agonistic encounters and piracy between harriers and Short-eared Owls. The minimal temporal overlap observed in the Meadowlands area permitted only 2 interspecific agonistic encounters [1 Northern Harrier, 1 Rough-legged Hawk (*Buteo lagopus*)] and suggests a benefit of temporal avoidance. In contrast, at least 3 agonistic encounters with neighboring harriers were observed when owls hunted in the late afternoon at the Sod Farms site.

Initial Activity. On 22 evenings at the Meadowlands site, I observed a total of 54 instances of owls emerging from their ground roosting sites in the marsh. In most cases the initial flight was diagnostic as owls would suddenly emerge from the reeds and immediately ascend to an altitude of 15–20 m. At this point, owls would normally engage in a steady direct flight with unchanging altitude, sometimes in tandem (11 times), presumably en route to a predetermined hunting site. Only occasionally did

hunting begin immediately at the roost departure site.

Nocturnal Activity. Kemp (1982) reported that Short-eared Owls have been seen by car headlights hunting in total darkness (no data or source given). Clark (1975) suggested that some hunting takes place at night for he was able to 'squeak them in' at various times of the night in areas where he knew birds often hunted. In my study, observations of nocturnal activities were aided by the use of car headlights, streetlights, flashlights, or scanning for owl silhouettes on moonlit nights or against the glow of city lights on the horizon. I made night observations up to 5 hr after sunset (2230 H) and observed that the owls hunted throughout the period on at least 7 nights. These observations help support the notion that the species is not merely crepuscular, but nocturnal as well.

Short-eared Owls used a combination of flying and perch-sitting as hunting methods. On-the-wing hunting was used conspicuously more on windy nights

as would be expected on the basis of flight energetics (Schnell 1967). Low coursing flights were made over the reeds, typically 2–4 m above the ground similar to that previously described in detail by Clark (1975). Only 4 observations of hover hunting were observed; 2 owls hovered about 15 m above ground adjacent to streetlights. Clark (1975) observed frequent use of hovering and suggested that this hunting strategy perhaps correlated with low prey density. Lack of suitable perch sites could also induce such behavior, for hovering is often used extensively by wintering Red-tailed Hawks (*Buteo jamaicensis*) hunting in open *Phragmites* marsh or on top of sanitary landfills (pers. obs.).

Perch hunting was used for extended periods when wind speed was near zero. Short-eared Owls chose a variety of elevated perch sites (total 33) including bare-topped telephone poles (14), telephone wires (7), saplings (4), fence posts (3), broken-off tree stubs (2), bent steel cable (1), high-tension wire (1), metal sign (1) and once on a Wood Duck (*Aix sponsa*) box. Often an owl would make several short flights or pounces returning frequently to the same perch. On 1 windless night, a Short-eared Owl was observed perching atop a telephone pole for at least 87 min during which time it made 4 unsuccessful pounces (the owl was still perched when I left at 2007 H). On another windless night, an owl was observed at 5 different perches during a 25 min period and then proceeded to make 7 additional hunting flights from the same telephone pole during the next 75 min period (ending at 2145 H). Clark (1975:35) stated that "Short-eared Owls accomplish an undetermined, but probably small, amount of hunting from a perch." My observations, accomplished before and after dark, suggest that perch-hunting plays a more significant role than previously thought, especially after dark, and could represent the primary hunting method used during periods of low wind velocity.

Social Interactions. Few agonistic interactions were observed between owls in the study areas. I observed 1 case of attempted piracy, 1 skirmish at the Sod Farms site on 20 February 1988, and 1 brief encounter, possibly courtship-related, on 10 March 1983 at the Meadowlands site. Similarly, other investigators did not usually notice any significant agonistic interactions until March (Short and Drew 1962) or late February when breeding territories are first defended (Clark 1975). In the Sod Farms site up to 6 owls were seen hunting simultaneously before dark with no apparent territoriality. Clark (1975)

has noted as many as 6 owls hunting the same 20 ha field in winter. Vocalizations were rarely heard in the field (2 times). However, on 5 different nights, I broadcasted taped Short-eared Owl calls at known Short-eared Owl locations and owls responded on 3 nights. The owls typically responded within 10 s–3 min with several vigorous circling flights over the vehicle. On 2 occasions, owls also responded vocally to the tape by producing the same call—several short series of 3 barking notes ("wrak, wrak, wrak"). Owl response quickly waned in less than 2–3 min and could not be induced again despite continued or periodic broadcasting at the same location. On 2 unsuccessful nights, the vehicle was in view of a perched owl which only reacted by frequent glancing at the broadcast site. Since the owls I studied did not appear to be territorial, the vigorous response to playback may have been due to social curiosity and mate seeking. I am not aware of any previous reports of call playback techniques to detect Short-eared Owls, but the present results suggest that this method could be a useful management tool for population surveys and identifying Short-eared Owl habitat.

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SEXUAL DIFFERENCES IN TIMING OF AMERICAN KESTREL MIGRATION AT HAWK MOUNTAIN SANCTUARY, PA

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ABSTRACT.—Bimodal migration patterns occur in many raptor species but have not been conclusively documented for American Kestrels (*Falco sparverius*) along their Appalachian migration route. Kestrels migrating past Hawk Mountain Sanctuary, Pennsylvania had a bimodal fall migration pattern when data were averaged over a 26-year period (1963–1988). Peaks at Hawk Mountain centered around 11 September and 2 October. Proportion of males increased slowly over the course of the fall migration; the median date for female kestrels preceded males' by 11 days. Both males and females showed bimodal migration patterns. Potential factors resulting in such patterns include timing of molt, location of summering grounds, and seasonal weather patterns.

Migration patterns of numerous North American raptors exhibit a bimodal distribution. Juvenile Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*A. cooperii*), Northern Goshawks (*A. gentilis*), and Northern Harriers (*Circus cyaneus*) precede conspecific adults in migration (Bildstein et al. 1984; Clark 1985a; Mueller and Berger 1967, 1968; Mueller et al. 1981) and female Merlins (*Falco columbarius*) migrate earlier than males (Clark 1985b).

Female American Kestrels precede males during fall migration at one site in the eastern Great Lakes region (Haugh 1972; Duncan 1985). An analysis of banding data for kestrels during fall migration east of 100° latitude suggests that a two-wave fall migration pattern may extend throughout the eastern United States (Smallwood 1988). However, no observational data document this pattern along specific migration routes other than the Great Lakes flyway. Although kestrels migrating past the Great Lakes and Appalachian Mountains represent 2 different populations with distinct winter ranges (Roest 1957; Clark 1975; Duncan 1985), we cannot assume migration patterns are similar.

Banding data alone cannot substantiate migration patterns, since data may have a bias toward birds which are more susceptible to capture (McClure 1984:323–324). Timing of banding, type of lure used, and behavioral differences between sexes (especially if timing of capture susceptibility varies between sexes) could all contribute to an apparent bimodal pattern that does not accurately reflect true migration timing. Patterns seen in banding data and replicated with observational data become more believable.

In this study, we first examine kestrel migration data collected at Hawk Mountain Sanctuary, Penn-

sylvania to see whether a bimodal pattern for kestrels exists along Appalachian migration routes. We follow this with analysis of counts of known sex kestrels seen at Hawk Mountain, to see if a sexual difference in timing of migration exists. Documentation of such a pattern along the Appalachian migration route would support the hypothesis that separation of sexes must occur on breeding grounds or early in migration (Smallwood 1988).

METHODS

Hawk Mountain Sanctuary, Pennsylvania (40°44'N, 75°50'W), is located on the Kittatinny Ridge, the southernmost line of the northern Appalachians. Geographic and topographic features concentrate tens of thousands of migrating raptors along this ridge each fall (Brett 1986). Migration counts have been taken at Hawk Mountain Sanctuary North Lookout (elevation 464 m) since establishment in 1934. Observers record number and species of all migrating raptors seen from the lookout almost daily during the fall.

We summed the number of kestrels sighted during each week of fall migration from daily counts made during fall migrations of 1963–1988. We then calculated a weekly average for the 10 most active weeks of kestrel migration, 25 August through 2 November. We omitted observations made before 1963 because of numerous gaps in the data

Heavy precipitation usually halted migration and resulted in a daily count of zero. We included zero-count days in the calculation of weekly means with the assumption that overall weekly migration volume was not affected; kestrels halted by poor weather conditions probably resumed migration when weather conditions improved. Weekly means were used to alleviate short-term fluctuations in migration volume caused by the passage of weather fronts.

Before 1 September, some zero-count days were caused by the absence of an observer at the lookout. Although data for the first week of the migration period may slightly underestimate migration volume, we feel that the difference was minor and did not affect the overall migration
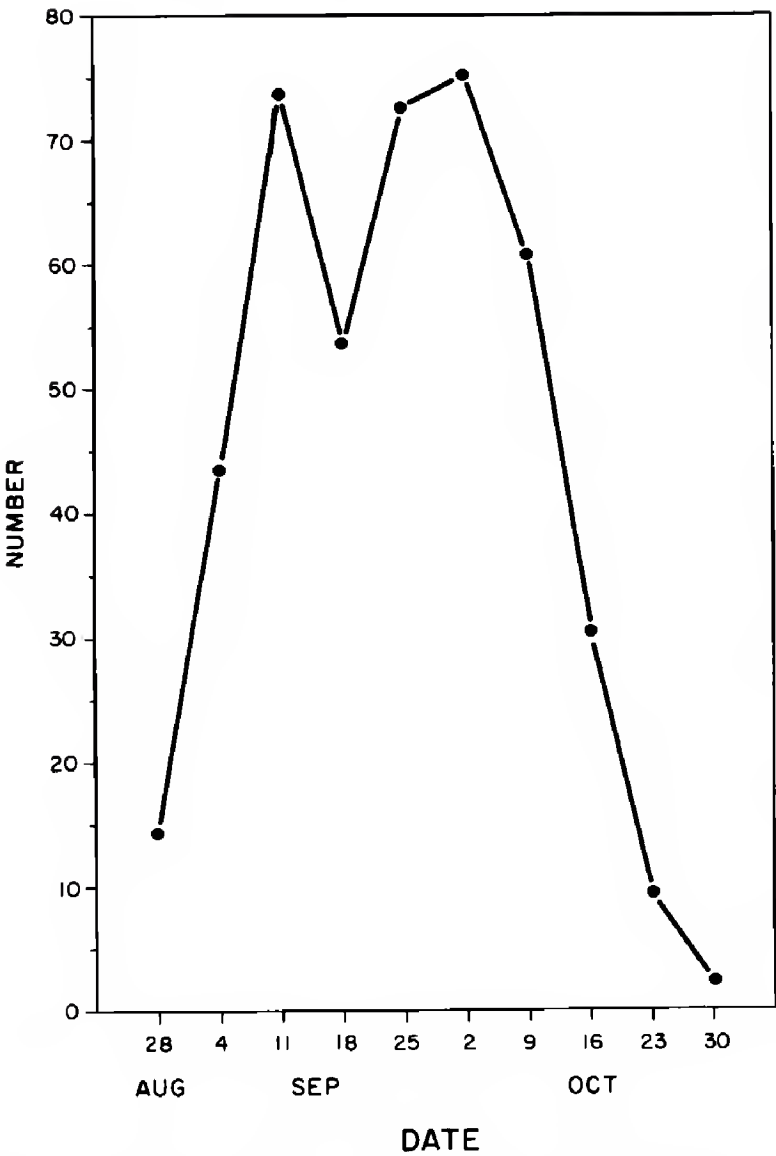
Figure 1.   Mean number of American Kestrels seen weekly during fall migration at Hawk Mountain Sanctuary, 1963–1988. Mid-week dates are given.

pattern observed. We included a test of kurtosis (Sokal and Rohlf 1981) to verify non-normality of the data.

In 1979 observers at Hawk Mountain began to record sex of kestrels passing the lookout. Sightings were tabulated by sex and date of observation. We searched for a difference in the timing of migration by each sex using ranked dates of observation in a Wilcoxon two-sample test (Sokal and Rohlf 1981). To test for a difference in relative numbers of males and females during 2 periods of the migration period, we used a G-test (Sokal and Rohlf 1981) for all sexed birds. G-test analysis was performed twice. First, we used 18 September as the date to divide the migration period; 18 September represented a trough in the bimodal pattern of kestrel migration. Second, we used the median date for all sexed kestrels (22 September) as a dividing date.

We compared weekly totals for counts of each sex to

the overall migration pattern, again limited to the ten heaviest weeks of kestrel migration. Sampling effort for sexed kestrels varied over the course of the migration period (<6%->22% of passing kestrels). We adjusted raw numbers of kestrels of each sex observed each week by multiplication with a correction factor for sampling effort, as follows:

$$\frac{\text{number of kestrels sexed during the week}}{\text{total number of kestrels seen during the week}}$$

RESULTS

Mean weekly number of kestrels during fall migration at Hawk Mountain peaked on 11 September and 2 October (Fig. 1) when averaged over the 26-year period (1963–1988), representing an extreme platykurtosis ($g_2 = -0.796$; $t_s = -17.304$, $P < 0.001$) A bimodal pattern existed in many individual years at Hawk Mountain and was especially clear in 1963–1965, 1968, 1971, 1974, 1977, 1985 and 1987 (Fig. 2).

Relative number of males increased gradually during the 10 heaviest weeks of the migration period (N = 793), although both sexes showed a bimodal distribution in timing of migration (Fig. 3). Because of low counts for the final 2 weeks of the period, data for 20 October–2 November were lumped into a single data point for presentation. When all sexed birds were tabulated (N = 837), the G-test revealed a significant difference in the proportions of males and females around the trough date (G = 35.47, P < 0.001). On or before 18 September, females outnumbered males (males = 161, females = 201); after 18 September, males outnumbered females by almost 2:1 (males = 309, females = 166). Conclusions did not differ when the median date of all sexed birds (22 September) was used as the dividing date (G = 32.58, P < 0.001). Median date of sighting for female kestrels, 14 September, differed significantly from that of males, 25 September ($t_s = 6.547$, P < 0.001).

DISCUSSION

American Kestrels migrating past Hawk Mountain Sanctuary (1963–1988) had a bimodal migration pattern (Fig. 1). The proportion of male kestrels increased as the fall progressed, indicating a differential timing of migration by each sex. Relative val-

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Figure 2.   Total number of American Kestrels seen during each week of fall migration at Hawk Mountain Sanctuary, 1963–1988. Week numbers correspond to mid-week dates presented in Figure 1.
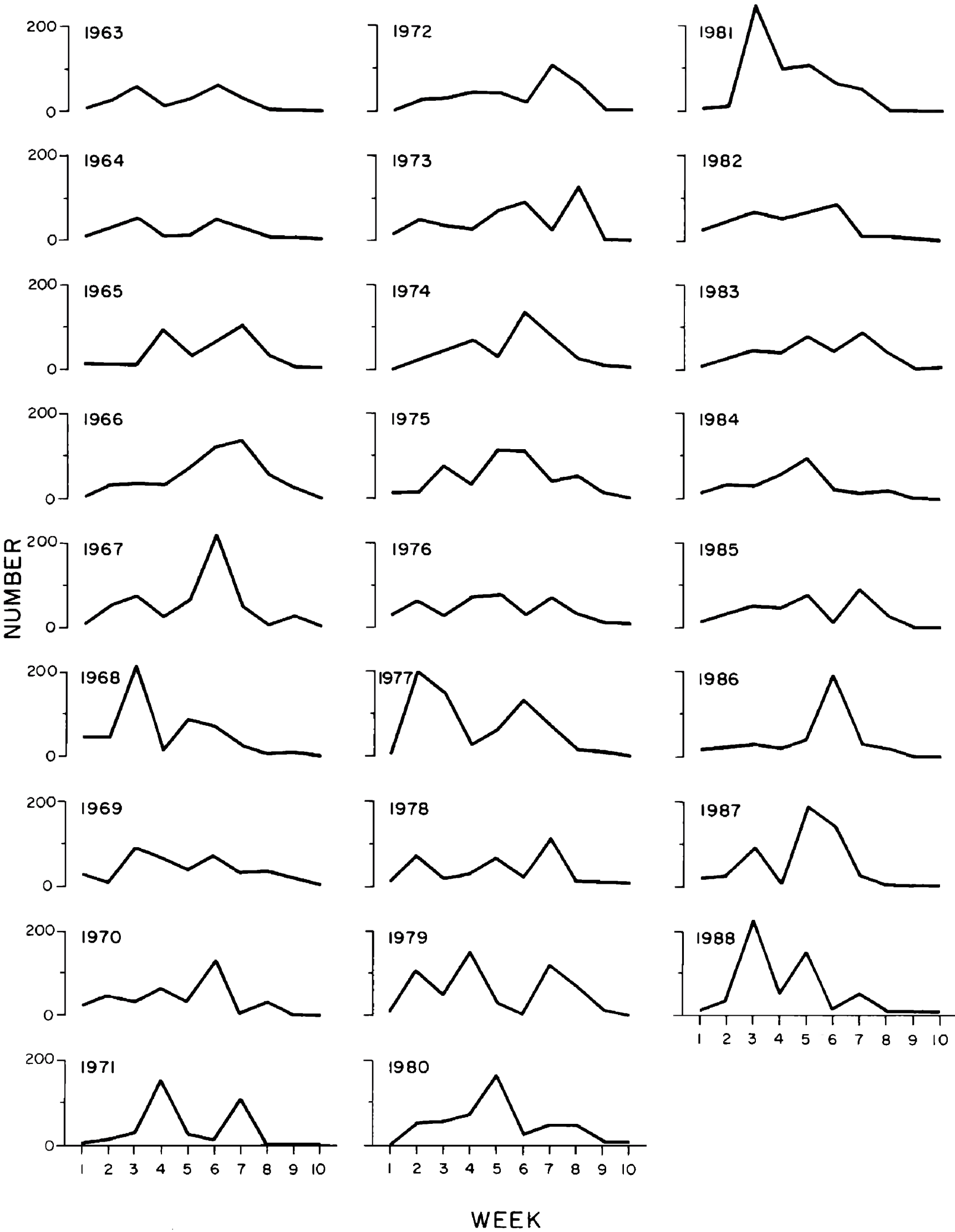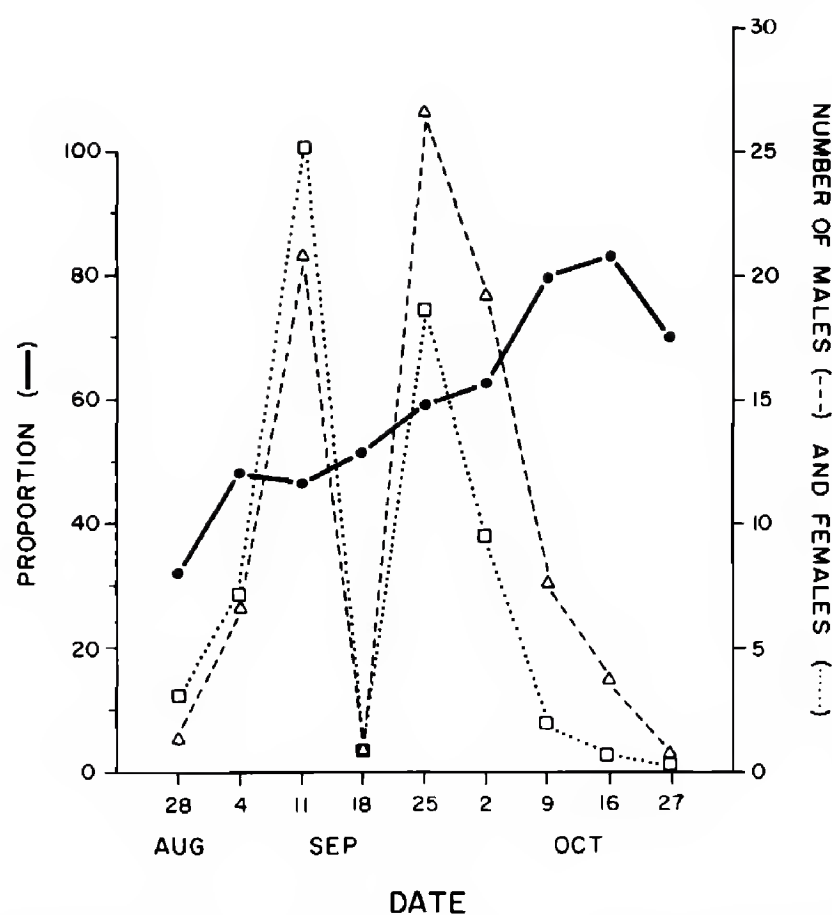
WEEK

Figure 3.   Proportion of male American Kestrels (●) ob-
served at Hawk Mountain Sanctuary, relative
to all known sex kestrels recorded during each
week (1979-1988). Adjusted numbers (see text)
of male (△) and female (□) kestrels seen each
week of the migration period (1979-1988).

ues of these proportions over time should be unaf-
fected by the apparent skew toward males in the
sexed kestrels. The skew toward males does not ap-
pear to represent a bias toward males in sampling
for sex, as the pattern for all sex and age classes
(Fig. 1) shows a corresponding larger second peak.
Our data indicate that a sexual difference in migra-
tion timing may be a general pattern common to all
kestrels in eastern North America (Duncan 1985;
Smallwood 1988). The data may also confirm that
different arrival times of sexes to wintering grounds
is not an artifact of a local separation of birds on or
near wintering grounds, but rather a difference in
time of departure from breeding grounds (Small-
wood 1988).

Sexual difference in migration timing may be re-
lated to different roles during the breeding season.
Smallwood (1988) suggested that female kestrels are
able to initiate migration before males because fe-
males complete their molt earlier. Males provide
most of the food for their mate and developing young
during the breeding season and molt later than fe-
males (Willoughby and Cade 1964; Smallwood
1988).

Female kestrels are slightly larger than males
(Reynolds 1972; Snyder and Wiley 1976), but no
sexual dominance is obvious. On wintering grounds
in Florida, both territorial male and female kestrels
are able to exclude late-arriving members of either
sex (Smallwood 1988). Therefore, females may ben-
efit by migrating as early as their molt permits in
order to establish territories in favorable habitats
before males arrive on wintering grounds (Small-
wood 1988). Sexual variation in migration timing
could explain differential habitat use which has been
reported for kestrels (Koplin 1973; Mills 1976; Stin-
son et al. 1981; Bohall-Wood and Collopy 1986;
Smallwood 1987, 1988).

Differential migration timing by sex may also be
related to a difference in distance traveled. Some
investigators have reported that male kestrels winter
further north than females (Roest 1957; Willoughby
and Cade 1964; Johnson and Enderson 1972; Stin-
son et al. 1981). Males compete for breeding terri-
tories in the spring (Newton 1979), and may be at
an advantage to winter on or near breeding terri-
tories. Selection may favor males with greater ability
to survive in the rigorous habitats of more northern
wintering grounds (Mills 1976), and these males
may delay their migration relative to females.

Sexual difference in migration timing among kes-
trels passing Hawk Mountain Sanctuary does not
preclude the possibility that juveniles precede adults
in migration and may also contribute to the observed
bimodal pattern. Juveniles of many raptor species
migrate before adults (Mueller and Berger 1967,
1968; Mueller et al. 1981; Bildstein et al. 1984).
Analyses of banding data (Smallwood 1988) suggest
that juvenile kestrels and adult females precede adult
males in migration. We expect the effect of juveniles
on the patterns observed at Hawk Mountain to be
minimal since the migrations of juvenile raptors are
concentrated along the Atlantic coast (Clark 1985b).

The striking trough seen in migration counts for
both sexes of kestrels passing Hawk Mountain (Fig.
3) may be related to a number of factors. The molt
timing hypothesis (Smallwood 1988) described above
suggests that non-breeding males, in addition to fe-
males, could benefit from an early migration, and
the first peak of males (Fig. 3) could represent non-
breeding males that did not have their molt delayed
by food provisioning. Confirmation would require
matching breeding status of migrants to the timing
of their migration but would not explain the second
peak for females.

An alternative explanation might be that the 2

peaks for each sex represent individuals from separate populations. Verification would require knowledge of summering grounds of kestrels passing Hawk Mountain. This explanation alone does not seem adequate, because the data accordingly suggest that sex ratios of each population are different.

The trough could also indicate an overriding annual weather pattern which consistently limits kestrel migration during the third week of September. However, variation in annual patterns (Fig. 2) suggests that such a mechanism did not operate every year. A more detailed examination of weather effects at Hawk Mountain is needed. None of our explanations excludes any other and observed patterns probably result from a complex interaction of numerous factors.

ACKNOWLEDGMENTS

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THE USE OF LINE TRANSECTS TO EVALUATE THE ABUNDANCE OF DIURNAL MAMMALIAN PREY

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ABSTRACT.—While studying the foraging behavior of accipiters in northern New Mexico, chipmunk abundance was evaluated with a line transect technique. This is a timely, cost-effective method for providing quantitative estimates of the abundance of diurnal small mammal prey in different habitats. The limitations and general applicability of this method to raptor prey studies are discussed.

Many feeding ecology studies of diurnal raptors suffer from difficulties in assessing prey abundance in foraging areas. Fitzner et al. (1977) described techniques for determining densities of raptor prey species, emphasizing procedures that would provide quantitative data for comparisons of prey exploitation rates and prey densities. Methods traditionally used for collecting these data are time-consuming and labor-intensive. Other problems with these methods have been widely addressed, and no unified approach toward obtaining comprehensive and systematic estimates of small mammal density or population size has been developed (Otis et al. 1978). Most density estimation methods also sample relatively small areas (<10 ha) and are not practical for determining animal abundance in large foraging areas used by raptors (>100 ha for many species). In addition, precise quantitative density estimates may not be necessary to answer many of the questions addressed in raptor studies.

Many studies have attempted to estimate animal abundance by counting all individuals in a known area (Hayne 1949; Krebs 1966; Hirst 1969; Emlen 1971; Franzreb 1981). However, most of these methods were not designed to sample chipmunks (*Tamias* sp.) or other diurnal small mammals which are common raptor prey. In addition, species and habitat comparisons may not be possible because the sample area sizes and the relationship between indices of abundance and absolute abundance are difficult to assess (Burnham et al. 1980). Because of these difficulties, many recent papers have suggested that enumeration methods are not sound and should not be used to evaluate animal abundance (Burnham et al. 1981, 1985; Jolly and Dickson 1983; Smith and Brisbin 1984; Montgomery 1987).

We have been studying the foraging behavior of a population of Cooper's Hawks (*Accipiter cooperii*) nesting in northern New Mexico. Cooper's Hawks feed primarily on medium-sized passerines, wood-peckers, and chipmunks (Kennedy 1985). To evaluate foraging areas, sampling methods were needed that were suitable for sampling prey populations over large areas in a timely, cost-effective manner and would provide results appropriate for comparisons.

To determine chipmunk abundance in Cooper's Hawk foraging areas, we modified the line transect method of Burnham et al. (1980, 1981). Burnham et al. (1980) have shown that line transect sampling is practical, relatively inexpensive, and efficient for calculating density estimates, particularly when a study area is stratified by some feature such as habitat. Despite the potential usefulness of line transect sampling, it has been infrequently used (Burnham et al. 1980). In this paper we describe our application of this method and evaluate its usefulness in quantifying the abundance of diurnal small mammals in different habitats.

STUDY AREA

The study was conducted in the Jemez Mountains in north-central New Mexico. The study area and the Cooper's Hawk nesting habitat are described in detail in Kennedy (1988).

METHODS

For comparison of prey abundance between foraging areas, 2 habitats commonly used by Cooper's Hawks (as determined from radio-tracking data) were examined: mesa tops and canyon bottoms. Mesa tops are dominated by pinyon-juniper (*Pinus edulis-Juniperus* sp.) woodland and Gambel oak (*Quercus gambelii*). Canyon bottoms are characterized by large ponderosa pine (*Pinus ponderosa*), scattered Douglas fir (*Pseudotsuga menzesii*), cottonwood (*Populus* sp.), and numerous shrub species.

During 1986, prey populations in foraging areas of 5 nesting pairs of Cooper's Hawks were sampled. Transects of varying lengths (1.61–3.22 km) were established in mesa top and canyon bottom habitats. Transect lengths were determined by the amount of homogeneous habitat [from vegetation maps (Allen 1989)] available for sampling in each foraging area. Transects were run for 3 sampling periods in 1986 which were designed to coincide with the

late incubation/early nesting period (late May–early June), late nestling/early fledgling dependency period (late June–July), and late fledgling dependency period (August–early September).

During 1988, transects varying from 2.90–3.70 km in length were established in mesa top and canyon bottom habitats near 2 Cooper's Hawk nest sites. In 1988, transects were run during the first and third sampling periods. Total transect lengths established in each habitat for 1986 and 1988 are shown in Table 1.

An observer walked along each transect at a continuous pace of about 1.6 km/hr, alternating between slow walking and brief pauses to look and listen. All chipmunks seen or heard along the transect were counted. The type of detection (auditory or visual) was noted with each observation. In the canyon bottom habitat, estimates of the perpendicular distance from the observer to each detection (Burnham et al. 1980) were recorded within each of four distance categories: 0–7.6 m, 7.7–15.2 m, 15.3–22.9 m, and 23.0–30.5 m. In the mesa top habitat, which had more vegetative cover, distances could not be accurately estimated beyond 23 m so only the first three distance categories were used. Efforts were made not to count individuals more than once. When an observed individual fled, the escape route was monitored to ensure against duplication in counts.

Only 1 transect was traversed each day. Sampling guidelines established for breeding bird transects (Emlen 1971) were followed. One observer conducted all censuses to avoid multi-observer biases (Faanes and Bystrak 1981). Transect counts were conducted only on days with no precipitation, moderate cloud cover (<50%) and low wind speeds (<1 m/sec) (Newman 1959; Robbins 1981). Transects were run for approximately 2 hr and were traversed from 0800–1100 (Verner and Ritter 1986).

Chipmunk densities for each sampling period within each habitat were calculated using the exponential polynomial estimator in program TRANSECT (Burnham et al. 1980). Computation of the Shapiro-Wilk statistic (W) indicated that the density data were a random sample from a normal distribution (W = 0.95, P = 0.74). Differences in chipmunk density between habitats were evaluated for the data using a paired t-test. All statistics were computed with the SAS Statistical Program (SAS 1985a, 1985b).

RESULTS

Table 1 shows estimates of chipmunk density within each habitat calculated using the line transect method. Significantly more chipmunks were counted in the canyon bottom habitat than in the mesa top habitat during all sampling periods (t = 3.37, P = 0.02).

DISCUSSION

Our results indicate that this line transect method is suitable for evaluating chipmunk abundance within different habitats. However, this method has limitations; these and the assumptions addressed by Burnham et al. (1981) should be considered before

Table 1. Estimates of chipmunk densities in mesa top and canyon bottom habitats in Cooper's Hawk hunting areas.

	HABITAT			
	MESA TOP		CANYON BOTTOM	
SAMPLING PERIOD	TRANSECT LENGTH (KM)	DENSITY (#/HA) (SE)	TRANSECT LENGTH (KM)	DENSITY (#/HA) (SE)
1986				
1	12.87	0.45 (0.34)	7.24	2.69 (0.87)
2	14.48	1.82 (0.64)	18.02	1.98 (0.47)
3	11.26	1.32 (0.61)	23.02	2.60 (0.48)
1988				
1	9.33	0.79 (0.52)	10.14	4.32 (0.94)
3	9.33	0.90 (0.55)	9.66	3.14 (0.82)
Average density (SE)		1.09 (0.25)		2.78 (0.37)

this method is used to sample prey populations in raptor studies.

Four basic assumptions in line transect sampling were recognized by Burnham et al. (1981): (1) animals directly on or very near to the line will always be detected; (2) there is no movement of animals in response to the observer and none are counted more than once during a given walking of the line; (3) all distance data are recorded without measurement error; and (4) sightings of different individuals are statistically independent events. We violated assumptions 1 and 2. However, Burnham et al. (1981) indicate that the robustness of the TRANSECT estimators allows for moderate violations of these assumptions.

Habitat type influences the level of survey accuracy because more detectability problems occur in dense, heavily vegetated habitat than in open, sparsely vegetated habitat. The screening effect of dense vegetation can result in variable detectability of animals near the transect line (violation of assumption 1). Thus, we recommend the line transect method be used primarily in relatively open habitats where the observer can see clearly in all directions to catch quick movements of individuals.

In addition to limited visibility in dense habitat, the observer makes more noise walking through thick vegetation. As a consequence, individuals may be frightened and move away from the center line, thus
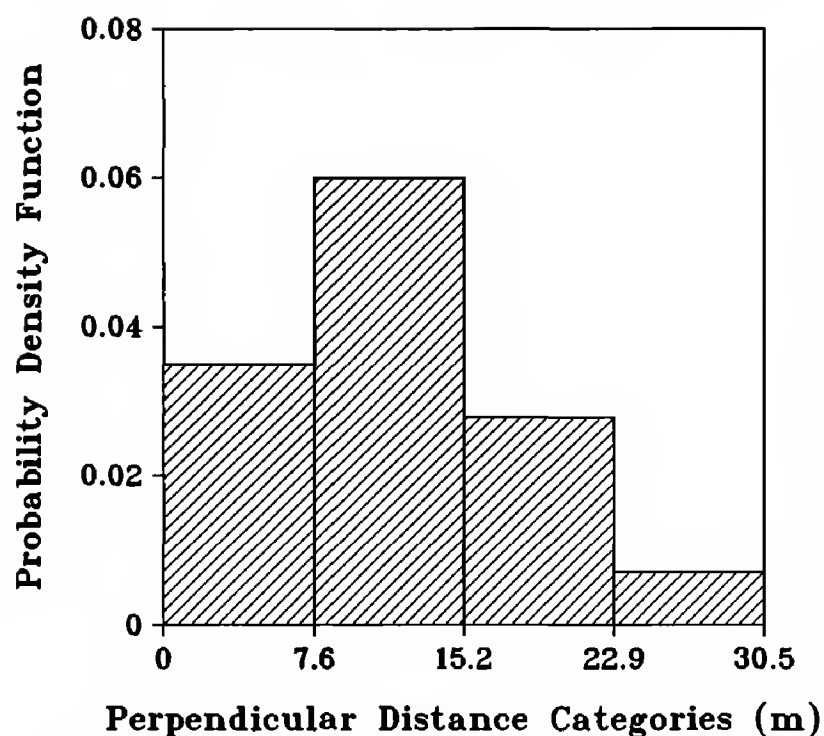
Figure 1. A frequency histogram of chipmunk perpendicular distance data collected in the mesa top habitat during sampling period 1 in 1986.

escaping detection. Undetected nonrandom movement as a result of lower visibility or reaction to the observer is the problem most frequently encountered in applying line transect sampling methods to wildlife populations (Burnham et al. 1981). Such nonrandom movement tends to increase the perpendicular distance of the animal from the line or cause it to be missed. If the animal is spotted, it would be at a point farther from the line than its original position; this violates assumption 2 (Burnham et al. 1980).

The characteristic pattern one can expect to see in the data histogram generated by TRANSECT if evasive movement occurs is shown in Figure 1, a representative frequency histogram of the chipmunk distance data collected in this study. Tests of the robustness of various estimators to animal movement (Burnham et al. 1980) revealed that the exponential polynomial estimator is substantially more robust to movement than other estimators, thus we used it to calculate chipmunk densities.

Due to the movement response of chipmunks to the observer, we do not recommend measuring the exact perpendicular distance to each individual from the transect line. Additional observer movements resulting from these measurements would increase evasive responses of the sample animals and introduce additional errors into the density estimates.

Assigning individuals to distance categories during sampling eliminates this problem and the ability to take distance data as grouped greatly extends the applicability of the line transect procedure (Burnham et al. 1981). Density estimates can be calculated from grouped distance data and assumption 3 is not violated if there is no error in category assignment (Burnham et al. 1980).

Minimizing the number of observers and training them in distance estimation in each habitat prior to sampling will improve estimator accuracy. The number of distance categories should be as large as possible to improve estimator accuracy but not so large that distance estimation errors are introduced.

Although we used this line transect method only to assess chipmunk abundance, the method is suitable for surveying other small, diurnal mammals. When we began this study, we attempted to record all species of diurnal mammals encountered on each transect. To improve consistency of the methodology and thus density estimates (Temple 1981), we recommend that each survey be conducted for 1 or 2 species at a time. Obtaining simultaneous counts for calculating density estimates on gregarious ground-dwelling small mammals [chipmunks or Golden-mantled Ground Squirrels (*Spermophilus lateralis*)] is not difficult. This may be more difficult for less detectable mammals such as Rock Squirrels (*S. variegatus*) which may have a greater flushing distance, and consequently a lower probability of detection along the transect line. To obtain suitable counts for more reclusive species, these species should be surveyed separately. In addition, line length and/or the number of distance categories may need to be increased.

This technique is also suitable for arboreal mammals such as Abert's Squirrels (*Sciurus aberti*) or Red Squirrels (*Tamiasciurus hudsonicus*). Surveying the trees and the ground simultaneously is difficult; therefore, we recommend that arboreal species be surveyed at a different time than ground-dwelling species.

In summary, our results indicate that within certain limitations, this line transect method can be useful for evaluating prey populations in raptor foraging areas.

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USE OF EXPLOSIVES TO ENHANCE A PEREGRINE FALCON EYRIE

JOEL E. PAGEL

ABSTRACT.—Explosives were used effectively to increase the size and nesting potential of a traditional Peregrine Falcon (*Falco peregrinus anatum*) eyrie in northern California. Ledge dimensions were increased from 15 cm deep × 31 cm wide to 41 cm deep × 152 cm wide by removal of blast loosened rock. Prior to this enhancement (1982, 1983), nesting attempts were unsuccessful due to the displacement of eyases and eggs from the small eyrie. From April 1984–June 1988, 13 Peregrine eyases (2.6/yr) have successfully fledged from the enhanced eyrie, with no further fatalities induced by ledge dimensions.

Nesting sites for many raptors may be artificially produced or altered to increase reproductive potential. Bohm (1977) noted that artificial nesting platforms could be used to excise Great Horned Owls (*Bubo virginianus*) from natal areas by placing structures in locations where adequate nests were lacking. Fyfe and Armbruster (1977) described the physical excavation of sandstone cliffs for the creation of artificial ledges for Prairie Falcons (*Falco mexicanus*) which resulted in an increase of the resident breeding population. Boyce et al. (1980) discussed an artificial nesting structure that had been erected on a historic Prairie Falcon ledge with productive results.

Peregrine Falcons (*F. peregrinus*) show high fidelity to established nest sites (Hickey and Anderson 1969; Ratcliffe 1980), an aspect of their nesting biology which makes it practical to enhance traditional and/or alternate nest ledges. Boyce et al. (1982) reported a nesting pair of Peregrines that deserted a historical nest site for an alternate ledge enhanced through excavation.

Attempts to create nesting platforms in rock faces with explosives have been documented for falcons. Becker (1981) used Kinepeck explosives to create nesting cavities for Prairie Falcons. Smith (1985) reported the use of Detaprime WG (pentaerythritioltetranitrate or PETN) to blast potential Prairie Falcon eyries in rock exposed by a large surface coal mine.

Investigations of the nesting chronology and reproductive success of a Peregrine Falcon eyrie in California were completed in 1982 and 1983 (Ledig 1982; Lehman 1983) and revealed that eyases and eggs, respectively, had been displaced from a small nest ledge in both years. Herein, I report and describe the successful use of explosives to enhance this traditional Peregrine eyrie in northern California.

MATERIALS AND METHODS

During September–December 1983, approximately 120 person-hr were devoted to the enhancement of a Peregrine Falcon ledge in the Klamath National Forest (KNF) of northwestern California.

The eyrie was located 23 m above the base of a 36 m dolomitic limestone cliff. The nesting ledge prior to enhancement measured 15 cm deep × 31 cm wide and was created by a natural horizontal fracture.

Personnel entered the existing eyrie following reproductive failure in 1983 to assess the potential for enlargement of the eyrie (Lehman 1983). Hand tools proved ineffective to enhance the nest ledge, and explosives were believed to be necessary to enlarge the existing falcon ledge to dimensions regarded as typical (50 × 50 cm) (Ratcliffe 1980).

The base of the cliff was located 1.1 km from the nearest road and was situated above a 60–70% slope. Consequently, all materials had to be hand-carried to the site. The cliff top and base were easily accessible to climbers. Access to the ledge was gained by rapelling. A drill and explosives were hoisted to the ledge by a z-drag hauling system backed up by reverse jumars (May 1972). Climbers placed 1 piton and 4 Star climbing bolts (9.5 mm × 50 mm) with normal hangers 1–2 m above the ledge to allow greater mobility during preparation procedures.

A gasoline powered Cobra percussion rock drill was used to bore 4 holes 60 cm into the rock. A 1.9 cm rotating hardened steel drill bit was used with good results. Holes were placed 25–30 cm apart directly above the largest portion of the existing ledge. A staggered pattern of drilling facilitated a rhomboidal area of concentrated blast zone (USFS 1980) similar in principal to shaped charges (Smith 1985). High ambient air temp resulted in frequent pauses to prevent the drill bit and engine from overheating.

A civilian licensed blaster was contracted to prepare and detonate the charges. The type of explosive charges to be used was decided by the blaster. Ditching dynamite (60% nitroglycerin) in 2.5 × 46 cm cartridges was used in combination with electrically initiated, instantaneous blasting caps; 1.5 cartridges per bore hole were used. Thirty m of electric lead line was attached to the blasting cap leg wires and strung up the cliff face to a protected location. Logging roads beneath the blast zone were blocked and unnecessary personnel vacated the site during actual blasting. The

charges were detonated by touching the ends of the electric lead line to the battery pack of a hand-held 1.5 volt portable radio.

Results and Discussion

Following detonation of charges, the ledge was examined and excess debris was removed. Upon descent to the ledge we noted that 2 charges with blasting caps attached had not detonated. These charges were removed and examined manually. We believe that these charges did not explode due to the age of the ditching compound (estimated to be 15+ years old). Though only 2 of 4 charges (1.5 sticks/charge/ bore hole) had exploded, the ledge was enlarged to a sufficient size.

Ditching dynamite is a high energy explosive agent which detonates at 5791 m/sec (Du Pont, Inc. 1977). This explosive was not the best to use in dolomitic limestone due to the proximity of the bore holes. If all charges had detonated as intended, the existing ledge may have been destroyed. As ditching dynamite progresses in age, it becomes more unstable and dangerous to use. Most licensed blasters are cognizant of this fact. Extreme caution is advised in determining the type and condition of explosives used on similar projects to prevent elimination or destruction of ledge or eyrie.

Access to the cliff was an important consideration in the application of explosives on this ledge. This facet makes wilderness or remote enhancements with explosives difficult at best.

Bolts affixed to the rock above the eyrie proved crucial in securing climbers, necessary equipment and to serve as placement for suspension of the rock drill during use, or rest breaks. The bolts have been subsequently helpful to climbers entering the eyrie to band young. No rust streaks have occurred to date despite precipitation runoff down the cliff face, and the bolts are invisible to observers from the base of the cliff.

Portions of the ledge were loosened to such a degree that 34 kg of masonry mortar was required to re-affix some blast debris to the main portion of the ledge. Dimensions of the ledge were found to have been increased to 41 cm × 152 cm. Mortar was allowed to cure, and 45 kg of sifted sand and gravel was spread on the ledge to form adequate substrate for nesting falcons. The eyrie has been examined yearly (1984–1988), with no further work required to replace or repair the mortared rock.

The enhanced ledge has been occupied by Peregrine Falcons yearly since the enhancement with 13 eyases (2.6/year) having fledged between 1984 and 1988 (Pagel 1988). Total investment in this project was $2000. Rough breakdown of these costs is as follows: $300, explosives and blaster's services; $400, ropes, bolts, ascenders and slings; and $1300 for 120 person-hr of labor.

Conclusions

Explosives offer an effective means to enhance existing nest ledges of cliff dwelling raptors when hand tools are not effective. Extreme care and forethought should be considered at active nest sites. Any work, including preliminary examinations, should not be conducted during the nesting period. Improvement of alternate nest ledges should be considered before the time and expense of explosive enhancement is utilized. Blasts more forceful than necessary may decrease the dimensions of the nesting platform or remove the existing nest ledge entirely.

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SHORT COMMUNICATIONS

RANGE EXTENSION OF THE BARRED OWL IN WESTERN WASHINGTON AND FIRST BREEDING RECORD ON THE OLYMPIC PENINSULA

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The Barred Owl (*Strix varia*) has been extending its range west and south for more than 4 decades (Grant 1966; Taylor and Forsman 1976; Boxall and Stepney 1982). The first observation of a Barred Owl in Washington State was made in 1965 in the eastern edge of the state by Rogers (1966). In 1973 the first Barred Owl recorded on the west side of the Cascade Mountains was found dead in Skykomish, King Co. (Taylor and Forsman 1976). Reichard (1974) found a pair in the northwestern Cascade Mountains, and since 1976 several records of Barred Owls nesting along the western flanks of the Cascade Mountains have been reported (Allen et al. 1985; Harrington 1985, Wash. Dept. Wildl., pers. comm.).

No formal surveys have been conducted on the Olympic Peninsula. However, because Barred Owls respond readily to Spotted Owl (*S. occidentalis*) calls (Hamer 1987), surveys for Spotted Owls might effectively be considered Barred Owl surveys. Spotted Owl surveys have been con-
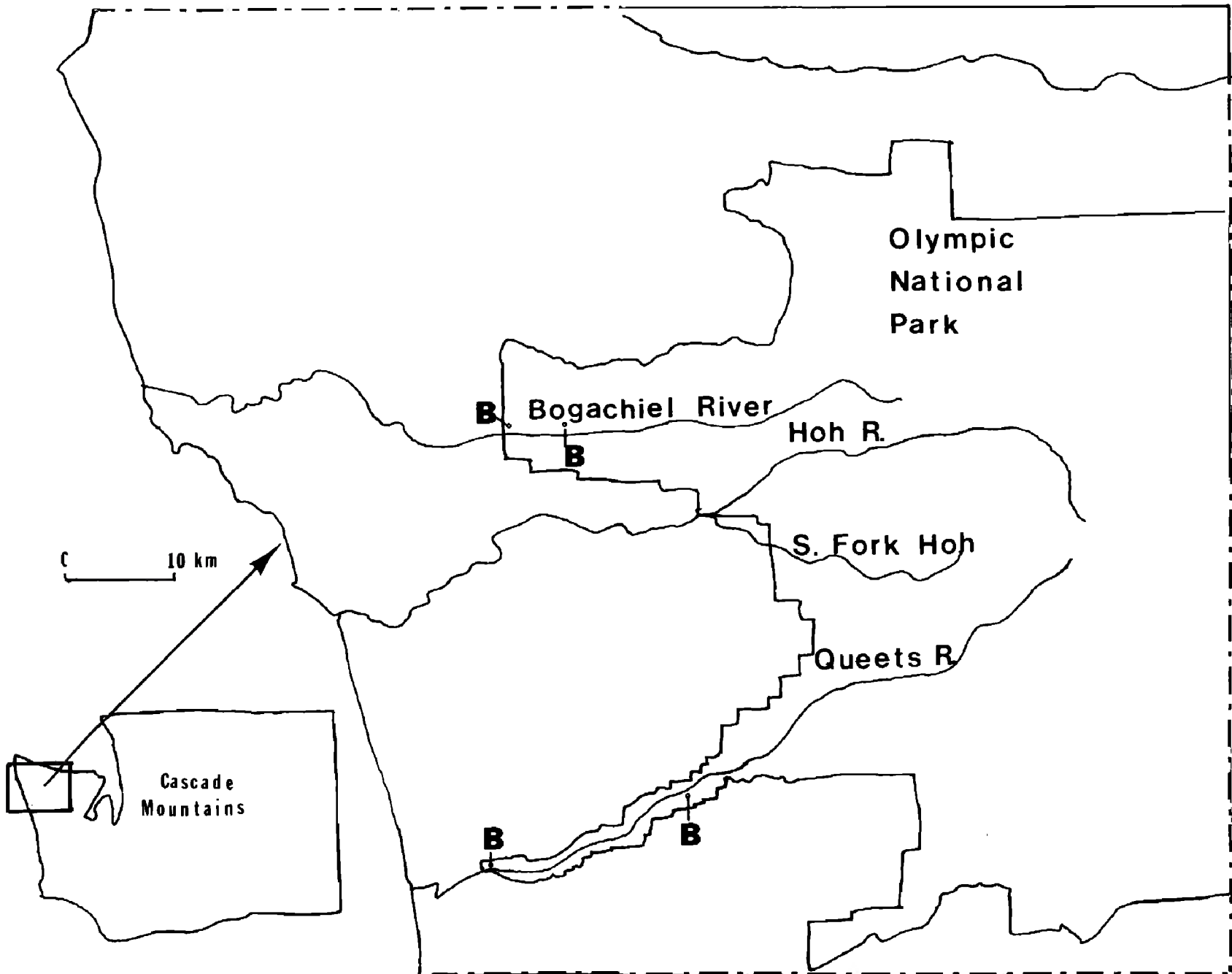
Figure 1. Locations where Barred Owls (B) were observed on the west side of the Olympic Peninsula, Washington State in 1985.

ducted on the Olympic National Forest since 1978 but have elicited no Barred Owl responses. Similarly, Spotted Owl survey results from the Washington Department of Wildlife since 1983 have not reported Barred Owl responses. Postovit (1977) surveyed Spotted Owls along 55 routes, each about 4 km in length, on the Olympic Peninsula, including 8 drainages in Olympic National Park. No Barred Owl responses were reported.

Barred Owls were first observed on the Olympic Peninsula in 1985 during a 2 yr call survey for Spotted Owls in Olympic National Park by an interagency team with representatives from the Washington Department of Wildlife (WDW), Department of Natural Resources, and Olympic National Park (WDW 1987). Four river drainages were call surveyed for Spotted Owls along the west side of Olympic National Park between May and July 1985 (WDW 1987). Responses were obtained from Barred Owls at 4 locations: 2 in the Queets River valley and 2 in Bogachiel valley (Fig. 1). At the Bogachiel response sites Spotted Owls answered either simultaneously, within a half-hour, or within 500 m of the Barred Owls. In 1986 both sites were occupied by Barred Owls, and no Spotted Owls were heard, suggesting that the Spotted Owls might have moved or been displaced. One response site along the Queets Valley road was occupied by a pair of Barred Owls that produced 3 young in 1985 and 1986. Responses in Olympic National Park in 1987 (Sharp et al. 1987) were from river terrace or lowland areas.

Range expansion by the Barred Owl might be a threat to the Northern Spotted Owl, whose numbers are declining due to fragmentation and loss of old-growth habitat (Marcot and Gardetto 1980; Forsman et al. 1984; Simberloff 1987). Barred Owls are known to occupy a greater variety of habitats, and have several adaptive breeding strategies and behavioral patterns that might cause competition with the Spotted Owl (Hamer 1987).

ACKNOWLEDGMENTS

Kate Foster and Chuck Sisco discovered and identified the first Barred Owls on the west side of the Olympic Peninsula. Eric Forsman, Bruce Moorhead and L. Scott Mills reviewed the manuscript.

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Peregrine Falcon Takes Black-bellied Plover from Sea off Kenya

Jennifer F. M. Horne and Lester Short

At 0645 H on 8 January 1989 we noticed a Peregrine Falcon (*Falco peregrinus*) in flight ½ km from shore at Watamu, Kenya. The falcon was making rather slow, circling swoops between us ashore and a grassy, rocky islet about 1 km east of the former home of the late falconiform specialist Leslie Brown. We then observed a bird in the water around which the falcon flew. The bird in the sea attempted to fly and actually rose from the water for 1–2 m, then crashed down. The falcon increased its speed and swooped at the bird, which raised 1 or both wings and lowered its head at the approach of the falcon. The bird in the water appeared waterlogged and injured, but for 10 min or so it made movements (beating wings, head and neck thrust under water) to evade the Peregrine, whose stoops became more regular and in tighter circles.

At 0658 H we began counting the Peregrine's swoops, and noted that the prospective prey, which likely had been attacked by the falcon and injured before we arrived at the beach, was less active, only ducking its head and moving its wings on the water. By 0707 H we had counted 75 stoops of the Peregrine, the "circles" over the bird had become smaller, more elliptical, and from one side and then the other (instead of full swoops around and back from only one direction). At 0710 H the Peregrine adroitly lifted the bird from the sea, which was moderate but not rough in a light wind. The Peregrine made a half circle, clutching the bird, about 5 m over the water, then headed momentarily toward the islet before reversing and flying back (west) toward us, with the east (inshore) wind behind it The falcon landed on a rock 100 m south of us, near the shore, and began plucking feathers from its prey. The Peregrine likely was a subadult, as it was mainly barred below with some streaking, and pale above.

We approached the falcon slowly at 0711 H. One min later it carried the prey 30 m farther south to a larger rock, where it continued plucking and began to feed. We had seen feathers fall at the first site, so we now left the beach, hoping the falcon would finish its meal and leave enough remains for us to identify the rather small bird it had taken. We returned about 20 minutes later at 0735 H, the Peregrine was gone. We sought remains of the prey, finding: a) at the first site body feathers and the head of a Black-bellied Plover (*Charadrius squatarola*); and, b) at the second, intestines, some tail and body feathers and the 2 wings, attached by some flesh, bearing the diagnostic black axillary feathers of the species. We surmise that the plover, common at Watamu in the boreal winter, had been flying north or south parallel to the coast, where it was attacked by the Peregrine (likely hunting out from the islet). It must have been injured when struck, likely just over the sea (this plover usually flies close to the water), into which it fell before the Peregrine could retrieve it.

The actual kills of wild Peregrines are rarely witnessed (Ratcliffe 1980:128). It is clear (Brown 1976; Brown et al. 1982) that most prey of Peregrines is taken in the air. Experienced (adult) Peregrines are adept at shepherding prospective landbird prey out over the water (although they may pursue it toward land when the prey tires and becomes more vulnerable), and water birds, inland (Hunt et al. 1975; Treleaven 1977; Sherrod 1983).

Beebe (1960) studied breeding Peregrines of the northwestern North American coast, and found that they preyed almost exclusively on small alcids and storm-petrels that were attacked mainly over land and the shoreline as the prey headed from ground nests toward the sea. His many observations include only *one* hunting episode over the sea itself. Peregrines are apt to avoid getting wet or plunging into the sea, especially after heavy prey that has fallen. Walter (1979:96), concerning the related Eleonora's Falcon (*Falco eleonorae*) wrote that they mainly hunt small landbirds over the sea and "avoid touching the salt water " Prey, other than very small land birds that can be easily plucked from the surface, pose problems of the Peregrine getting wet, and attracting the attention of competitive large gulls (e.g., *Larus marinus,* or, in Kenya, *Larus hemprichii*) and sea eagles (in Kenya, the large, coastal African Fish-eagle, *Haliaeetus vocifer*) that can enter the water and might prey on the falcon (see Rudebeck 1953:212, cases 12 and 17). Actual accounts of "plucking" from water by the Peregrines are few. Rudebeck (1953:210) noted a dead starling (*Sturnus vulgaris*) taken from the sea; Cade's works (1960, 1982) mention only a jay (*Perisoreus canadensis*) taken from a river from which it was "floundering out" (Cade 1960:215), a longspur (*Calcarius* sp.) plucked from a river by a large female Peregrine, and a grayling fish (*Thymallus arcticus*) grasped by a Peregrine as it was "breaking the surface" of the water. Ratcliffe (1980:156) stated that British coastal breeding Peregrines "are mostly careful not to knock their prey into the sea."

The persistence of the Peregrine we observed is notable. Rudebeck (1953) gave no numbers, but mentioned that Peregrines rarely stooped at fleeing prey more than 50

times. Although some Peregrines may be persistent in actual chases, we have found no descriptions of repeated attacks on live prey that they have knocked into the sea.

It is well known that Peregrines may burst into a flock, e.g., of shorebirds, then select and pursue a single individual, but in one-on-one attacks many shorebirds dodge well and evade Peregrines (Hunt et al. 1975:121). Treleaven (1977) noted that young Peregrines in the autumn concentrate on snatching unsuspecting waders from the edges of flocks feeding on the shoreline.

Black-bellied Plovers in coastal Kenya tend to fly alone, and not high above the sea, into which they can go as a last resort (not diving directly, as, e.g., can alcids). The plover we observed, whether it had been wounded or driven into the sea by the Peregrine, never actually went beneath the surface, nor did it defend itself. Rather, all its movements were to evade the falcon by lowering its head and fluttering away when the falcon stooped, and to attempt to get airborne. It did not move any distance under its own power during the course of our observations. Our observations suggest that the killing and plucking of a 190–200 g (Cade 1960) Black-bellied Plover presented a major problem to the Peregrine. Its persistence, however, paid off.

ACKNOWLEDGMENTS

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NORTHERN HARRIER (Circus cyaneus) PREDATION OF
LESSER PRAIRIE-CHICKEN (Tympanuchus pallidicinctus)

DAVID A. HAUKOS AND GERALD S. BRODA

The Northern Harrier (Circus cyaneus) is not considered a significant predator of Lesser Prairie-Chicken (Tympanuchus pallidicinctus) (Palmer et al. 1988). However, Campbell (1950) reported that Northern Harriers will harass lekking Lesser Prairie-Chickens by repeated lek flushes and an occasional attack. The objective of this paper is to report and describe 5 cases of Northern Harrier predation on Lesser Prairie-Chicken in west Texas.

Throughout 2 spring lekking periods (1987 and 1988), we observed and recorded interactions of Northern Harriers with Lesser Prairie-Chickens during >750 hrs of lek observation (Haukos 1988). The study area was in Cochran and Yoakum Counties, Texas. The area has a sandy duned topography supporting range cattle production; with dominant vegetation of sand shinnery oak (Quercus havardii), sand sagebrush (Artemisia filifolia), and bluestem (Andropogon spp.) plant communities. Other raptors in the area include Golden Eagle (Aquila chrysaetos), Cooper's Hawk (Accipiter cooperii), Red-tailed Hawk (Buteo jamaicensis), Swainson's Hawk (B. swainsoni), Rough-legged Hawk (B. lagopus), Ferruginous Hawk (B. regalis), and Prairie Falcon (Falco mexicanus). The number and composition of raptors on the study site fluctuates greatly during the lekking period as raptors migrate through the area. However, harriers have been observed ground-nesting on the study site (pers. obser.).

Throughout the study, harriers approached and harassed (caused lek display to cease) Lesser Prairie-Chickens on leks. Northern Harriers, alone (females) or in pairs (female and male), quartered leks and caused a full lek flush on 3 of 67 observed lek approaches (4%). During the morning display period (½ hr before–2 hrs after sunrise), observed harriers quartered only leks and not areas between leks, causing partial lek flushes in 30% (20 of 67 approaches) of lek approaches. Male prairie-chickens usually ceased displaying when harriers quartered over leks. However, no attacks by harriers on Lesser Prairie-Chickens were observed at leks.

All observed harrier predation of prairie-chickens were on birds away from leks, but within 100 m of a lek. On 10 March 1988, a live juvenile female Lesser Prairie-Chicken was recovered from a female Northern Harrier. The prairie-chicken had been captured on the side of a sand dune dominated by sand shinnery oak. A male harrier was present on the ground near the site. The female harrier was attempting to control the prairie-chicken by standing on her back; however, the prairie-chicken was able to travel several m (<10) after the initial attack while the harrier was grasping her. We did not observe any male harrier assistance in subduing the prairie-chicken. Our presence caused the harriers to flush and we were able to retrieve the prairie-chicken. Upon examination, the prairie-chicken had suffered no severe damage (i.e., flight capable) except a puncture wound just below the nape between the wings caused by the raptor's talons. The area immediately surrounding the wound was free of feathers. Prairie-chicken feathers were scattered around the capture site indicating a struggle or plucking by the harrier.

On 23 February 1988 a female harrier was flushed from a recently killed adult male prairie-chicken. Feathers were scattered around the site. An area bare of feathers was found below the nape and the carcass had been decapitated.

On 19 March 1988, a female harrier was flushed from a fresh carcass of a juvenile female prairie-chicken. Prairie-chicken feathers were scattered over the kill area and the carcass had been decapitated. Evidence at the site indicated that the carcass had been dragged from the kill site 10 m into bluestem grass cover, but whether the harrier dragged the carcass is unknown.

On 23 February 1987, an adult male harrier was flushed from a carcass, no more than 2 d old (the carcass was not near the location 2 d previous), of an adult male prairie-chicken. A scattering of feathers was present in an area approximately 7 m in diameter. The carcass had been decapitated.

On 16 March 1988, a juvenile male prairie-chicken was trapped which had talon wounds along with an area free of feathers below the nape. We determined that the bird had likely survived a Northern Harrier attack and was in good condition with no obvious difficulty in flight.

Examination of all birds and carcasses found with Northern Harriers had the following characteristics: (1) a talon wound on the neck which was surrounded by a small area free of feathers; (2) carcasses were decapitated;

and (3) prairie-chicken feathers were scattered around the area representing either a struggle during the kill or plucking by the harrier. We suggest that harriers are probably unable to kill Lesser Prairie-Chickens in flight or deliver death blows with talons. Harriers do appear, however, to be capable of pinning Lesser Prairie-Chickens to the ground and successfully decapitating them.

Northern Harriers have been studied in the presence of Greater and Attwater's Prairie-Chicken (*T. cupido*) Lehmann (1941) noted that harriers repeatedly flushed and dove at Attwater's Prairie-Chicken; no kills were reported. Berger et al. (1962) reported that harriers caused a full lek flush on 38% of all approaches (886) and a partial lek flush on 30% of all approaches. In comparison to this study, harriers cause a full lek flush more frequently in Greater Prairie-Chickens, but partial lek flushes are the same between the 2 studies. Berger et al. (1962) reported 1 observed kill of a Greater Prairie-Chicken by harriers and concluded that "harrier harrassment is ordinarily a matter of little consequence."

In all likelihood, few Lesser Prairie-Chickens are probably killed directly by Northern Harriers. However, subsequent mortality by survivors of harrier attacks may occur. Attacked birds may be in a weakened state and subject to a higher probability of predation from other avian and mammalian predators.

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AN INSTANCE OF CARRION-FEEDING BY THE PEREGRINE FALCON (*Falco peregrinus*)

DAN C. HOLLAND

Diet of the Peregrine Falcon (*Falco peregrinus*) consists primarily of birds (see Bent 1937; Hickey 1969; Palmer 1988), but predation on mammals has also been observed (Fischer 1968; C. White, pers. comm.). Few reports describe the use of carrion by these falcons (Beebe 1960; Ratcliffe 1980; C. White, pers. comm.), an instance of which I report here. Observations were made on 11–12 July 1988 at the U.S. Fish and Wildlife Service San Simeon field station at Piedras Blancas, San Luis Obispo County, California. Activity was observed from a distance of 114 m with a 60× Bausch and Lomb spotting scope.

A single falcon in juvenile plumage was first seen perched on a telephone pole near the station access road at 0910 H on 12 June. The bird made 5 short (8–10 m height) stoops on the carcass of a juvenile California Ground Squirrel (*Otospermophilus beechyi*) laying in the road. The squirrel was killed by a vehicle at approximately 1730 H on 11 June.

At 0920 H the bird seized the carcass and dragged it to the road's edge, and after a brief pause, moved it off the road. The bird mantled the carcass and began feeding at 0924, making a total of 47 feeding movements in a 3 min period followed by 3 min of inactivity. At 0930 activity resumed and 111 feeding movements were observed in a 25 min period. The bird ceased feeding until 1036, and made another 21 feeding movements before being frightened off the carcass at 1038 by a passing vehicle. The falcon had not returned to the carcass by 1108, at which time the squirrel was collected. The carcass had been moved 3 m, and the remains weighed approximately 150 g. The head was missing, and most of the pelt in the left axillary area had been removed. Extensive tissue removal was noted from the deltoideus, rhomboideus, triceps and biceps.

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Thesis Abstracts

Characteristics of Breeding Habitat for Peregrine Falcons on the Colorado Plateau

The endangered Peregrine Falcon (*Falco peregrinus*) has experienced large scale population declines in much of its cosmopolitan range. Although the Peregrine is one of the most widely studied birds, breeding habitat requirements have not been critically evaluated, especially in the Rocky Mountain states. Data from 65 historically and currently active eyries were analyzed to describe and quantify habitat parameters for breeding Peregrines on the Colorado Plateau. Surveys for active eyries were concentrated in national parks between 1984–1986. A total of 144 variables (e.g., topography, hydrology, vegetation, competing species, cliff characteristics, human disturbance factors, etc.) were measured and rated for each eyrie. Physiographic parameters, trends in eyrie occupancy, and reproductive success were also examined. Correlations between eyries were observed in cliff height and distance to permanent water. Computer programs (SAS) were used to analyze individual variables. This data base is useful for locating new breeding sites and for potential reintroduction of Peregrines at historical sites. This data base will be useful in future years for standardizing and correlating new information. **Teresa, Sherry, Master of Arts in Geography, University of California, Los Angeles, 1988. Professor Hartmut Walter, Chair.**

Reversed Size Dimorphism, Determinants of Intraspecific Dominance, and Habitat Use by American Kestrels (*Falco sparverius*) Wintering in South Carolina

This study examines the importance of sex, age, weight, and residency on the dominance status of wintering American Kestrels (*Falco sparverius*), examines habitat segregation by sex in kestrels wintering in South Carolina and Maryland, and experimentally tests the female dominance hypothesis proposed to explain reversed size dimorphism in raptors Kestrels were randomly paired in an arena containing food (a mouse) either in aviaries at Clemson University or in the field. During 20 minute observation periods, all interactions between birds were recorded. Females tended to dominate males, and heavier birds tended to dominate lighter ones. The female dominance hypothesis was supported Although sample sizes were too small for strong conclusions, there were indications that age and residency are also important determinants of dominance. Field observations revealed no habitat segregation, either in South Carolina, or in Maryland, but did suggest strong non-random habitat use. Both sexes were found significantly more in open habitats, such as plowed fields, pastures, and meadows, and significantly less often in wooded and residential areas. **Aborn, David A. 1989. M.Sc. Thesis, Dept. of Biological Sciences, Clemson University, Clemson, SC 29634-1903. Thesis Advisor: Dr. Sidney A. Gauthreaux, Jr.**

Raptors of El Imposible Forest, El Salvador, C.A.

The purposes of this research were to determine raptor species composition and obtain baseline natural history data Thirty species of resident and migratory raptors were observed. Representatives of 6 species were mist-netted and banded. Data were recorded on the nesting of 13 species, and 111 hr of observations were recorded on a King Vulture (*Sarcoramphus papa*) nest. Four of the observed species were listed as endangered, five threatened, and four previously unrecorded in El Salvador. **West, Jane Noll. 1988. M.Sc. Thesis, Department of Biology, Central Washington University, Ellensburg, WA 98926.**

NEWS AND REVIEWS

A Dictionary of Ethology by Klaus Immelmann and Colin Beer. Harvard University Press, Cambridge, Massachusetts and London, England, 1989. 336 pp. Cost, hardcover, $35.00 U.S.

We have good news for fellow lexicophiles (i.e., those who compulsively browse through dictionaries), especially those with a behavioral bent. Over the last 2 decades, several volumes defining the vernacular of ethology have appeared on the market. The publication listed above (hereafter, Dictionary) is the most recent book attempting to clarify the terms and concepts of animal behavior.

This volume is, in our opinion, the most useful to students of ethology. In a text that is well-organized, attractively illustrated (about 20 line and stipple drawings), and largely error-free, the authors present about 700 terms in clear concise language. They provide not only a definition, but also examples, information on the origin of the term, very often a synonym, and, even more useful, an evaluation of the current value of each term.

Classifying the book as a dictionary somewhat disguises its full value. The volume includes much more information than would be expected even in an unabridged dictionary. Rather, the tome appears to be a powerful attempt to canonize the preferred terminology of ethology. Far beyond merely defining terms, it provides a commentary on which terms have come into general use, which have not, and which are so abused in the literature (e.g., instinct, motivation) that they are now of little use to the scientist. The book also provides definitions and clarifications of terms which even the serious student of ethology has probably given little thought.

To illustrate the Dictionary's value as a clarifier of appropriate uses for specific terms, let's examine the term, "interaction". Define the term in your own mind and state all appropriate uses as you perceive them. Next, compare your perceptions with the 3 uses presented by the authors: (1) an encounter between animals, (2) an influence of an animal on its environment or vice versa, and (3) in a statistical sense, the synergistic influence of 2 or more variables on an animal or its environment. Now, decide if you have not in fact sharpened and deepened your own perceptions of the ethological concept. With the dictionary in hand, of course, this exercise is much more effective as you examine, in this case, 13 lines of text rather than our terse summary of the 3 uses of the term.

As much as we recommend the book, in our role as critics, we must state a few minor concerns. First, this volume covers a wider range of terms than would be expected for an ethological dictionary. It is surprising to see that the authors have included definitions for such basic biological terms as gamete, embryo, fossil, FSH, and many more Second, as students of raptor ecology, we take exception to the authors citing raptors as prime examples of species for which the adults commit infanticide (i.e., the authors interpret nestling neglect [passive] as a form of infanticide [active]) Third, although over 75 publications from the primary and secondary literature are cited in the text, most terms and concepts, even when lengthy, remain uncited. Perhaps this omission was essential in controlling the length of the text, but the result of this exclusion is that the book is much less useful as a means of entering the ethological literature.

Finally, Beer states in the preface that the authors excluded highly technical terms (e.g., the names/titles of specific behavioral acts) to make the book more useful to the non-specialist. Fortunately, titles and definitions of a few of these specialized terms are available in Heymer's *Ethological Dictionary* (Verlag Paul Parey, Berlin and Hamburg, 1977) In our opinion, however, Immelmann and Beer missed a propitious opportunity. The time is ripe for the presentation of standard terminology naming homologous behavioral acts (ethons) that are common to different taxonomic groups. Standardization is possible for some ethons at least as high as the Class level. Shaking (of the body), various feeding ethons, and many more could be linked by common terminology. A few ethons (e.g., yawning, stretching, and running as performed by different taxonomic Classes) are so obviously related that their titles have received *de facto* standardization even without the ethologist's help. Many more terms could also be standardized but the authors have refused to do so on the grounds that including highly specialized terms would "overload" the text. They canonize instead such curious terms as "shake to death."

Even with this omission, we consider the Dictionary invaluable in clarifying ethological concepts and facilitating communication between ethologists and other scientists in related fields. Immelmann and Beer have provided a powerful tool for refining concepts and thereby generating original thought, the mechanism of discovery in any branch of science. **David H. Ellis and Linda J. Miller, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708.**

James R. Koplin Travel Award. In honor of Dr. James R. Koplin, the Raptor Research Foundation, Inc., established an endowment to support the travel of students to annual RRF meetings. Dr. Koplin was a professor of wildlife management at Humbolt State University, in Arcata, California, and had a long-term interest in the study of raptor distribution and abundance. All students are eligible to apply for this award; however, because of Dr. Koplin's interest in Latin American raptors, preference will be given to applicants from the neotropics. This program was initiated at the 1989 RRF meeting held in Veracruz, Mexico, and consists of a $100 award. In the future, as the endowment permits, more awards in greater amounts will be provided. Selection of the recipients of this award will be based on the quality of the research conducted, financial need, and professional potential as a raptor biologist.

To be eligible for the Koplin Travel Award, a student must be a member of the Raptor Research Foundation, Inc., and the senior author on a paper to be presented at the meeting for which travel funds are requested. To apply for the 1990 award, students must submit their request to the J. R. Koplin Travel Awards Committee Chairperson by 1 September 1990.

Application materials include: (1) a two-page (double-spaced) description of the research results to be presented at the meeting; (2) an itemized budget of the total cost associated with attending the meeting, accompanied by an explanation of how the expenses not covered by this award will be met; and (3) a letter of recommendation. This letter is very important in the selection process and should be written by the student's major professor. It should contain a thorough evaluation of the applicant's academic abilities, the significance of the research being reported, his or her contribution to this research, and the potential for future contributions by the student to the field. **Send application to Michael W. Collopy, James R. Koplin Travel Award Committee, % Dept. of Wildlife and Range Sciences, 118 Newins-Ziegler Hall, 0304 IFAS, University of Florida, Gainesville, Florida 32611-0304 USA.**

Course Study on Birds of Prey. The Institute of Conservation and Ecology at the University of Kent at Canterbury is offering a 2-yr part-time course in the study of birds of prey leading to an advanced university diploma in raptor biology. The program is comprised of 2 parts: a 100-hr instructed course dealing with all aspects of raptor biology, and an individual study project. The course is designed for anyone with a genuine interest in raptors including enthusiastic amateurs, curators of raptor collections and conservation workers. Part I will commence in the 1989/90 academic year. For further details on the program outline, admission requirements and fees please write to: **Mike Nicholls, Christ Church College, Canterbury CT1 1QU, U.K.**

Biology & Conservation of Small Falcons

**A three day Conference under the aegis of
The Hawk Trust
and hosted by the
Durrell Institute of Conservation and Ecology
at the University of Kent at Canterbury, England
on 6–8 September 1991**

The study of the smaller falcons is often neglected in favour of that of the larger species.

The theme of the Conference will therefore be aspects of the biology and conservation of kestrels, merlins, hobbies and other small raptors, particularly, but not exclusively, in the genus *Falco*.

Topics to be covered at the conference will include aspects of taxonomy and evolution, ecology and behaviour, health and disease, captive breeding and associated research.

Further offers of papers and poster demonstrations are invited, and requests for more information should be sent to: **Mike Nicholls, Christ Church College, CANTERBURY, Kent, CT1 1QU, England.**

Tully Memorial Research Funds Available. The Raptor Research Foundation will provide a $600 grant from the Stephen R. Tully Memorial Fund for research, management, or conservation of birds of prey. Students and serious amateurs are encouraged to apply. Send 5 copies of a succinct proposal (5 pages maximum), outlining your background, study goals and methods, anticipated budget, and other funding requests to **James H. Enderson, Chairman, Tully Grant Committee, Colorado College, Colorado Springs, CO 80903.** Applications must be *received by* 10 September 1990, and the award will be announced in October 1990.

CONTENTS FOR VOLUME 23, 1989

NUMBER 3

Number 4

The Journal of Raptor Research is distributed quarterly to all current members. Original manuscripts dealing with all aspects of general ecology, natural history, management and conservation of diurnal and nocturnal predatory birds are welcomed from throughout the world, but must be written in English. Contributors should submit a typewritten original and three copies of text, tables, figures and other pertinent material to the Editor. Two original copies of photographic illustrations are required. All submissions must be typewritten double-spaced on one side of 8½ × 11-inch (21½ × 28 cm) good quality, bond paper. Number pages through the Literature Cited section. The cover page should contain the full title and a shortened version of the title (not to exceed 30 characters in length) to be used as a running head. Author addresses are listed at the end of the Literature Cited section. Provide an abstract for each manuscript more than 4 double-spaced typewritten pages in length. Abstracts are submitted as a separate section from the main body of the manuscript and should not exceed 5% of the length of the manuscript.

Both scientific and common names of all organisms are always given where first appearing in the text and should conform to the current checklists, or equivalent references, such as the A.O.U. Checklist of North American Birds (6th ed., 1983). Authors should ensure that all text citations are listed and checked for accuracy. If five or fewer citations appear in the text, place the complete citation in the text, following these examples: (Brown and Amadon, Eagles, Hawks and Falcons of the World. McGraw-Hill, New York, 1968), or Nelson (*Raptor Res.* 16(4):99, 1982).

Metric units should be used in all measurements. Abbreviations should conform with the Council of Biology Editors (CBE) Style Manual, 5th ed. Use the 24-hour clock (e.g., 0830 and 2030) and "continental" dating (e.g., 1 January 1984).

A more detailed set of instructions for contributors appeared in *J. Raptor Res.*, Vol. 21, No. 1, Spring 1987, and is available from the Editor. Send all manuscripts for consideration and books for review to the Editor.