(ISSN 0892-1016)

THE JOURNAL OF RAPTOR RESEARCH

VOLUME 21 AUTUMN 1987 NUMBER 3

CONTENTS

****

Persons interested in predatory birds are invited to join The Raptor Research Foundation, Inc. Send requests for information concerning membership, subscriptions, special publications, or change of address to Jim Fitzpatrick, Treasurer, 12805 St. Croix Trail, Hastings, Minnesota 55033, U.S.A.

The Journal of Raptor Research (ISSN 0892-1016) is published quarterly for $15.00 per year by The Raptor Research Foundation, Inc., 12805 St. Croix Trail, Hastings, Minnesota 55033, U.S.A. Application to mail at second class rate is pending at Hastings, Minnesota, and additional mailing office. Printed by Allen Press, Inc., Lawrence, Kansas, U.S.A.

THE JOURNAL OF RAPTOR RESEARCH

A QUARTERLY PUBLICATION OF THE RAPTOR RESEARCH FOUNDATION, INC.

VOL. 21 AUTUMN 1987 NO. 3

J. Raptor Res. 21(3):85–94

METHODS OF CONTROLLING GOLDEN EAGLE DEPREDATION ON DOMESTIC SHEEP IN SOUTHWESTERN MONTANA

MARC R. MATCHETT AND BART W. O'GARA

ABSTRACT.—Potential for extensive Golden Eagle (*Aquila chrysaetos*) depredation on lambs of Domestic Sheep (*Ovis aries*) exists when jackrabbit (*Lepus* spp.) populations are low and/or lambing seasons are cool or wet. Such conditions were present during 1974 and 1975 on two ranches near Dillon, Montana, when eagle depredation on lambs was high. Golden Eagles were trapped on the ranches from 1975 through 1983 and translocated to areas where chances of depredation were deemed small. The translocation program was expensive, had little demonstrated effect on depredation and may have functionally transplanted the problem, not solved it. Harassment of eagles by chasing with a small airplane, discharging rifles and firing explosive shotgun shells failed to stop depredation, to reduce the number of birds present or to alter distribution. Human-like scarecrows placed on high knobs and ridges, accompanied by harassment, appeared to reduce depredation and displace eagles from the lambing sheep bands during 1984. We tested the hypothesis that eagles avoided scarecrows and that scarecrows, combined with harassment and increased human activity, reduced depredation. This combination kept eagle sighting rates to a minimum, redistributed birds and reduced depredations. No single predator control technique will always work in every situation, but we conclude that scarecrows, combined with harassment, offer the most feasible means of protecting lambs under range lambing conditions in southwestern Montana.

The topic of Golden Eagle (*Aquila chrysaetos*) depredation on lambs of Domestic Sheep (*Ovis aries*) is controversial. Raptor enthusiasts and sheepmen are often at odds over the severity of depredations or the fact that they even occur. Golden Eagles are efficient predators known to kill lambs (Glover and Heugly 1970; Nesse et al. 1976; Tigner and Larson 1977, 1981; Foster and Crisler 1978, 1979; O'Gara 1978, 1981; Wade and Livingston 1978, 1979). Reportedly, Golden Eagles have killed domestic calves (*Bos taurus*), Mule Deer (*Odocoileus hemionus*), Bighorn Sheep (*Ovis canadensis*), Dall's Sheep (*Ovis dalli*), Mountain Goats (*Oreamnos americanus*), and even Coyote (*Canis latrans*) (McLean 1925; Dixon 1934; Allen 1939; Couey 1944; Wood 1946; Boyer 1948; Clawson 1948; Kennedy 1948; Brown and Couey 1950; Casebeer et al. 1950; Riney 1951; Ford and Alcorn 1964).

Most depredation problems occur at lambing time (Arnold 1954; Murphy 1977; U.S. Dept. Int., Fish and Wildl. Serv. 1983) and are relatively short-term conflicts, although economic losses can be great. Littauer and White (1981) estimated lamb losses due to eagle depredation at $87 000 in New Mexico from 1 January–1 May 1981. Lamb losses to eagle predation on two ranches in southwestern Montana were estimated at $38 000 in 1974 and $48 000 in 1975 (O'Gara 1978). Arnold (1954:30) concluded from his studies of eagle depredation on sheep in Colorado, Wyoming and Texas that depredations were "spasmodic . . . and may vary considerably under changing local conditions."

Factors that influence the severity of Golden Eagle depredation on sheep include: natural prey densities, availability of carrion, weather, ranching practices, vegetative cover, and topography as well as Golden Eagle age, behavior, densities and distribution (Arnold 1954; Lockie and Stephen 1959; Snow 1973; Bolen 1975; Brown 1975; Tigner and Larson 1977, 1981; O'Gara 1978, 1981; Gober and Lockhart 1979). Interaction of these factors in combination with economic, social and political values contributes to emotionally charged, opinionated and highly contested conflicts.

During June 1974, the Director of the U.S. Fish and Wildlife Service (USFWS) received two applications from Peter and George Rebish and from Rebish and Helle, Inc. requesting a permit to kill Golden Eagles that were killing lambs. Law enforcement agent E. Cofer (USFWS), who had extensive experience identifying predator kills, was dispatched to Dillon. Cofer found 16 fresh, eagle-killed lambs within two hr. Service biologists, animal damage control agents and a representative of the National Audubon Society met in Dillon to discuss the situation. The applicants were willing to cooperate in an eagle live-trapping and removal program or a documentation study. Thus began an 11 yr research/management program on Golden Eagle-lamb depredation in southwestern Montana. This paper summarizes research results and describes management practices.

STUDY AREA

Rebish Brothers/Rebish-Konen and Rebish and Helle, Inc., ranches are located about 40 and 25 km southeast of Dillon, Montana, respectively. The former covers about 9300 ha of rolling grassy hills near the head of Rock Creek at about 2100 m elevation. Steep hills and deep valleys associated with strong winds and thermal updrafts provide ideal flying conditions for eagles.

Rebish and Helle, Inc., ranch consists of about 3000 ha of sagebrush (*Artemisia* spp.) and scattered grasslands with pockets of aspen (*Populus tremuloides*) and conifers along the North Fork of Sweetwater Creek. Large boulders and rock outcrops are common, providing ideal perches for eagles.

Rebish-Konen ranch was divided into two areas to test scarecrow efficacy during 1985. The two areas, Rock Creek (2000 ha) and Little Rock (3000 ha), were adjacent and had similar vegetation and topography. Rock Creek had high eagle use during previous years (J. Konen, pers. comm.) and many eagle kills were found there (O'Gara 1978, 1981, 1983). Eagles also used Little Rock and were trapped in both areas from 1975 through 1983 (Niemeyer 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983). Sheep stocking rates were similar to past years with 1400 lambing ewes on Rock Creek and 500 lambing ewes and 600 yearling ewes on Little Rock.

Lambing Practices. Range lambing begins on both ranches during mid- to late May and is completed by early July. The ranchers minimize human disturbance of the sheep during lambing in efforts to prevent lamb abandonment by ewes. Ewes and lambs are moved to mountain rangelands during July and remain there through September. Golden Eagle depredation occurs primarily on lambing grounds during May and June. Ranchers report no problems from eagles on summer ranges.

After lambing is completed, tails of lambs are removed (docked) and animals are prepared for movement to summer ranges. Accurate counts are made at docking time. The number of lambs divided by the number of ewes, multiplied by 100, is referred to as the docking percentage. Docking percentages are frequently used, erroneously, as indicators of predation severity. During years of severe depredation, bad weather, high disease incidence or combination of a myriad of other mortality factors, docking percentages will be low. Nevertheless, docking percentages can be used as a relative indicator of lamb production.

METHODS

Carcass Searches, Depredation Rate and Identification of Eagle-killed Lambs. Sheep carcasses were located with cursory drives around each ranch and by sighting groups of eagles or Common Ravens (*Corvus corax*) (White and White 1985). Many carcasses were located during aerial surveys and examined later on the ground If cause of death was not immediately discernible, carcasses were skinned to examine any wounds and dissected to examine internal organs if present. Some carcasses were brought in by field crews and ranchers for necropsy. Eagle depredation rate during 1985 was calculated by dividing the number of eagle-killed lambs found by the number of adult ewes on a given study area. The number of ewes present was our best indicator of number of lambs available. Depredation rate differences between study areas were evaluated with a proportional test using a Z statistic (Zar 1984).

O'Gara (1978, 1981) outlined methods for identification of eagle-killed lambs. Additional characteristics of predator-killed animals were given by Rosko (1948), Rowley (1970), Wiley and Bolen (1971), Bowns et al. (1973), Davenport et al. (1973), Brown (1976), Nesse et al. (1976) and Tigner and Larson (1977, 1981). Subcutaneous hemorrhage at talon wounds was the primary indicator for eagle-killed lambs. Evidence of arterial spurts also indicated a kill. Large amounts of blood originating from eye wounds generally indicated a raven kill. Ravens sometimes pecked the eyes of young lambs and "pecking bruises" were often noted when these kills were skinned.

Capture, Translocation, Radio Instrumentation and Monitoring. From 1975 through 1983 eagles were captured for translocation using the Lockhart method (Niemeyer 1975). Padded, steel, leg-hold traps (No. 3 or 4) were baited with dead rabbits or lambs, placed at visible locations and observed from a distance. A live decoy eagle was usually staked near the traps. Four, unanchored, concealed traps chained together to form two pairs surrounded each bait. Sometimes a length of rope was attached to each trap pair. When an eagle was captured, the weight of the traps and their tendency to snag on surrounding vegetation allowed ground crews to contain the eagle and remove the trap. Captured eagles were transported to holding facilities and then to release sites (Niemeyer 1975).

Nine eagles were captured for radio instrumentation during 1985 using a helicopter and Coda (Coda Enterprises, Inc., Mesa, AZ) net gun (O'Gara and Getz 1986). Radio-transmitters (SB2, AVM Instruments, Livermore, CA), were attached ventrally on the most recently molted central rectrix approximately 2 cm distal to the follicle. Transmitters were attached to the feather with three pairs of nylon string that were embedded in the transmitter potting material. Anterior and posterior string pairs were tied around the feather shaft, and one of the middle strings

was passed through the feather shaft using a needle, and then tied around the transmitter. String tails were tied together forming a "net" around the transmitter. The antenna was attached to the remaining distal portion of the feather at four equally spaced intervals. Surgical knots were used throughout and super glue (Duro) was applied to each knot. Transmitter packages weighed approximately 26 g. Eagles were radio-tracked from a Piper Super Cub utilizing a rotating H antenna and Telonics (Telonics, Inc., Mesa, AZ) receiver. A few locations were recorded from the ground on an opportunistic basis.

Eagle Surveys. Aerial and ground counts and age classifications of eagles were made during 1975 and 1976 (Niemeyer 1975, 1976). Notes on relative abundance and age of eagles observed during trapping efforts were made from 1977 through 1982 (Niemeyer 1977, 1978, 1979, 1980, 1981, 1982). Age, sex and total number of eagles captured was also recorded annually between 1975 and 1983.

Parallel strip transects approximately 1 km wide were flown at an altitude of about 100 m across the entirety of both ranches from 1983 through 1985. The pilot and observer looked for eagles within 0.5 km of the aircraft on 2–4 d intervals from May through July. Total numbers of eagles observed and approximate locations were recorded during 1983 and 1984. During 1985, the number of eagles observed from aircraft, vehicle, and horseback, and eagle activity, age and exact location (Universal Transverse Mercator coordinates within 100 m) were recorded. Search effort (flight survey time or time and km driven/ridden) was also noted during 1985.

Eagle Harassment and Frightening Techniques. Eagle harassment consisted of discharging explosive shotgun shells (crackershells), discharging a rifle near perched birds and approaching birds via vehicle, foot, or horseback causing them to move. Taped eagle "chitter" and alarm calls were used during 1983 in attempts to frighten eagles from sheep carcasses. Eagles were also harassed using a Piper Super Cub during 1983 by "buzzing" them, attempting to force them to fly and by chasing birds with the aircraft and firing shotshells or crackershells (O'Gara 1983).

Human-like scarecrows and suspended eagle carcasses were placed on high points and ridges late in the lambing season of 1983 in attempts to discourage eagles from lambing areas. Scarecrows were hung with wire on a pipe, allowing movement in the wind and were also used during 1984 and 1985 (O'Gara et al. 1984; O'Gara and Matchett 1985). Shiny tin pans were tied to each scarecrow with string after they had been in place for about two wk in efforts to increase visibility and retard eagle habituation to scarecrows.

Experimental Test of Scarecrow Efficacy. Scarecrows were erected on Rock Creek study area and Little Rock study area served as a control area without scarecrows or harassment during 1985. Both areas were similarly surveyed for eagles and lamb carcasses. Expected results were that Rock Creek and Little Rock would have similar eagle sighting and predation rates before placement of scarecrows. If scarecrows deterred eagle depredation, rates would be expected to decrease on Rock Creek and stay the same or increase on Little Rock.

Number of eagles observed were evaluated on a per unit effort basis (number of eagles observed/min or km of search effort) for pre- and post-scarecrow placement time periods. Differences between mean sighting rates during pre- and post-scarecrow placement time periods and between Rock Creek and Little Rock Creek study areas were evaluated with Student's t-Tests using separate variance estimates (Sokal and Rohlf 1981; Nie 1983).

Measurements of distances between scarecrow sites and both eagle radio-locations and sightings of unmarked eagles before and after scarecrow placement were used to quantify potential eagle avoidance of scarecrows. Mean distances were calculated for pre- and post-scarecrow time periods. Our hypothesis was that eagles would be closer to individual scarecrow sites before scarecrows were placed and would avoid scarecrows and be farther from scarecrow sites after placement. We tested our hypothesis using Mann-Whitney U-Tests and Student's t-Tests on differences in eagle distance from scarecrow sites during pre- and post-scarecrow time periods (Sokal and Rohlf 1981; Nie 1983).

RESULTS AND DISCUSSION

Lamb Mortality and Circumstances Related to Eagle Depredation. Little depredation documentation was attempted during 1975–1982 and 1984. Compared to 1974 and 1975, depredations were evidently low from 1976 through 1985 (Table 1). Eagle-killed lambs were easily found with minimal search effort during 1974 and 1975, but relatively few eagle-killed lambs were found from 1977–1985. Many of the carcasses necropsied between 1977 and 1982 were brought in by ranchers and field crews. Selection for suspected eagle-killed lamb carcasses was a possibility. Docking percentages approached normal (rancher acceptable) levels from 1976–1985. If significant depredations were occurring during this period, larger numbers of eagle-killed lambs would have been found and docking percentages would have been lower.

An apparent decline in jackrabbit (*Lepus* spp.) populations throughout the West appeared to be an important factor leading to extensive sheep depredation during 1974 and 1975 (O'Gara 1978, 1981, 1983). Conclusive data were unavailable, but communications with biologists from 17 western states indicated that jackrabbit populations crashed during 1972–1973 and that jackrabbits were scarce during 1974 and 1975. Lambing seasons of 1974 and 1975 were unusually cool and wet on the study areas (U.S. Dept. Comm. 1974, 1975) and Richardson's Ground Squirrels (*Spermophilus richardsonii*) and Yellow-belly Marmots (*Marmota flaviventris*) were relatively inactive due to cool temperatures (O'Gara 1981). Few alternative prey species were available to eagles, whereas lambs were abundant.

Table 1. Domestic sheep docking percentages and summary of predator-killed lambs found on the Rebish brothers/Rebish-Konen and Rebish and Helle, Inc., ranches near Dillon, Montana from 1974 through 1985.

YEAR	TOTAL CARCASSES EXAMINED	TOTAL PREDATOR KILLS	TOTAL EAGLE KILLS	% OF EXAMINED CARCASSES KILLED BY EAGLES	DOCKING[a] PERCENTAGE
1974	58[b]	47	44	76	56
1975	17[c]	15	15	88	48
1976	0	0	0	0	76
1977	31	2	1	3	78
1978	11	0	0	0	77
1979	32	19	15	47	78
1980	13	6	1	8	78
1981	17	3	0	0	90
1982	21	13	11	52	81
1983	287	36	16	6	87
1984	37	17	5	13	73[d]
1985	416[e]	37	10	2	72[d]

[a] Docking percentages represent the average of both ranches combined.
[b] Sixteen found by E. Cofer in 2 hr and the remainder found by O'Gara in just a few days. Additionally, 36 carcasses heavily fed upon by eagles were found, but cause of death could not be identified.
[c] All found on the Rebish-Konen ranch within 6 hr.
[d] Values from the Rebish-Konen ranch only.
[e] Search effort totaled 2039 km via truck, 56 hr via aircraft and 173 km via horseback.

Aerial and ground censuses during 1975 and 1976 showed that eagle numbers declined steadily from January through April (Niemeyer 1975, 1976). Natural dispersion of wintering birds from, or movement of migrants through the area, and eagle removals from trapping undoubtedly accounted for the decline (Niemeyer 1975, 1976). In May 1975 and 1976 during the peak of the lambing season numbers of eagles, 50–75% juveniles and subadults, suddenly increased. Trapping success increased markedly with the influx of birds. Numbers of eagles fluctuated thereafter, but were highest during lambing (Niemeyer 1975, 1976).

Boeker and Ray (1971) aerially censused Golden Eagles across a 26 000 km^2 area in east-central New Mexico from 1964 through 1969 and found that an average of only 31% of the general population was composed of immature birds between November and April. Counts between 1973 and 1984 in the Birds of Prey Area in southeastern Idaho indicated that the proportion of immatures fluctuated but did not exceed 50% (M. Kochert, pers. comm.). In contrast high proportions of immature birds were observed during trapping efforts in Montana (Niemeyer 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983). Seventy-six percent of the eagles captured on the study area were immature birds. Similarly, Foster and Crisler (1978) reported that 77% of their sightings were of immature eagles during a Golden Eagle-sheep depredation study in Oregon.

Young eagles appeared to be responsible for killing more lambs in this study than adult eagles (O'Gara 1981). Young eagles or birds in poor condition do not defend territories and may congregate in areas of food abundance (Gober and Lockhart 1979). Fourteen Golden Eagles, predominantly immature birds, were observed feeding simultaneously on one sheep carcass during 1985.

Evaluating Depredation Severity. Golden Eagle food habit studies have been used as indicators of livestock depredation severity, and livestock is generally considered a minor diet component (Olendorff 1976). Prey remains at nest sites are frequently used as indicators of prey taken (e.g., McGahan 1967; Mollhagen et al. 1972; Bloom and Hawks 1982; Collopy 1983). Presence of lamb remains at nest sites is not a good indicator of eagle depredation. Non-territorial or non-breeding eagles do not maintain a nest but may account for most of the depredation. Lamb remains at nests are generally fed upon

extensively and are difficult if not impossible to classify as kills or carrion. One Golden Eagle nest was located on the Rebish-Konen ranch and was occupied during most years of the study. Lamb remains were frequently found at the nest, but cause of death could not be determined. Eagles undoubtedly carry more small (less than 2 kg) than large prey items to nests. Eagle-killed lambs in the present study typically weighed more than four kg. Even with ideal flying conditions, eagles could not carry such lambs to a nest (Cameron 1908; Seton 1937; Walker and Walker 1939, 1940; Arnold 1954; Olendorff 1972). Prey items at nest sites only represent animals eaten during the nesting season. Food habit studies based on castings or crop/stomach analyses are also limited and distinction between kills and carrion is impossible.

Studies are limited in their ability to accurately quantify actual eagle depredation. Proportions of eagle kills identified by examining carcasses are often reported but are likely biased by carcass search effort, ability to locate carcasses and carcass selectivity. Hence, the relationship between data on examined eagle kills (Glover and Heugly 1970; Wiley and Bolen 1971; Klebenow and McAdoo 1976; Nesse et al. 1976; Tigner and Larson 1977, 1981; Foster and Crisler 1978, 1979; Wade and Livingston 1978, 1979; O'Gara 1981, 1983; O'Gara et al. 1983, 1984; O'Gara and Matchett 1985) and actual eagle depredation rate is unknown.

Eagle Trapping and Translocation. The USFWS personnel in Montana were committed by the Director of the USFWS to trap and translocate eagles from 1975–1983. No data were gathered on dispersal or fate of translocated birds. Eagles were released in Flathead and Swan Valley in northwestern Montana (approximately 325 km northwest of the study areas) and north-central Colorado (approximately 750 km southeast of the study areas) during 1975. All translocated eagles were released in Yellowstone National Park (approximately 160 km southeast of the study areas) from 1976 through 1983. One hundred forty-five eagles were captured and removed during 1975 at a cost of $23 600 (Niemeyer 1975; O'Gara 1981). Even so, docking percentages were lower in 1975 than in 1974 (Table 1). Translocated eagles totaled 432 between 1975 and 1983 and cost of the project totaled $112 771. Number of eagles captured generally decreased from 1976 through 1983, as did relative depredation severity as indicated by docking percentages.

Jackrabbit populations were apparently increasing during and after 1976 (U.S. Dept. Int., Bur. Land Manage. 1972–1980; Stoddart 1977; Knowlton 1980; Johnson and Peek 1984), and weather during lambing seasons was warmer compared to 1974 and 1975 (U.S. Dept. Comm. 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983). Eagles were not censused from 1977 through 1982 because so few appeared on the ranches (Niemeyer 1977, 1978, 1979, 1980, 1981, 1982). Low numbers of eagles on the ranches could have resulted from the translocation program, but most likely resulted from an increase in natural prey and mild weather. We suspect that eagle numbers in southwestern Montana did not change dramatically between 1977 and 1985, but rather eagles were concentrated in lambing areas during 1974 and 1975 and more dispersed after 1976. Captured eagles totaled 145 in 1975 and 69 in 1976, yet the capture rate averaged only 31 between 1977 and 1983 with a high of 48 in 1978 (Niemeyer 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983). Eagles killed lambs after 1976, but impacts were minor compared to 1974 and 1975. Translocation did not stop depredation during 1975, and by 1983 the program was determined not to be the solution. Translocation was expensive and had little demonstrated effect on depredation rates. In addition translocated eagles might continue to kill lambs in other areas or eventually return to the original depredation area as was evident in 1977 (Niemeyer 1977).

A helicopter-net gun capture technique provided a more efficient and selective method for removing depredating eagles compared to the Lockhart method as birds could be selectively removed from carcasses. Pit traps and cannon nets might also be effective methods (P. Bloom, pers. comm.). Eagle translocation is a reactionary measure, does not prevent depredation, could be expensive if large numbers of eagles were involved and may only transplant the problem, not solve it.

Harassment and Scarecrows. Law enforcement agent E. Cofer (USFWS) estimated that 40 eagles were on the Rebish and Helle, Inc., ranch when he found 16 fresh eagle-killed lambs on 6 June 1974. Cofer counted 20 Golden Eagles in the air at one time. Use of rockets and crackershells failed to disperse the eagles or reduce depredation (O'Gara 1978).

Harassment of eagles from an airplane during 1983 failed to stop depredation, to reduce the number of birds present or to alter their distribution (O'Gara

1983). Eagles could not be flushed more than twice, even when "buzzed" about 1 m from the wheel of the aircraft. The use of taped eagle "chitter" and alarm calls failed to frighten eagles from sheep carcasses (O'Gara 1983). Eagles simply looked towards the source of the taped calls and resumed feeding. Capture and handling of eagles for radio-instrumentation could be considered harassment. Refusal by radio-marked birds to leave the area indicates that harassment alone will not cause birds to abandon lambing areas.

Six scarecrows and 11 eagle carcasses were placed at prominent points near lambing grounds late during the lambing season of 1983. These devices did not immediately reduce the number of eagles on the ranches, but both showed potential for altering the distribution of eagles relative to lambing bands (O'Gara 1983). Depredation ceased after scare device placement, but other factors (human activity, harassment, movement of sheep to summer range) may have contributed (O'Gara 1983).

Twenty-two scarecrows were placed on prominent points during 1984. Harassment associated with scarecrows seemed to keep eagles away from lambing bands during 1984 (O'Gara et al. 1984). Numbers of eagles observed on census flights decreased after scarecrow placement, and the distribution of eagles apparently shifted (O'Gara et al. 1984). Lack of search effort and exact eagle location data precluded rigorous analysis of the apparent change in eagle numbers or shift in use areas (see following results for 1985). Eagles were observed near scarecrows within two wk of scarecrow placement. Ground harassment was then initiated. In addition to harassment of eagles during 1984 efforts were made to kill Common Ravens, but only two were actually killed. Eagles apparently took cues from ravens on the presence of danger (O'Gara 1983; O'Gara et al. 1984).

Eagle-killed lambs were easily found from the air during 1983 (O'Gara 1983), but none were observed on 21 flights or during visits on the ground during 1984 (O'Gara et al. 1984). O'Gara verified five eagle-killed lambs brought in by ranchers before scarecrows were erected in 1984.

Sheep characteristically bed on high knobs and ridges, and many eagle-killed lambs were found near sheep bedding areas. Placement of scarecrows at or near bedding grounds made them visible and in close proximity to sheep during morning hours. If lambs were "protected" for the first few hours of daylight, eagles would usually kill some alternative prey before sheep left the vicinity of the scarecrows. Scarecrows are inexpensive to construct, place and maintain and should be erected just prior to lambing and removed immediately after to minimize eagle habituation.

Experimental Evaluation of Scarecrow Efficacy. Scarecrows (11 on Rock Creek and 18 on Rebish and Helle, Inc.) and harassment helped to prevent eagle depredation on lambs during 1985 (O'Gara and Matchett 1985). Sighting rates (eagles observed/min of search time) decreased slightly on Rock Creek when scarecrows were erected and remained relatively low throughout the lambing season (Fig. 1). Sighting rates increased on Little Rock after scarecrows were placed on Rock Creek and remained relatively high throughout the remainder of the lambing season (Fig. 1).

Analyses of aerial observation rates (eagles observed/min search time) supported the hypothesis that eagles avoided scarecrows. Mean eagle observation rates were 0.1445 on Rock Creek and 0.2427 on Little Rock for 24 d prior to scarecrow placement and 0.1497 and 0.5283, respectively, for 24 d post-scarecrow placement. Sighting rates between study areas did not differ significantly prior to scarecrow placement (Student's t-Test, $P > 0.05$). Sighting rates were also similar before and after scarecrow placement on Rock Creek (Student's t-Test, $P > 0.05$). Sighting rates increased significantly in Little Rock after scarecrow placement on Rock Creek (Student's t-Test, $P < 0.005$). Sighting rates were significantly higher on Little Rock than on Rock Creek during the 24 d post-scarecrow placement (Student's t-Test, $P < 0.001$).

Twenty-four d pre- and post-scarecrow placement was the maximum time in the field prior to scarecrow placement. Results of comparisons of 24 d prior to scarecrow placement with 55 d post-scarecrow placement were virtually identical to those described above. The trend from ground sighting rates was similar, but more variable than for aerial surveys. Relatively few data were available for ground sighting rates prior to scarecrow placement.

One hundred eighty-one observations of eagles were made during 24 d prior to scarecrow placement and 256 observations during 24 d post-scarecrow placement. The apparent influx of eagles was similar to that described for 1975 and 1976. Scarecrows likely caused newly arriving eagles to avoid Rock Creek and use Little Rock instead. Immature birds

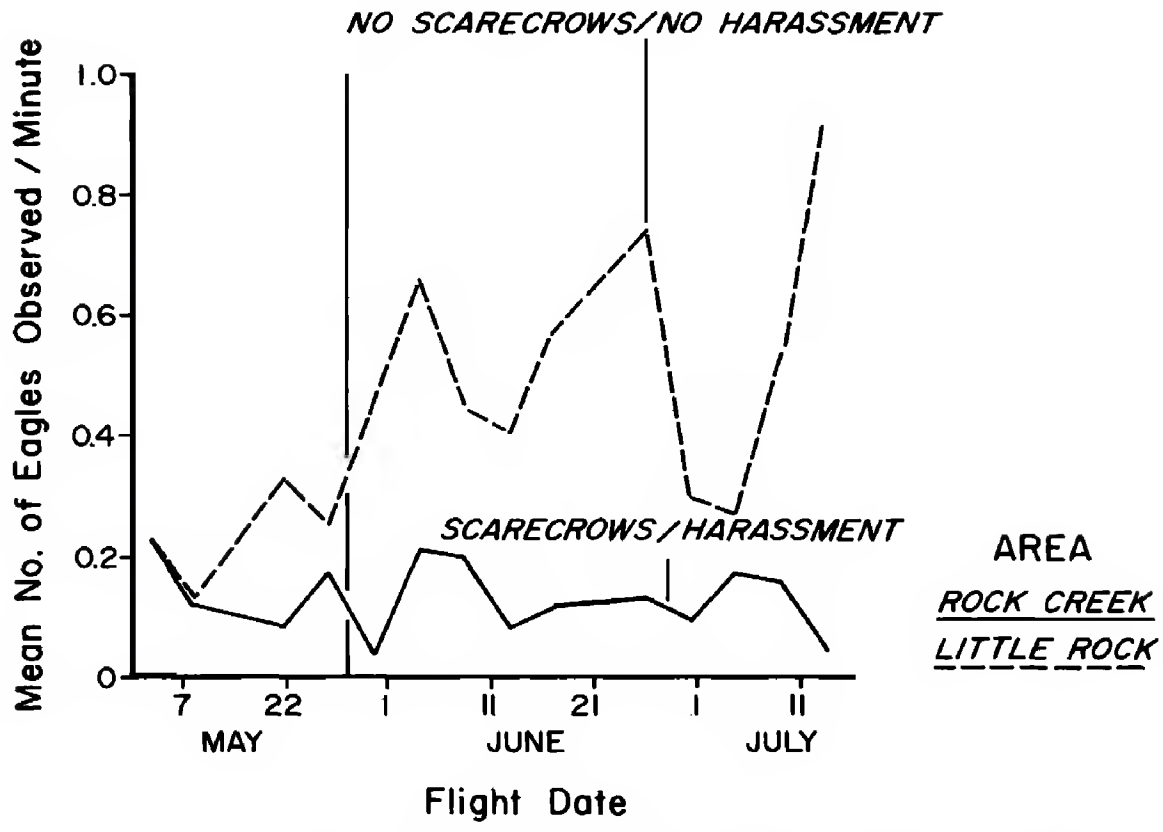

Figure 1. Golden Eagle sighting rates from flight surveys during 1985 on the Rebish-Konen ranch near Dillon, Montana. Means were based on 4 d groups. The reference line from the X-axis indicates scarecrow placement date.

comprised 64% of 204 eagle observations where age class was determined (Rock Creek and Little Rock combined).

Little Rock contained relatively few lambs and little carrion. Rock Creek contained nearly three times the number of lambing ewes as Little Rock and thus would be expected to attract more eagles. The contention that eagles avoided scarecrows and harassment was further supported by sighting rates remaining relatively low on Rock Creek after scarecrow placement, even with the potentially strong attractant of many lambs and abundant carrion. Routine removal of carrion near range lambing bands would minimize a potential eagle attractant.

Eagle depredation rate (number of eagle-killed lambs found/total number of ewes) during 1985 was significantly higher on Little Rock (0.01) than on Rock Creek (0.001) ($Z = 3.34$, $P < 0.001$). Examined lamb carcasses totaled 213 on Rock Creek and 51 on Little Rock. Two eagle-killed lambs were found on Rock Creek and five were found on Little Rock. Search effort was similar in both areas. Scarecrows were erected at the onset of lambing and there was little opportunity for eagle depredation prior to scarecrow placement.

Although not statistically significant, the distance between eagles and the nearest scarecrow site increased after scarecrows were erected (O'Gara and Matchett 1985). Only 9 d of radio-tracking were available prior to scarecrow placement. Mean (SE) distances between eagle radio locations and nearest scarecrow sites were 3.72 (0.61) km, 4.36 (1.30) km, and 6.09 (0.74) km, respectively, during the 9 d pre-, 9 d post-, and 55 d post-scarecrow placement time periods. Median distances between eagle radio locations and nearest scarecrow sites were 2.93 km, 4.46 km, and 5.65 km, respectively, for the same time periods.

Most harassment during 1985 was directed at Common Ravens shortly after scarecrows were erected (five were killed). Eagles and ravens soon learned to take flight upon sighting a moving person or a truck (O'Gara and Matchett 1985). Our presence alone often caused ravens and eagles to leave the area during the last two-thirds of the lambing season. McAdoo and Klebenow (1978) also noted that human activity, in itself, is a deterrent to predation.

ACKNOWLEDGMENTS

We extend our gratitude to ranchers P. Rebish, G. Rebish, D. Rebish, J. Helle and J. Konen for their assistance and cooperation during this study. Many biologists and technicians worked on this study, and we are grateful for the efforts of D. Balser, E. Boeker, S. Crow, M. Goos, V. Jameson, E. Cofer, M. Lockhart, S. Matchett, N. Miner, C. Niemeyer, J. Pachtel, B. Phillips, D.

Pond and M. Zahn. This study was greatly enhanced by the excellent flying abilities and friendship of S. Hoem and D. Getz. M. Kochert, P. Bloom and D. Smith reviewed an earlier draft of this manuscript.

LITERATURE CITED

ALLEN, J. C. 1939. Ecology and management of Nelson's bighorn on the Nevada mountain ranges. Trans. North Am. Wildl. Conf. 4:253–256.

ARNOLD, L. W. 1954. The Golden Eagle and its economic status. U.S. Fish and Wildl. Serv. Circ. 27. 35 pp.

BLOOM, P. H. AND S. J. HAWKS. 1982. Food habits of nesting Golden Eagles in northeast California and northwest Nevada. *Raptor Res.* 16:110–115.

BOEKER, E. L. AND T. D. RAY. 1971. Golden Eagle population studies in the Southwest. *Condor* 73:463–467.

BOLEN, E. G. 1975. Eagles and sheep: a viewpoint. *J. Range Manage.* 28:11–17.

BOWNS, J. E., J. W. DAVENPORT, J. P. WORKMAN, D. B. NIELSON AND D. D. DWYER. 1973. Determination of cause and magnitude of sheep losses in southwestern Utah. *Utah Sci.* 34:34–37,52.

BOYER, R. H. 1948. Fawns escape Eagle's attack. *Yosemite Nature Notes* 27:129–130.

BROWN, D. L. AND F. M. COUEY. 1950. Eagle-game relationships in Montana. Third Annu. Northwest Wildl. Conf.

BROWN, J. E. 1976. Field criteria for predator damage assessment. *Utah Sci.* 37:26–30.

BROWN, L. H. 1975. Brown on Golden Eagles and sheep. Pages 129–133. *In* J. R. Murphy et al., EDS. Population status of raptors. Proc. Conf. Raptor Conserv. Tech., Raptor Res. Rep. 3.

CAMERON, E. S. 1908. Observations on the Golden Eagle in Montana. *Auk* 25:251–268.

CASEBEER, R. L., M. J. ROGNRUD AND S. BRANDBORG. 1950. The Rocky Mountain goat in Montana. Montana Fish Game Comm. Wildl. Restoration Div. Bull. 5.

CLAWSON, M. M. 1948. Golden Eagle attacks young deer. *Yosemite Nature Notes* 27:107–109.

COUEY, F. M. 1944. Golden Eagle vs. bighorn sheep. *Montana Wildl. Bull.* 1(1):2–3.

COLLOPY, M. W. 1983. A comparison of direct observations and collections of prey remains in determining the diet of Golden Eagles. *J. Wildl. Manage.* 47(2):360–368.

DAVENPORT, J. W., J. E. BOWNS AND J. P. WORKMAN. 1973. Assessment of sheep losses to coyotes—a problem to Utah sheepmen, a concern to Utah researchers. Utah State Univ., Logan Agric. Exp. Stn. Res., Logan. Rep. 7. 17 pp.

DIXON, J. S. 1934. A study of the life history and food habits of mule deer in California. *Calif. Fish and Game* 20(3):181–282 and 20(4):315–354.

FORD, H. S. AND J. R. ALCORN. 1964. Observations of Golden Eagle attacks on coyotes. *Condor* 66:76–77.

FOSTER, H. A. AND R. E. CRISLER. 1978. Evaluation of Golden Eagle predation on domestic sheep, Temperance Creek-Snake sheep and goat allotment, Hells Canyon National Recreation Area, Oregon. U.S. Fish and Wildl. Serv., Anim. Damage Control Program. (Unpubl.) 26 pp.

———. 1979. Evaluation of Golden Eagle predation on domestic sheep, Temperance Creek-Snake sheep and goat allotment, Hells Canyon National Recreation Area, Oregon. U.S. Fish and Wildl. Serv., Anim. Damage Control Program. (Unpubl.) 16 pp.

GLOVER, F. A. AND L. G. HEUGLY. 1970. Final report: Golden Eagle ecology in West Texas. National Audubon Society, Colorado Coop. Wildl. Res. Unit, Colorado State Univ., Fort Collins. 80 pp.

GOBER, D. R. AND J. M. LOCKHART. 1979. Factors affecting Golden Eagle predation on livestock in Trans-Pecos Texas. Paper presented at the 1979 annual meeting of the Texas chapter of The Wildl. Soc., April 6, Alpine, Tex. 24 pp.

JOHNSON, D. R. AND J. M. PEEK. 1984. The black-tailed jack rabbit in Idaho, life history, population dynamics and control. Coop. Ext. Serv., Univ. Idaho, College of Agric., Moscow. Bull. 637. 16 pp.

KENNEDY, C. A. 1948. Golden Eagle kills bighorn lamb. *J. Mammal.* 29(1):68–69.

KLEBENOW, D. A. AND K. MCADOO. 1976. Predation on domestic sheep in northeastern Nevada. *J. Range Manage.* 29:96–100.

KNOWLTON, F. F. 1980. Population indices of some predator and prey species on the Idaho National Engineering Laboratory (INEL), Report through Calendar 1980. Predator Ecology and Behavior Proj., Utah State Univ., Logan. (Unpubl.) 5 pp.

LITTAUER, G. A. AND R. J. WHITE. 1981. Sheep and lamb losses in New Mexico, January 1–May 1, 1981 New Mexico Dept. Agric. (Unpubl.) 11 pp.

LOCKIE, J. D. AND D. STEPHEN. 1959. Eagles, lambs and land management on Lewis. *J. Anim. Ecol.* 28:43–50.

MCADOO, J. K. AND D. A. KLEBENOW. 1978. Predation on range sheep with no predator control. *J. Range Manage.* 31:111–114.

MCGAHAN, J. 1967. Quantified estimates of predation by a Golden Eagle population. *J. Wildl. Manage.* 31(3): 496–501.

MCLEAN, D. D. 1925. The Golden Eagle as a deer enemy. *Yosemite Nature Notes* 4:27.

MOLLHAGEN, T. R., R. W. WILEY AND R. L. PACKARD 1972. Prey remains in Golden Eagle nests: Texas and New Mexico. *J. Wildl. Manage.* 36(3):784–792.

MURPHY, J. R. 1977. Eagles and livestock—Some management considerations. Pages 307–313. *In* R. D. Chancellor, ED. World conf. on birds of prey, Vienna, 1–3 October, 1975. Rep. of Proc., International Council for Bird Preservation.

NESSE, G. E., W. M. LONGHURST AND W. E. HOWARD. 1976. Predation and the sheep industry in California, 1972–1974. Div. Agric. Sci., Univ. California, Davis. Bull. 1878. 63 pp.

NIE, N. H. 1983. SPSSX user's guide. McGraw-Hill Book Co., New York. 806 pp.

NIEMEYER, C. 1975. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 13 pp.

———. 1976. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 19 pp.

———. 1977. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 24 pp.

———. 1978. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 17 pp.

———. 1979. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 16 pp.

———. 1980. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 18 pp.

———. 1981. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 20 pp.

———. 1982. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 21 pp.

———. 1983. Montana Golden Eagle removal and translocation project. Final Rep. U.S. Fish Wildl. Serv. Area Office, Billings, Mont. (Unpubl.) 25 pp.

O'GARA, B. W. 1978. Sheep predation by Golden Eagles in Montana. Proc. Vert. Pest Control Conf. 8:206–213.

———. 1981. Predation by Golden Eagles on domestic lambs in Montana. Pages 345–358. *In* J. M. Peek and P. D. Dalke, EDS. 1982 Wildlife-Livestock Relationships Symposium: Proc. 10. April 20–22, 1981. For., Wildl., Range Exp. Stn., Univ. Idaho, Moscow. 614 pp.

———. 1983. Experimental control of depredation on lambs and kids by Golden Eagles. Prog. Rep. Montana Coop. Wildl. Res. Unit, Univ. Montana, Missoula. (Unpubl.) 20 pp.

———, K. C. BRAWLEY, J. R. MUNOZ AND D. R. HENNE. 1983. Predation on domestic sheep on a western Montana ranch. *Wildl. Soc. Bull.* 11:253–264.

———, D. POND AND B. PHILLIPS. 1984. Evaluation of scarecrows for frightening Golden Eagles from lambing herds. Comp. Rep., Montana Coop. Wildl. Res. Unit, Univ. Montana, Missoula. (Unpubl.) 20 pp.

——— AND M. R. MATCHETT. 1985. Evaluation of scarecrows for frightening Golden Eagles from lambing bands. Comp. Rep., Montana Coop. Wildl. Res. Unit, Univ. Montana, Missoula. (Unpubl.) 45 pp.

——— AND D. C. GETZ. 1986. Capturing Golden Eagles using a helicopter and net gun. *Wildl. Soc. Bull* 14:400–402.

OLENDORFF, R. R. 1972. Eagles, sheep, and power lines. *Colo. Outdoors* 21:3–11.

———. 1976. The food habits of North American Golden Eagles. *Am. Midl. Nat.* 95:231–236.

RINEY, T. 1951. Relationships between birds and deer *Condor* 53:178–185.

ROSKO, L. 1948. Losses of sheep from predatory animals on summer range in Iron County, Utah. Utah Coop Wildl. Res. Unit Rep. 16 pp.

ROWLEY, I. 1970. Lamb predation in Australia: inci dence, predisposing conditions, and the identification of wounds. *CSIRO Wildl. Res.* 15:79–123.

SETON, G. P. 1937. The king of birds. *Natural Hist.* 39: 353–356.

SNOW, C. 1973. Golden Eagle *Aquila chrysaetos*. Habitat management series for unique or endangered species Rep. 7. U.S. Dept. Interior, Bureau of Land Manage Tech. Note: T-N-239, Denver, Colo. 52 pp.

SOKAL, R. R. AND F. J. ROHLF. 1981. Biometry. W. H Freeman and Co., New York. 859 pp.

STODDART, L. C. 1977. Population dynamics, movement and home range of black-tailed jack rabbits (*Lepus californicus*) in Curlew Valley, northern Utah. Prog. Rep. for U.S. Energy Res. and Dev. Adm., Contract No. E(11-1)-1329 by Dept. Wildl. Sci., Utah State Univ., Logan. (Unpubl.) 44 pp.

TIGNER, J. R. AND G. E. LARSON. 1977. Sheep losses on selected ranches in southern Wyoming. *J. Range Manage.* 30:244–252.

———. 1981. Golden Eagles: scavengers and predators on domestic lambs. Pages 359–361. *In* J. M. Peek and P. D. Dalke, EDS. 1982 Wildlife-Livestock Relationships Symposium: Proc. 10. April 20–22, 1981. For , Wildl., Range Exp. Stn., Univ. Idaho, Moscow. 614 pp.

U.S. DEPARTMENT OF COMMERCE. 1974. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 77(13).

———. 1975. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 78(13).

———. 1976. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 79(13).

———. 1977. National Oceanic and Atmospheric

Administration: Climatological data, annual summaries. Vol. 80(13).

———. 1978. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 81(13).

———. 1979. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 82(13).

———. 1980. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 83(13).

———. 1981. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 84(13).

———. 1982. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 85(13).

———. 1983. National Oceanic and Atmospheric Administration: Climatological data, annual summaries. Vol. 86(13).

U.S. DEPARTMENT OF INTERIOR, BUREAU OF LAND MANAGEMENT. 1972–1980. Jackrabbit population indices for the Snake River birds of prey study area, 1972–1980. Boise District Off., Boise, Idaho. (Unpubl.)

U.S. DEPARTMENT OF INTERIOR, FISH AND WILDLIFE SERVICE. 1983. Western Golden Eagle management source document: Review and preliminary options for development of the national management plan. Div. Wildl. Manage., Washington, D.C. (Unpubl.) 51 pp.

WADE, D. A. AND C. W. LIVINGSTON, JR. 1978. Operation dead lamb: summary of necropsy results: 27 February–30 May 1978. Texas A&M Univ. Res. and Ext. Center, San Angelo. (Unpubl.) 3 pp.

———. 1979. Lamb and kid necropsies and mortality factors found in operation dead lamb 1978–1979. Texas A&M Univ. Res. and Ext. Center, San Angelo. (Unpubl.) 2 pp.

WALKER, L. AND M. WALKER. 1939. From egg to eaglehood. *Natural Hist.* 43:284–289,302.

———. 1940. Headlines on Eagles. *Nature Mag.* 33: 321–323.

WHITE, C. M. AND M. T. WHITE. 1985. Unusual social feeding and soaring by the Common Raven (*Corvus corax*). *Great Basin Nat.* 45:150–151.

WILEY, R. W. AND E. G. BOLEN. 1971. Eagle-livestock relationships: livestock carcass census and wound characteristics. *Southwestern Nat.* 16:151–169.

WOOD, D. T. 1946. Eye-witness account of Golden Eagle killing calf. *Condor* 48:143.

ZAR, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

Montana Cooperative Wildlife Research Unit, HS 107, University of Montana, Missoula, MT 59812. Current address of first author: P.O. Box 741, Lewistown, MT 59457.

Received 6 January 1986; Accepted 10 August 1987.

J. Raptor Res. 21(3):95–97

DIET SHIFTS IN BREEDING AND NONBREEDING SPOTTED OWLS

CAMERON W. BARROWS

ABSTRACT.—Shifts in the diets of breeding and nonbreeding Spotted Owls (*Strix occidentalis*) are compared. Breeding owls prey more on larger rodents, and statistical differences in the percentage of large mammalian prey between breeding and nonbreeding owls are apparent only after feeding of young begins. Whether these diet shifts reflect prey availability or in part prey selection is not conclusively determined. However, seasonal diet differences and diet shifts immediately following breeding failures suggest prey selection plays a role.

The Spotted Owl (*Strix occidentalis*) feeds primarily on a wide range of mammalian prey (Barrows 1980; Forsman et al. 1984). Breeding performance appears to vary with diet, with a preponderance of large prey species taken during successful breeding years (Barrows 1985). Herein, I describe diet shifts in Spotted Owls and suggest whether the shifts are a reflection only of prey availability or of availability and preferential prey selection.

Distinguishing in the field between prey availability and preference or selection of certain prey types by Spotted Owls presents a difficult problem. Sampling methods for estimating densities of major prey species such as Dusky-Footed Woodrats (*Neotoma fuscipes*), Northern Flying Squirrels (*Glaucomys sabrinus*) and Red Tree Voles (*Phenacomys longicaudis*) vary considerably. I did not quantify prey populations; without such data any effort to clarify the importance of preferential predation falls short. I was able, however, through natural occurrences such as nesting failures and by examining seasonal changes in diet to imply a role of differential prey selection in the Spotted Owl diet.

STUDY AREA AND METHODS

Prey data presented here were from ten Spotted Owl territories (A–I). Territories A–F were at or in areas adjacent to the Nature Conservancy's Northern California Coast Range Preserve in Mendocino County, California; G and H were at Butte Creek, Humboldt County; I and J were in Cuyamuca State Park, San Diego County, California. Prey data in this study are from regurgitated pellets I collected weekly between 1977 and 1985 during spring and summer months below diurnal roosts and in nest cavities. On this basis, 1829 individual prey items were identified. Skulls and jaws were used to enumerate total prey/sample, providing a conservative estimate of prey numbers but eliminating double counts of large prey items that occurred in two or more pellets.

Mammalian prey items were grouped into two size classes: large (>100 g) and small (<100 g), corresponding to a natural gap in prey sizes taken by Spotted Owls (Table 1). Only mammalian prey were considered in this analysis as they constitute >90% of the biomass consumed by Spotted Owls (Barrows 1980). Seasonal comparisons of diet were divided between spring (courtship/incubation) and summer (nestling/fledgling) phases of the breeding cycle.

RESULTS

Spotted Owls took larger prey when successfully breeding than in years when they did not breed. Year-to-year prey size variation in relation to breeding performance by owls in two territories provides an example of this trend (Fig. 1). Difference in percentage of large prey in the diet of all breeding Spotted Owls compared with non-breeders included in this study was significant (Mann-Whitney U- Test (11,17) = 143; $P < 0.02$) (Fig. 2).

Fewer large prey items appeared in diets of nonbreeding owl pairs in summer compared to spring (Fig. 2). Differences between the two seasons was not significant (Mann-Whitney U-Test (8,8) = 46, $P < 0.20$), although a reduction occurred in seven of eight nonbreeding owl pairs. Pair B did not reduce large prey in their diet in summer of 1984 but had shown a seasonal reduction in their diet in each of three previous nonbreeding years.

In contrast breeding pairs significantly increased the percentage of large prey in their diet between spring and summer (Mann-Whitney U-Test (5,5) = 25; $P < 0.05$). Spring diets of breeding and nonbreeding Spotted Owls had no significant difference between proportions of large and small prey ($U(5,8) = 15.5$; $P > 0.20$). However, the difference in summer diets of breeding and nonbreeding owls was highly significant ($U(5,8) = 40$; $P < 0.002$).

In 1983 and again in 1985 after two–three wks incubation the breeding effort of Spotted Owls in territory B failed due to an undetermined cause. Comparison of this pair's diet preceeding and following breeding failures (Fig. 3) indicates a clear

Table 1. Frequencies of prey species taken by eight Spotted Owl pairs in California.

		Owl Territories									
Weight[a] (g)	Species	A	B	C	D	E	F	G	H	I	J
300	*Sylvilagus bachmani*	0	0	0	3	0	0	1	4	1	0
269	*Neotoma fuscipes*	28	9	20	28	22	42	15	17	31	47
115	*Glaucomys sabrinus*	14	15	18	21	3	5	8	4	0	0
100	*Thomomys bottae*	0	0	0	0	0	0	1	3	11	9
60	*Eutamias speciosus*	0	0	0	0	0	0	0	0	1	0
56	*Scapanus latimanus*	0	1	1	0	0	0	0	0	1	0
39	*Microtus californicus*	2	2	4	1	1	0	12	5	0	0
28	*Lasiurus cinereus*	0	0	1	1	0	0	1	0	0	0
27	*Phenacomys longicaudus*	23	36	16	21	22	31	26	34	0	0
22	*Peromyscus maniculatus*	14	16	21	8	37	16	26	5	37	25
11	*Neurotrichus gibbsi*	0	0	0	0	0	0	0	2	0	0
9	*Sorex trowbridgei*	1	1	0	0	0	0	4	0	0	0
	Birds	8	8	3	0	0	0	1	2	4	11
	Arthropods	11	11	15	17	12	21	3	20	13	7
Sample Size		406	672	114	91	32	37	225	100	97	55

[a] $\bar{x}$; From Burt and Grossenheider (1976) and Forsman et al. (1984).

and significant shift from primarily large to smaller prey (χ^2 = 11.6, 12.6; df = 1; $P < 0.001$).

A single owlet produced in territory A in 1984 died the day it fledged. Again, a significant reduction of large prey taken by the adults followd (χ^2 = 11.6; df = 1; $P < 0.001$). The owlet weighed >20% less (325 g) than the fledging weights of two successful owlets from previous years (410 g and 420 g).

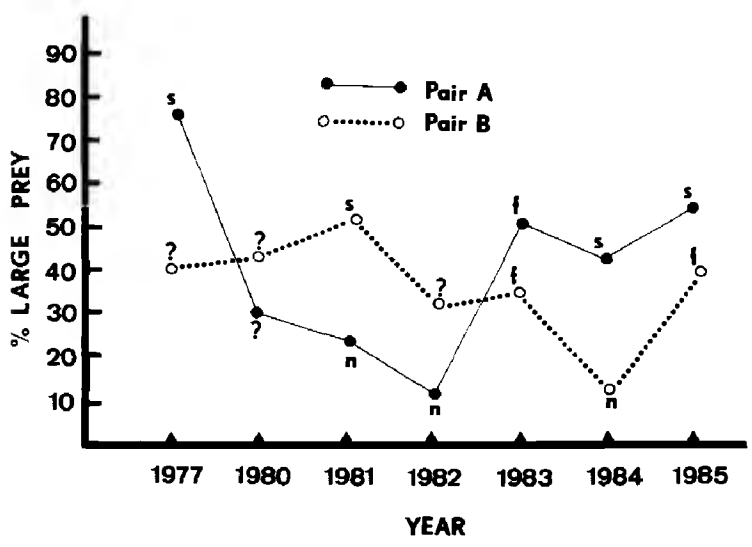

Figure 1. Yearly frequency (1977–1985) of large prey in the diet of two Spotted Owl pairs, including yearly variation in breeding status. s = successful breeding; ? = not breeding (whether or not breeding was attempted was not determined); n = no attempt at breeding; f = failed breeding attempt.

DISCUSSION

Evidence of nonselective (random) predation by owls comes from general diet descriptions and correlations between owl numbers or breeding success and fluctuations in primary prey populations (Craighead and Craighead 1956; Wendland 1984).

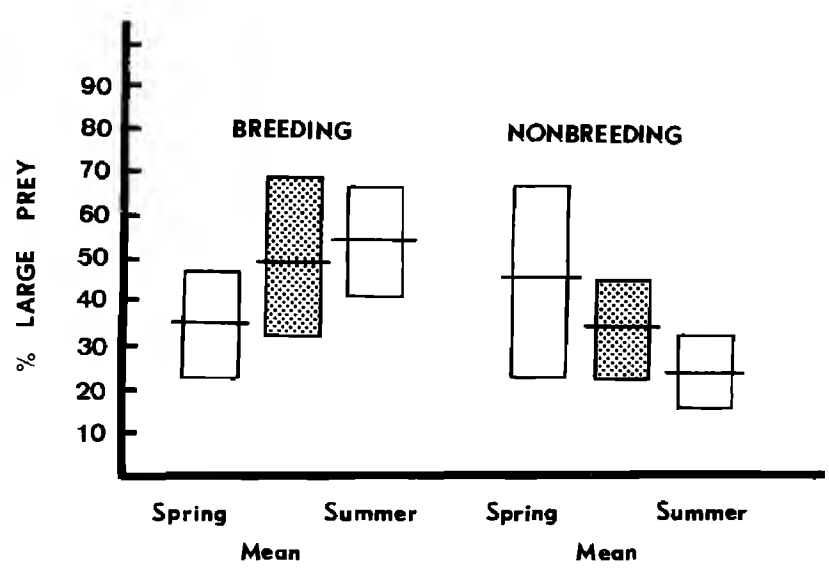

Figure 2. Seasonal variation and total mean variation in frequency of large prey in the diets of breeding and nonbreeding Spotted Owls. Horizontal bars = $\bar{x}$; vertical bars = ± one SD.

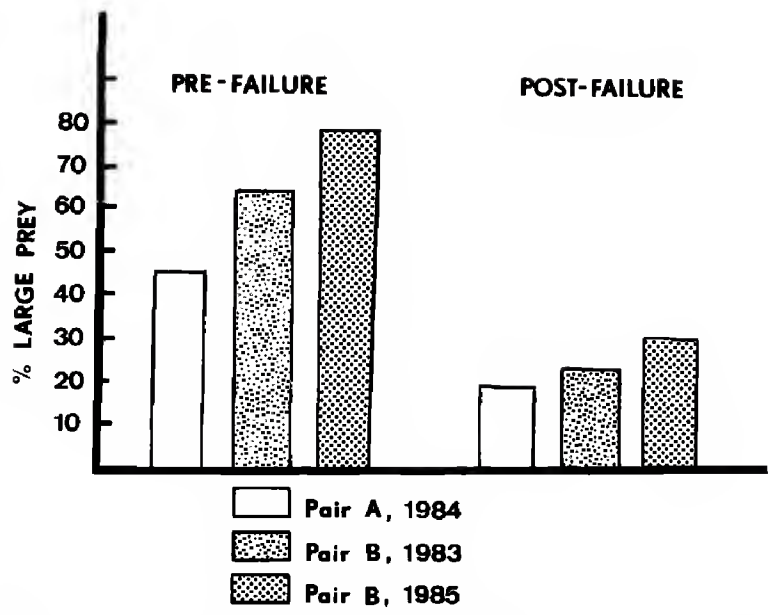

Figure 3. Frequency of large prey in the diets of two pairs (A and B) of Spotted Owls which had failed breeding attempts.

Forsman et al. (1984) described the occurrence of various prey species in the diet of Spotted Owls in Oregon and noted close similarity with seasonal availability of some prey such as Botta Pocket Gophers (*Thomomys bottae*) or Coast Moles (*Scapanus orarius*). Unquestionably, prey availability is a factor in determining the diet of predators. My objective here was to examine whether preferential predation also plays a part in the diet of breeding Spotted Owls.

Some measure of prey availability would provide a clearer assessment of Spotted Owl predation preferences. In lieu of these data I have used diet shifts following breeding failures and overall diet patterns in breeding and nonbreeding owls to postulate the occurrence of preferential predation. Shifts by breeding Spotted Owls to larger prey items post-hatching is in contrast with the opposite trend in nonbreeding owls, supporting a hypothesis of preferential predation on larger prey by breeding pairs. One test of the hypothesis would involve altering the breeding status of pairs which had already committed to breeding. A significant shift in predation pattern involving frequency of larger prey could be taken as support of the hypothesis. Breeding failures observed in territories A and B were natural "tests" of this kind. The observed, significant shift away from large prey was consistent with preferential predation hypothesis predictions.

While observations are in accordance with the hypothesis that breeding Spotted Owls preferentially prey on large rodents, this, or an alternative hypothesis was not rigorously tested. Concurrent studies of Dusky-Footed Woodrat and Northern Flying Squirrel population dynamics with Spotted Owl diets and breeding success are needed before conclusions can be reached.

ACKNOWLEDGMENTS

I thank C. J. Ralph, Katherine Barrows, Scott Carroll, Steve Bessinger, Carl Marti, Jim Devereux, Martin McNicholl, Jim Parrish and an anonymous reviewer for helpful comments on this manuscript.

LITERATURE CITED

BARROWS, C. W. 1980. Feeding ecology of the Spotted Owl in California. *Raptor Res.* 14:73–78.

———. 1985. Fledging success relative to fluctuations in diet for Spotted Owls in California. Pages 50–54 *In* R. J. Gutierrez and A. B. Carey, TECH EDS. Ecology and management of the Spotted Owl in the Pacific Northwest. Gen. Tech. Rep., Pacific Northwest Forest & Range Experiment Sta., U.S.D.A. Forest Service, Portland, OR.

BURT, W. H. AND R. P. GROSSENHEIDER. 1976. A field guide to the mammals. Houghton Mifflin Co., Boston. 289 pp.

CRAIGHEAD, J. J. AND F. C. CRAIGHEAD. 1956. Hawks, owls and wildlife. Stackpole, Harrisburg, PA.

FORSMAN, E. D., E. MESLOW AND H. M. WIGHT. 1984 Distribution and biology of the Spotted Owl in Oregon. *Wildlife Monog.* 87. 64 pp.

WENDLAND, V. 1984. The influence of prey fluctuations on the breeding success of the Tawny Owl *Strix aluco* *Ibis* 126:284–295.

53277 Avenida Diaz, Box 478, La Quinta, CA 92253.

Received 15 December 1986; Accepted 10 June 1987.

J. Raptor Res. 21(3):98–102

BETALIGHTS: AN AID IN THE NOCTURNAL STUDY OF OWL FORAGING HABITAT AND BEHAVIOR

GREGORY D. HAYWARD

ABSTRACT.—Due to difficulties in observing nocturnal owls, our understanding of their foraging habitat use is poor. I tested betalights used in conjunction with radio telemetry to aid in observations of foraging Boreal Owls (*Aegolius funereus*). Two betalight attachment positions were tested. Betalights attached atop backpack-mounted radio transmitters facilitated observation of owls only slightly compared to radio-marked owls without betalights observed with night vision goggles. By attaching the betalight to the radio antenna, however, it was held free of the owl's plumage and was more visible. This attachment method was not adequately tested but has potential to aid considerably in future nocturnal studies of owls.

To date the study of owl ecology has relied heavily on prey lists derived from pellet analysis and prey found at nests. Interpretation of feeding ecology, population stability, and food niche overlap data suffer because of difficulties associated with observing free-ranging nocturnal owls. Data are needed on owl foraging behavior, the structure of foraging habitats chosen by owls, and how that structure influences hunting success.

In my efforts to study habitat use by Boreal Owls (*Aegolius funereus*), I was frustrated by difficulties encountered observing nocturnally foraging owls. Thus, I sought to develop a method to aid in observing the small owls during nocturnal forays.

Betalights are pyrex capsules filled with tritium and coated internally with phosphore. Beta particles emitted by the tritium excite the phosphore, producing light. Betalights are manufactured by Saunders-Roe Developments Inc. (P.O. Box 5536, Winston-Salem, NC 27301) and have been used successfully in studies of various nocturnal mammals (Thompson 1982; Crabtree and Broome 1985). I am unaware, however, of betalights previously being used in owl studies. Herein I describe a method for using betalights in conjunction with radio-marking in owl studies and describe results of preliminary tests of the method.

METHODS

I designed a betalight system for attachment to backpack-mounted radio transmitters. My objectives in the design were to provide a secure attachment between betalight and transmitter, to reinforce the betalight to prevent breakage, and to attach the light in a visible position without hampering the owl's flight or the owl's ability to enter and leave a cavity.

Cylindrical betalights (type MH 35/g/75) measuring 11.5 mm × 1.4 mm dia were purchased from Saunders-Roe Developments, Inc. Each betalight was placed in a clear acrylic rod 15 mm × 10 mm dia, with a 13 mm × 1.5 mm dia bore centered along the long axis of the rod. The betalight was glued in place using Super Glue (Coctite Corp., Cleveland, OH 44128). Each betalight-acrylic rod package (hereafter betalight package) weighed 1 g. Two methods for attaching the betalight package to a radio transmitter were tested using a 6 g backpack style transmitter with 22 cm antenna (type MPB 1220 LD, Wildlife Materials Inc., RR 1, Giant City Road, Carbondale, Illinois 62901). Boreal Owls ranging in weight from 111–130 g carried the betalight packages.

Initially, I attached the betalight to the acrylic transmitter body with dental acrylic just above the antenna (Fig. 1). With the transmitter mounted on the bird's back, the long axis of the betalight was nearly perpendicular to the plane of the owl's back. Hereafter this method is referred to as Method I.

A second attachment method placed the betalight on the antenna about 3 cm from the transmitter body (Fig. 2). I reinforced the lower 2.5 cm of antenna base with heat shrink tubing and attached the betalight package just out from the reinforcement. The antenna was placed in a 1 mm groove cut into the acrylic rod housing the betalight (along the long axis of the rod). Epoxy glue bonded the betalight package to the antenna wire. With the transmitter mounted as a backpack on an owl, the long axis of the light was held at about 30° to the plane of the owl's back. Hereafter, this method is referred to as Method II.

Night vision goggles in conjunction with standard hand-held radio-telemetry equipment were used to monitor owls after dark. All owls marked with betalights were radio-tagged during a study of habitat use in the Frank Church-River of No Return Wilderness of central Idaho (45°23′N., 115°15′W.) in the mountains of Chamberlain Basin in seral and mature forest types of subalpine fir (*Abies lasiocarpa*) zone. All travel was restricted to foot. Three of 16 adult owls radio-tagged during the first three yrs of study carried betalight packages.

RESULTS

Three male Boreal Owls outfitted with betalights carried the betalight package a total of 11 mo. Two carried betalight packages mounted by Method I and the third by Method II. I removed the light when changing the transmitter package on the first owl

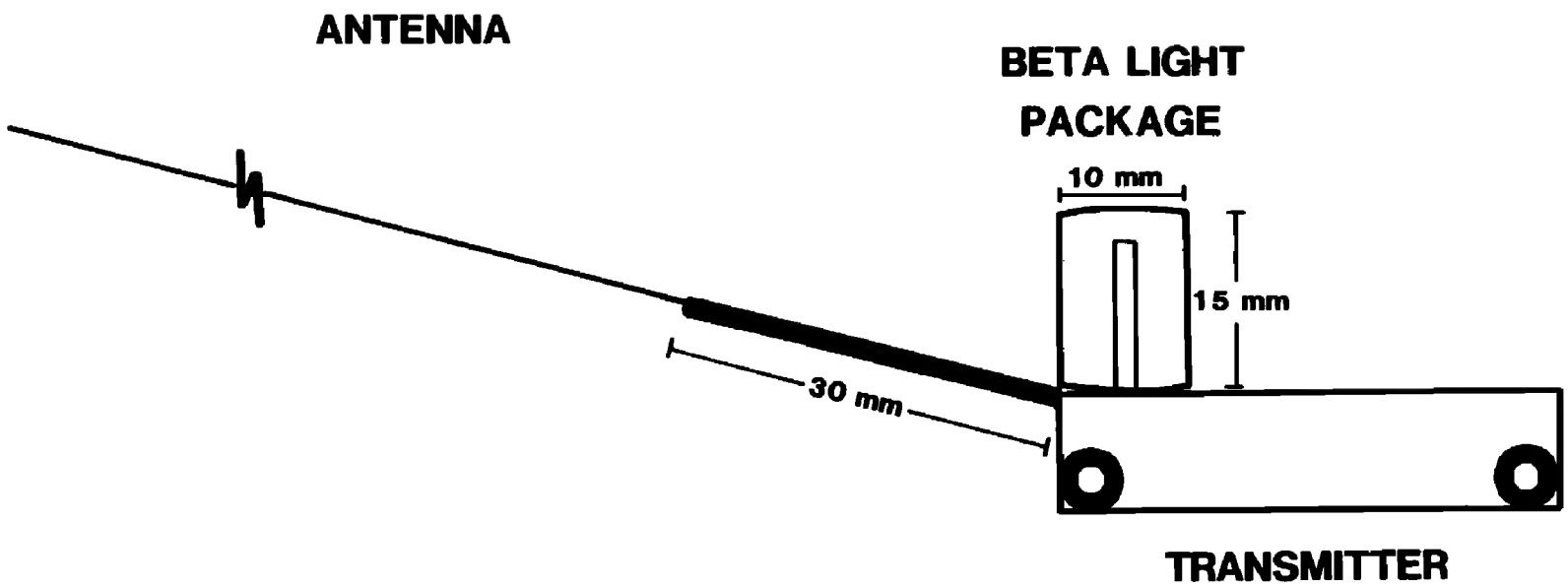

Figure 1. Betalight Attachment Method I. Betalight mounted in clear acrylic rod is bonded to radio transmitter with dental acrylic.

four mo after attachment. The owl gained 13 g (12% of its body weight) during this period from mid-March through mid-July. A second male carried a betalight five mo (September–January), and like two other owls recaptured in January 1986 had lost weight (16 g or 13% of its body weight). The third owl dispersed from the study area two mo after the betalight was attached in May. Two of 13 Boreal Owls radio-marked without betalights died whereas none of the three marked with betalights died. Mortality of radio-marked owls with betalights, then, was not increased compared to radio-marked owls without lights, although our sample size is quite small.

I followed owls during evening and night-time hunting forays a total of 23.3 hr on 10 nights. Observation sessions began when the owl left its daytime roost and ended when the owl became inactive 2–3 hr later or when contact was lost. During the first 0.5–1.0 hr of observation, night vision aids were not required; 4.6 hr of observation were made at dusk. During 16.3 hr I observed radio-marked owls not wearing lights. The remaining 7 hr of observation I followed owls wearing betalight packages. Frequent head turning and active posturing indicated the owls were foraging during my observations which contrasts sharply with normal roosting and preening behavior (G. Hayward, pers. obs.).

On three nights I followed one owl wearing a betalight attached using Method I for a total of 5.5 hr. Night-vision goggles facilitated observation of one prey capture, three feeding sessions and numerous perch locations. The betalight, however, was rarely visible. During a night involving three hr of observation I saw the betalight only twice. Plumage at the base of the head and along the owl's back concealed much of the betalight permitting a clear view only from directly behind the bird.

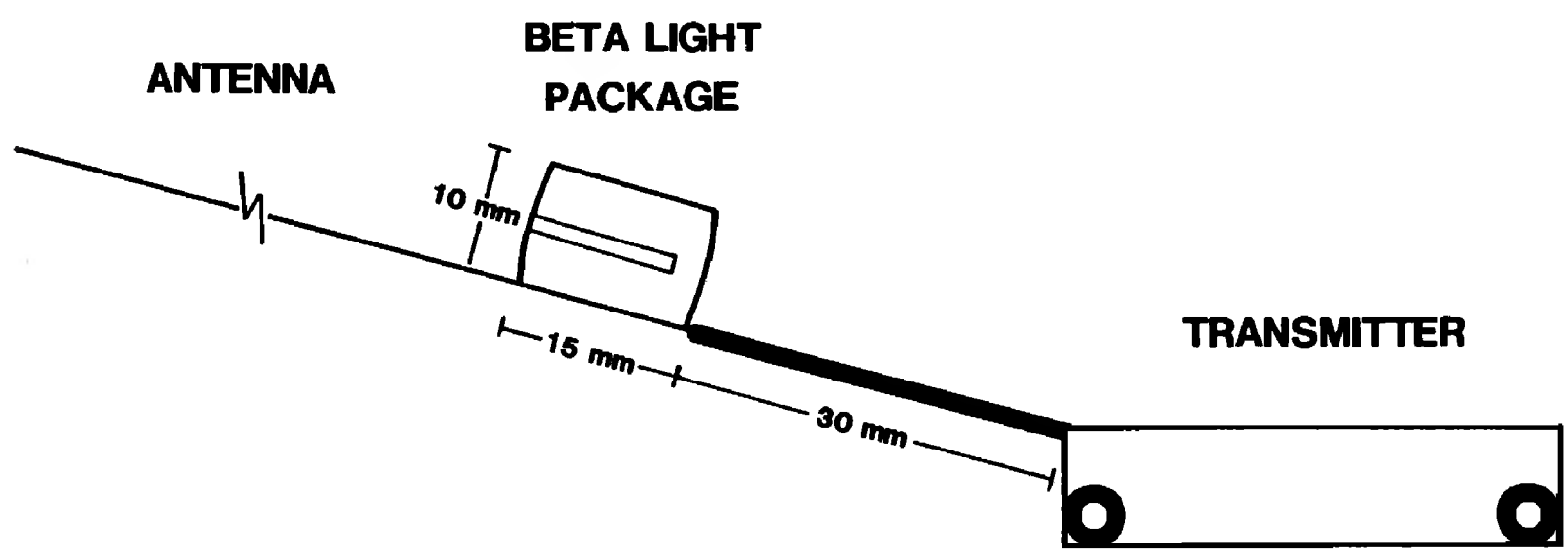

Figure 2. Betalight Attachment Method II. Betalight is glued to transmitter antenna with epoxy.

The betalight mounted by Method II remained clear of the owl's plumage. The light was visible from each side and behind the owl. I followed this owl for 1.6 hr over two nights. The light was visible from about 10 m without aid of night vision goggles. Unfortunately, the owl dispersed from the study area. The short observation period and the rapid rate at which this owl moved while foraging prevented a thorough assessment of attachment Method II.

Because I was unable to adequately evaluate attachment Method II (the more visible light position) in the field, I measured the distance over which the betalights were visible in a controlled situation. Simply holding the light against a dark background, I viewed the light at night with unaided vision and with night vision goggles (Model AN/PVS-5A; ITT, Electo-Optical Prod. Div.). Under a starlit sky with no moon and two km from city lights, the betalight was visible to the unaided eye for eight m and for 31 m with the aid of night vision goggles. A larger betalight would increase detection distances considerably.

Using radio-telemetry and night vision goggles, I also observed foraging owls not wearing betalight packages. In this way I gathered information on foraging behavior and foraging microhabitat unobtainable using triangulation or simple pellet collection. In situations where an owl's foraging strategy involved flights <75 m and searches of three min or more at each perch, I could follow the owl reasonably well as it foraged. These results are comparable to the observations obtained with betalights mounted as in Method I.

DISCUSSION

Understanding the ecology of nocturnal owl species has been hampered by a paucity of information on foraging behavior and habitat. Published analyses of niche overlap among sympatric species strongly emphasize prey species and size class with little consideration for where each owl species obtains food. Authors frequently speculate on mechanisms "that would allow two owl species to forage in sympatry" (Marks and Marks 1981:82) without information on where foraging occurs. Marti (1974), Herrara and Hiraldo (1976), Marks and Marks (1981), and Marks and Marti (1984) studied food niche overlap through quantitative analysis of size class and species overlap in prey but only alluded to the necessity of obtaining foraging habitat information. Holmes and Recher (1986) showed that habitat structure influenced foraging strategy and success in other avian predators. Lundberg (1980) emphasized the role of habitat differences in his discussion of interactions between Ural Owls (*Strix uralensis*) and Tawny Owls (*S. aluco*), and Southern and Lowe (1968) and Hirons (1985) demonstrated the importance of vegetation structure in determining prey availability and habitat use. Nesting success, territory size and productivity have been linked to habitat characteristics influencing prey availability (Hirons 1985).

Direct observation of foraging owls has been more successful in open habitats (examples: Clark 1975; Chamberlain 1980; Kertell 1986) than forested habitats. In Sweden Norberg (1970) studied the foraging behavior of the forest-dwelling Boreal Owl during twilight nights of summer in the far north. Foraging habitat of Boreal Owls was further studied by Sonerud et al. (1986) by following radio-marked owls during twilight, combining direct observations and triangulation to discern habitat use.

Further study of foraging behavior and habitat use by nocturnal owls, especially forest owls, will require a combination of radio-telemetry and a light source attached to the owl. In open habitats radio telemetry may not be necessary and owls marked simply with a light source may be observed with the aid of a light intensifying instrument (Braun Hill and Clayton 1985). Wolcott (1977) described a battery powered LED light source (weighing five g) visible from 300 m when viewed using a night scope which he used on Ghost Crabs (*Ocypode quadrata*). DeLong and Murphy (1982) used a similar package to study behavior of Long-eared Owls (*Asio otus*) at their nest sites. The LED light, however, has a limited effective life (one mo) and is heavy due to the size of the battery.

Betalights provide an effective alternative light-emitting marker with characteristics which make them preferable for marking owls. Powered by radioactive gas, betalights are lightweight (ours one g) and have extremely long effective lives (12 yrs). Betalights are inexpensive (<$10 U.S.) and are available in several colors to facilitate tracking individuals. The most significant drawback in using betalights as markers involves restrictions on transportation and handling of radioactive substances. Betalights are designed to be safe light sources, but the user must meet certain licensing requirements. The radiation control officer or other officials at the user's institution should be consulted concerning restrictions applying to local areas.

During my trials, several factors hampered observation of Boreal Owls during nocturnal forays, whether or not owls carried a betalight. Extremely dense forest vegetation restricted visibility, resulting in a bias against recording use of denser forest habitats. Dense forest vegetation and tree fall also restricted observer mobility. Apparently, the noise made while approaching Boreal Owls did not disturb the hunting owls who continued to hunt and obtain prey. Sonerud et al. (1986) were also able to follow foraging Boreal Owls on foot without disturbing the owls' hunting.

Betalight packages mounted by Method I enhanced observation of owls only slightly compared to radio-marked owls without betalights observed with night vision goggles. Mounting a betalight on the radio antenna rather than the transmitter rendered the betalight much more visible. Method II of attaching a betalight was not adequately field tested but has potential to aid considerably in future nocturnal studies of owl behavior and habitat use.

Limitations on size and placement of betalights on Boreal Owls contributed to the difficulties experienced with following owls after dark. The Boreal Owl is a cavity nesting bird which may use holes only slightly larger than its head. Therefore, the size of our betalight package was limited to the smallest light source manufactured by Saunders-Roe which produces only 75 microlamberts of light.

In more accessible areas betalight markers used in conjunction with night viewing aids would facilitate studies of owl movements. In particular studies of the large, platform nesting owls could be undertaken. On large *Strix, Bubo, Asio,* and *Tyto,* as well as others, larger betalights (e.g., Type "Q," a hemisphere, Saunders-Roe) mounted on a short pedestal (two cm) atop a radio transmitter or on the antenna would provide a visible light for night tracking. In studies of larger species the danger of predation by other owls as a result of the marker would be reduced, and concerns associated with weight and package size would be less critical. Betalights might be better suited for species inhabiting open habitats where vegetation places fewer restrictions on viewing distances and viewer mobility.

This preliminary work suggests that betalights are useful for studying foraging and other behavior and habitat use by owls. Although past studies of food habits, limited to pellet analysis, were important first steps in understanding owl ecology, future studies should emphasize where owls obtain prey. The interrelationship between an owl species, its prey and other owl species can only be defined with knowledge of where interactions are taking place. To avoid considering foraging habitat in future discussions of niche overlap among owls may significantly distort our perception of the indirect interactions between species! Betalights offer an effective method to aid in studies of owl foraging and habitat use, as well as other behavior, ultimately increasing our understanding of the ecology of these nocturnal predators.

ACKNOWLEDGMENTS

Fieldwork was carried out during a study of Boreal Owl habitat use, funded principally by the U.S. Forest Service Intermountain Forest and Range Experiment Station and Idaho Department of Fish and Game. Other contributors include the U.S. Department of Defense, North American Bluebird Society, Max McGraw Wildlife Foundation, University of Idaho Wilderness Research Center, Duracell Corp., and TDK Electronics Corp. L. Flaccus, P. Hayward, and A. Wright contributed significantly in the field investigations. Comments and suggestions by D. Clayton, E. O. Garton, P. Hayward, C. Marti, and D. Smith improved the manuscript.

LITERATURE CITED

BRAUN HILL, S. AND D. H. CLAYTON. 1985. Wildlife after dark: a review of nocturnal observation techniques. James Ford Bell Mus. Nat. Hist. Occ. Paper. 17. 22 pp.

CHAMBERLAIN, M. L. 1980. Winter hunting behavior of a Snowy Owl in Michigan. *Wilson Bull.* 92:116–120.

CLARK, R. J. 1975. A field study of the Short-eared Owl, *Asio flammeus* (Pontoppidan), in North America. *Wildl. Mono.* 47:1–67.

CRABTREE, R. L. AND L. S. BROOME. 1985. Nocturnal observation of foraging striped skunks in a wetland environment. Pages 35–38. *In* R. P. Brooks, ED. Nocturnal mammals: techniques for study. Forest Resources Research Paper No. 48. Pennsylvania State Univ., Univ. Park, PA.

DELONG, T. R. AND J. R. MURPHY. 1982. Effect of ambient conditions on nocturnal nest behavior in Long-eared Owls. M.Sc. Thesis. Brigham Young Univ. Provo, UT. 24 pp.

HERRARA, C. M. AND F. HIRALDO. 1976. Food-niche and trophic relationships among European owls. *Ornis Scand.* 7:29–41.

HIRONS, G. J. M. 1985. The effects of territorial behavior on the stability and dispersion of Tawny Owl (*Strix aluco*) populations. *J. Zool., Lond.* (B) 1:21–48.

HOLMES, R. T. AND H. F. RECHER. 1986. Search tactics of insectivorous birds foraging in an Australian eucalypt forest. *Auk* 103:515–530.

KERTELL, K. 1986. Reproductive biology of Northern Hawk Owls in Denali National Park, Alaska. *Raptor Res.* 20:91–101.

LUNDBERG, A. 1980. Why are the Ural Owl *Strix uralensis* and the Tawny Owl *S. aluco* parapatric in Scandinavia? *Ornis Scand.* 11:116–120.

MARKS, J. S. AND V. A. MARKS. 1981. Comparative food habits of the Screech Owl and Long-eared Owl in southwestern Idaho. *Murrelet* 62:80–82.

——— AND C. D. MARTI. 1984. Feeding ecology of sympatric Barn Owls and Long-eared Owls in Idaho. *Ornis Scand.* 15:135–143.

MARTI, C. D. 1974. Feeding ecology of four sympatric owls. *Condor* 76:45–61.

NORBERG, R. A. 1970. Hunting technique of Tengmalm's Owl *Aegolius funereus* (L.). *Ornis Scand.* 1:49–64.

SONERUD, G. A., R. SOLHEIM AND B. J. JACOBSEN. 1986. Home-range use and habitat selection during hunting in a male Tengmalm's Owl *Aegolius funereus. Fauna norv., Ser. C., Cinclus* 9:100–106.

SOUTHERN, H. N. AND B. P. W. LOWE. 1968. The pattern of distribution of prey and predation in Tawny Owl territories. *J. Anim. Ecol.* 37:75–97.

THOMPSON, S. D. 1982. Microhabitat utilization and foraging behavior of bipedal and quadrupedal heteromyid rodents. *Ecology* 63:1303–1312.

WOLCOTT, T. G. 1977. Optical tracking and telemetry for nocturnal field studies. *J. Wildl. Manage.* 41:309–312.

Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83843.

Received 20 December 1986; Accepted 9 June 1987.

J. Raptor Res. 21(3):103–110

EFFECTS OF STRYCHNINE ON THE BEHAVIOR OF GREAT HORNED OWLS AND RED-TAILED HAWKS

CARL D. CHENEY, STEPHEN B. VANDER WALL AND RUTHE J. POEHLMANN

ABSTRACT.—Objectives of this research included determining effects of dietary strychnine on raptor behavior. Toxin doses (0.8–2.3 mg/kg) were in the range of those possibly ingested when eating poisoned rodents in the wild. A series of experiments determined dose-response relationships in terms of movement, balance and severity of tremors and seizures. In addition we determined that subjects did not avert to strychnine-contaminated prey but did avert when lithium chloride induced gastrointestinal illness. Finally, effects upon foraging ability were ascertained. Doses of strychnine appeared to alter behavior such that subjects failed to switch patches efficiently. Sublethal doses of strychnine obtained in the wild from eating poisoned rodents can have deleterious effects on raptors. Constraints and implications of this conclusion are discussed.

Strychnine has been used for many years as a rodenticide on both forest and rangeland primarily in grain baits to control pocket gophers (*Thomomys* spp.), ground squirrels (*Spermophilus* spp.), and prairie dogs (*Cynomys* spp.). In 1983 the U.S. Environmental Protection Agency (EPA) banned outdoor above-ground use of strychnine bait due to risks to nontarget wildlife (Federal Register 1983). Among EPA concerns was that endangered and special interest species, primarily mammals and predatory birds, were becoming secondarily poisoned by consuming carcasses of rodents killed by strychnine (Schitoskey 1975). Golden eagles (*Aquila chrysaetos*) for example, have died after consuming prey poisoned with strychnine (Reidinger and Crabtree 1974). The EPA permits strychnine use for pocket gopher and ground squirrel control if concentration in bait is ≤0.5% and baits are placed below ground. Usage modifications were designed to decrease the chances of nontarget species such as raptors consuming bait or becoming secondarily poisoned by consuming poisoned rodents. Nevertheless, nontarget species are still being affected (e.g., Hegdal and Gatz 1976; Fagerstone et al. 1980).

Physiological effects of strychnine are well known. Strychnine is a convulsant poison which acts by lowering the stimulation threshold of spinal reflexes (Casarett and Doull 1980). The LD_{50} (lethal dose for 50% of the treated population) values for a variety of bird species range from about 2.0–24.0 mg/kg body weight (Hudson et al. 1984). Golden Eagle, the only raptor species tested thus far, has an LD_{50} of 4.80–8.10 mg/kg body weight (Hudson et al. 1984).

The objective of this study was to determine behavioral effects of sublethal doses of strychnine on Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (*Bubo virginianus*). In particular we examined how strychnine influenced behavior. Effects were determined with regard to probable levels of strychnine contamination encountered in the wild. Two types of behavior were of particular interest: First, we wished to ascertain how sublethal doses with physiological consequences would affect future food choices and foraging strategies. Second, we wished to know what other behaviors are affected by ingestion of sublethal toxins beyond taste aversion or motoric influences.

METHODS

Subjects. Two Great Horned Owls (GHO) and one Red-tailed Hawk (RTH) of unknown sex were used in the experiments. One owl (GHO_1) had been maintained in captivity for 13 yrs and had served as a subject in several behavioral experiments. A second owl (GHO_2) and the RTH were wild trapped birds that had sustained injuries to flight feathers and were being rehabilitated. Birds were fed fresh frozen rodents (white laboratory rats) or fresh beef heart daily and were food deprived to approximately 85% of *ad lib* body weight during all experiments. All food was weighed, and subjects were weighed weekly.

Facilities and Maintenance. Subjects were housed individually in 4.8 × 3.0 × 3.4 m wire mesh outdoor cages located at Utah State University, Green Canyon Ecology Research Station, Logan, Utah. Cages shared a wall with an indoor experimental enclosure measuring 9.5 × 7.3 × 3.5 m. Remotely operated

Table 1. Behavioral responses to strychnine. See text for further discussion.

TRIAL #	DOSE (mg) (mg/kg)	BEHAVIORAL RESPONSE
GHO_1		
1–6	0.0	Baseline
7	0.1	No effect
8	0.3	No effect
9	0.5	No effect
10	1.0	No effect
11	1.5 (1.22)	Slight loss of motor coordination
12	1.8 (1.29)	Significant loss of motor coordination
GHO_2		
1–6	0.0	Baseline
7	0.1	No effect
8	0.3	No effect
9	0.5	No effect
10	1.0 (0.83)	Significant loss of motor coordination
RTH		
1–6	0.0	Baseline
7	0.1	No effect
8	0.3	No effect
9	0.5	No effect
10	1.0	No effect
11	1.5	No effect
12	2.0 (1.93)	No effect
13	2.3 (2.09)	Slightly nervous, slightly uncoordinated
14	2.5 (2.33)	Nervous–very unsteady
15	2.8	Significant loss of motor coordination

doors permitted movement from outdoor to indoor enclosures. Experiments one through four were performed outdoors; experiment five indoors.

Experiment One (Exp 1)

Experiment One was designed to establish the minimum oral dosage of strychnine having significant, observable effects on motor functions. To avoid inadvertent stress to birds low doses of strychnine were gradually increased until effects were observable (Table 1). Experiment One also provided an opportunity to characterize precisely the types and extent of behavioral effects of selected dosages.

Exp 1 Procedures. Trials were run on alternate days to allow sufficient time for birds to metabolize or otherwise eliminate the toxin (Goodman and Gilman 1978). Birds were fed white laboratory mice carcasses weighing 22–28 g on test days, and fed sufficient beef heart to meet their metabolic needs for the 48-hr period on non-test days.

Six pre-test trials were conducted to provide baseline behavior data. Birds were fed mice injected with 0.1 ml commercial vegetable oil and observed for 30 min. Posture, excitability, preening, frequency of perch changes, and motor coordination was recorded. At the end of each 30-min observation period an observer walked slowly to the door of each enclosure and recorded the reaction of each bird. Test procedures used were exactly the same as during pre-test, except that mice were injected with 0.1 mg strychnine alkaloid suspended in the vegetable oil. Initial dosage was approximately 1% of the probable LD_{50} for these raptors (Evans and Lindsey 1984) and increased during subsequent trials (Table 1).

Exp 1 Results and Discussion. Behavior during pre-test differed markedly. Owls usually perched motionless for long periods, with their eyes partially closed, typical daytime activity for owls. The hawk was much more active, hopping or flying between perches as many as 48 times during the 30-min observation period. The hawk preened frequently and always appeared alert. When approached at the end of observation periods, the owls became alert, blinked their eyes, snapped their bills, and hissed. One owl (GHO_1) usually remained stationary, whereas GHO_2 often flew against the wire mesh screen and climbed upward one or two m. The RTH became active, was alert and sometimes flew to a perch away from the observer when approached.

At low dosage levels GHO_1 leaned slightly to one side. The most obvious effect of low level dosage was a decrease in motor coordination after brief periods of physical exertion. For example, GHO_1 had difficulty maintaining balance on a perch after a flight of two to three m, sometimes flapping his wings up to 10 sec while attempting to grip the perch. After regaining balance, several more seconds passed before the bird was able to fold its wings. Immediately following these brief periods of faulty balance, both owls appeared normal, including eye-blink, head-turn and other movements. Following flights across the enclosure the abnormal reaction became more pronounced. The owls sometimes could not regain balance and fell to the ground at which time their wings and body trembled uncontrollably for one to 20 sec. Severity of the response appeared propor-

tional to the level of exertion. Owls walked on the ground without difficulty, and walking never triggered trembling. Coordination of flight did not seem to be affected, at least not for the short flights observed within enclosures. Obvious debility of motor coordination and tremors began only after the bird landed or attempted to land. Wings, legs and feet seemed to be affected.

The RTH responded to low level dosage of toxin by becoming more agitated, excitable and slightly uncoordinated. When an observer approached the enclosure the hawk became active and frantically flew against the cage wall. Flights across the enclosure produced similar behavior as observed for GHO_1 and GHO_2. On two occasions RTH fell to the ground after a short flight. Pronounced tremors observed in the owls were not a characteristic reaction of the hawk (Table 1). When the observer withdrew, the hawk rapidly calmed and, like the owls, when perched appeared unaffected.

Experiment Two (Exp 2)

Experiment Two was designed to determine if Great Horned Owls and Red-tailed Hawks would acquire a taste aversion to sublethal quantities of strychnine. Learned taste aversion has been demonstrated in many species (e.g., Garcia et al. 1977; Gustavson 1977). The biological basis for the phenomenon appears related to the fact that many plants and some animals sequester toxins in their tissues as a defense against browsing or predation (Garcia and Hankins 1975; Brower and Fink 1985). Raptors, both captive and free-ranging, may learn to avoid prey items containing strychnine, after one or several sublethal encounters. The question centers about whether gastrointestinal distress is a necessary component of food aversion learning, since strychnine is not known to induce malaise (Gustavson et al. 1979).

Exp 2 Procedures. Experiment Two followed immediately after Exp 1; the last trial of Exp 1 served as the first trial of Exp 2. Subjects and procedures were the same as described for Exp 1. Strychnine dosages were the same as those determined to elicit significant behavioral responses in Exp 1. Weight-specific doses may have varied slightly. The dependent variable was consumption or rejection of a mouse previously associated with strychnine tremors.

Exp 2 Results and Discussion. Owls invariably swallowed mice whole and had little if any opportunity to taste the strychnine (Brett et al. 1976). The Red-tailed Hawk dismembered mice into several pieces but gave no indication that strychnine was tasted.

None of the subjects developed an aversion to mice injected with strychnine and all were quickly consumed. Behavioral response four hr after consumption of the mice was similar to and replicated that described in Exp 1. Raptors were not observed to regurgitate nor were regurgitated mice found in enclosures.

Latency (time between presentation and contact) to take the mouse carcasses did increase slightly as the experiment proceeded. Birds may have become hesitant to eat, but the level of deprivation could not be precisely controlled. In later experiments (see below) birds readily accepted poisoned carcasses suggesting that increased latency in this experiment was not a response to strychnine.

Experiment Three (Exp 3)

Experiment Three was conducted in order to determine if subjects could in fact learn to avert to food injected with a drug that causes gastrointestinal malaise. Inasmuch as strychnine poisoned rodents may die above ground (Hegdal and Gatz 1976; Fagerstone et al. 1980), another and related test was whether the bird averted to the taste of a novel food item or whether sight of a treated food item could cause aversion. Gustavson et al. (1978) reported that "bitter-flavored" dead mice were rejected on-sight by raptors.

Exp 3 Procedures. Subjects were food deprived 24 hr prior to treatment. Each bird was offered a dead black mouse injected with 0.5 ml of lithium chloride solution (0.25 g/3 ml H_2O). Immediately prior to each trial mouse carcasses were placed for 5 min in a solution of white vinegar diluted with an equal proportion of H_2O giving mice both a smell and (presumably) a taste. Birds had not eaten black mice for over four mo prior to Exp 3.

Exp 3 Results and Discussion. Each bird consumed the black treated mice, as well as other untreated food items in five sec or less. Owls clicked their beaks after taking the treated mice, perhaps in response to the vinegar. No noticeable signs of malaise occurred within one hr. No regurgitation of prey was observed, but more than the usual amount of feather fluffing and head turning was noticed.

The following day subjects were offered part of a dead white rat which was consumed within seconds.

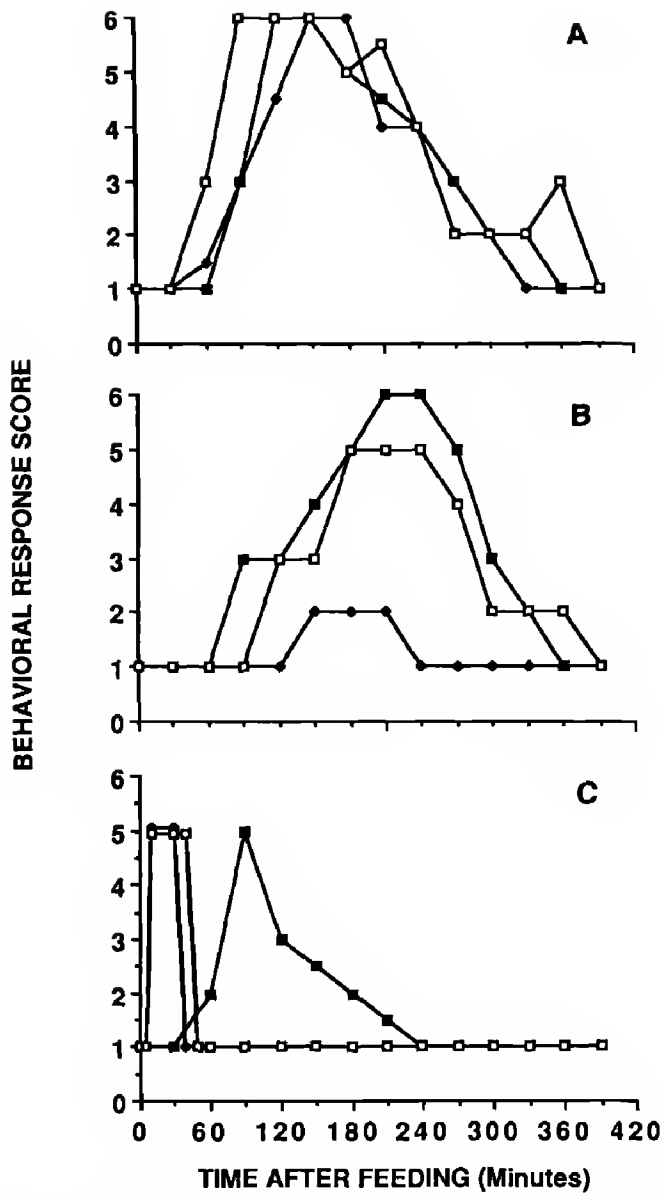

Figure 1. Changes in behavioral response of (A) GHO_1 to 1.8 mg strychnine, (B) GHO_2 to 1.0 mg strychnine, and (C) RTH to 2.8 mg strychnine. Each line represents a separate trial. Behavior response scores are 1, no effect; 2, slightly nervous, slightly uncoordinated; 3, markedly nervous, markedly uncoordinated, no tremors; 4, mild tremors (owls), very nervous (hawk), maintains perch; 5, marked tremors (owls), can't maintain perch; 6, can't stand upright on ground. See text for further explanation.

Dead, black, vinegar-flavored mice were again offered 24 hr later. None of the birds would approach the treated mouse and averted their gaze and even moved away. Odor as a cue cannot be completely ruled out, however, as the vinegar coating gave mice a distinctive smell. Nonetheless, we conclude that raptors will avert to prey treated with lithium chloride.

Experiment Four (Exp 4)

Experiment Four extended Exp 1 to determine the intervals of behavioral response to strychnine, as follows: 1) interval at which behavioral effects first become apparent following treatment; 2) duration of behavioral effects; 3) intensity of behavioral effects; and 4) changes in the intensity of behavioral response over time.

Exp 4 Procedures. Subjects were fed dead laboratory mice injected with strychnine suspended in vegetable oil. Three tests were conducted at 48 hr intervals. Dosages were the same as those that elicited noticeable behavior effects in Exp 1. However, weight-specific doses probably differed slightly from those of Exp 1.

Following treatment subjects were observed for one min periods spaced at 30 min intervals. During each observation period, birds were forced by our presence to fly across enclosures.

Exp 4 Results and Discussion. The RTH reacted to the drug more quickly than did the owls. Initial responses were detected in the hawk in as little as 20 min (two tests) and up to 60 min (one test). Owls initially responded within 60–120 min.

Peak behavioral response occurred in the hawk within 30–90 min. Peak response by GHO_1 occurred 90–150 min after feeding, whereas GHO_2 was affected maximally at 180–210 min. Why the owls differed in reaction time is unknown. Overt recovery in the hawk occurred within 60 min (two cases) and up to 240 min (one case) after feeding. Owls recovered after a 330–390 min period. Duration of observable behavioral effects was much shorter in the hawk (30–210 min) than in the owls (300–360 min).

Intertrial variation in response was greater for two of the three subjects (Fig. 1). Variation may have been due to difference in meal size. For Trials One and Two GHO_2 was fed a 15–20 g mouse containing 1.0 mg strychnine. For Trial Three the same amount of strychnine was given in a 39 g piece of rat carcass. Greater bulk in the gastrointestinal tract may have acted to dilute the strychnine, thereby diminishing effects.

Trial One for the hawk was markedly different than Trials Two and Three (Fig. 1C). The hawk's reaction to the strychnine in Trial One was delayed and of longer duration, similar to responses of the owls (Fig. 1A and 1B). The reason for different responses is not known but may be related to the hawk's feeding behavior. For Trials Two and Three the body cavity (into which the strychnine was injected) was torn open by the hawk before mice were ingested. During Trial One, limbs were consumed

before the body cavity was ruptured. Strychnine would then have been released more gradually and, consequently, absorbed by the gastrointestinal tract over a longer period of time.

Experiment 5 (Exp 5)

Possibly very small quantities of strychnine that have no conspicuous or only minimal effects on behavior might still affect sensory mechanisms or cognitive processes such as learning and memory. Disruption of such processes by an environmental toxin might alter critical behavioral processes such as foraging efficiency, mating activities, and other reproductive behavior. The purpose of Exp 5 was to establish whether sensory and cognitive processes were altered at low oral dosages. Two of the birds were trained to perform a relatively complex foraging task that required cognitive skills. Birds were then treated with small quantities of strychnine and observed during task performance.

Exp 5 Procedures. The procedure utilized is called reward following or reversal learning (Mackintosh 1974). A piece of rat carcass was placed in one of two closed prey chambers with an electronic perch in front that caused chamber doors to open when a subject landed (Cheney 1979). Each subject was allowed to choose a chamber. A food item was placed in the same chamber for all trials until three correct first choices were made in succession. The food item was then placed in an alternative chamber and trials repeated until the bird made three correct choices in succession. This procedure develops a win-stay, lose-shift strategy in most organisms such that with experience a reversal in choice behavior occurs after the first encounter of an empty chamber. Dependent measures with this procedure include latency to choose a chamber, latency to strike (see below), and perseveration after reaching criteria.

Procedures during pretesting and testing were similar. Trials were repeated at 24-hr intervals. Two hours prior to each trial birds were fed a 5–10 g piece of white rat carcass. During pretest, food was injected with 0.9 ml of plain vegetable oil. During testing, food was injected with strychnine suspended in the same type and amount of vegetable oil. Dosages were approximately 10% of the reported LD_{50} for Red-tailed Hawks and Great Horned Owls (Anthony et al. 1983): 1.0 mg for RTH and 0.8 mg for GHO_1.

At the beginning of each trial a 20–30 g piece of rat carcass was placed in one of the two food chambers. Each bird was observed by means of a television monitor. Interval between the bird entering the room and selection of a food chamber (opening of the lid) was recorded as were other features of the bird's performance and behavior. If the bird opened the lid of the baited food chamber first, that choice was recorded as correct. If the empty food chamber was opened first, the bird was allowed to open the other prey chamber.

After a correct choice was made, subjects were allowed to eat the food. Each bird was then allowed a maximum of five min to search the other box if it had not already done so. If the bird made no attempt to search for food in the other chamber within 5 min, the door to the outdoor enclosure was opened, permitting the bird to leave.

Exp 5 Results and Discussion. During pretest and test trials, both raptors perched quietly in the experimental enclosure for one to 30 min before choosing a food chamber. The hawk usually perched on a horizontal perch 0.5 m from the electronic perch for Chamber Two, which did not seem to influence the hawk's selection of food chambers. Usually GHO_1 perched across the room and flew to a horizontal perch near the electronic perches just prior to selecting a prey chamber.

The hawk underwent 50 pre-test trials prior to testing and GHO_1 underwent 62 pretest trials. Initially choice of food chambers was random and inconsistent. After the hawk's thirty-first trial and the owl's forty-eighth trial, choice behavior became consistent. The last 19 pretest trials of the hawk and 14 pretest trials of the owl are shown in Figure 2. During trials for the hawk, food was switched from Chamber One to Chamber Two back to Chamber One and then back to Chamber Two. The hawk successfully "tracked" the food making only one, four, and two incorrect choices following each switch, respectively. The minimum number of errors possible is one for each switch, so the hawk made between zero and three errors more than the minimum. During the owl's last 14 pretest trials, the food was switched from Chamber Two to Chamber One and back to Chamber Two. The owl also successfully "tracked" the prey, making only two incorrect choices following the first switch (one more than the minimum) and three incorrect choices following the second switch (two more than the minimum) before making three consecutive correct choices.

Initiation of treatment (i.e., ingestion of strychnine-treated mice two hr prior to choice tests) was

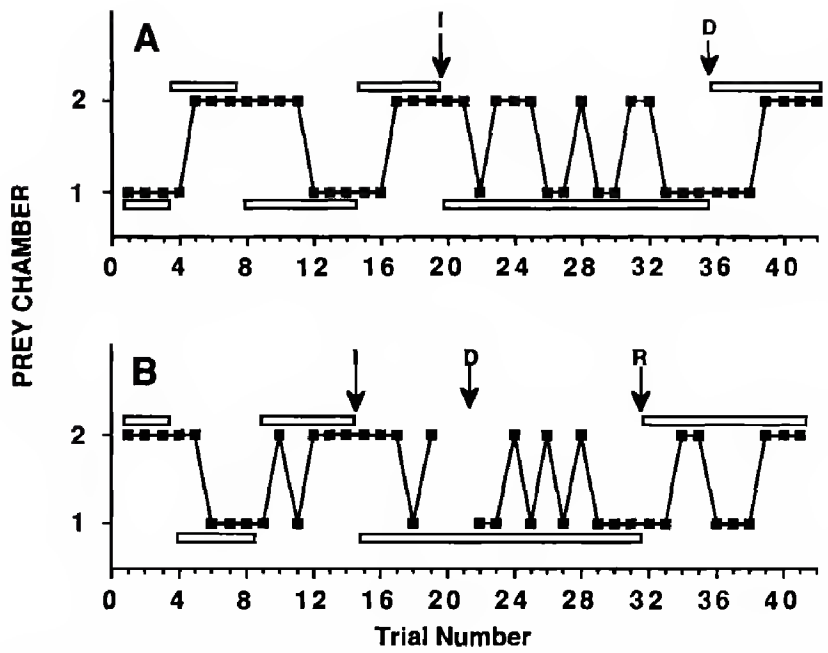

Figure 2. Choice of prey chambers by (A) RTH and (B) GHO_1. The open horizontal bars indicate the location of prey. Prey location was switched after three consecutive correct choices. The line connecting closed squares illustrates choice of prey chambers. For RTH strychnine (1.0 mg) was initiated (I) on Trial 20 and discontinued (D) on Trial 36. For GHO_1 strychnine (0.8 mg) was initiated (I) on Trial 15. On Trials 20 and 21, GHO_1 failed to respond to the test protocol, apparently due to accumulating toxic levels of strychnine in its system. On Trial 22 strychnine was discontinued and reinitiated (R) on Trial 32 at 0.4 mg. See text for further explanation.

coincident with switching food to the alternate chamber. The hawk's weight during Exp 5 ranged from 1147–1189 g ($\bar{x}$ = 1163 g), and the weight-specific dose was 0.86 mg/kg strychnine. GHO_1's weight ranged from 1171–1256 g ($\bar{x}$ = 1228 g) with a weight-specific dose of 0.65 mg/kg in the early phase of the test and 0.32 mg/kg in the later phase.

During Exp 5, the hawk made 13 choices before making three consecutive correct choices (Fig. 2A). Eight choices were incorrect. The overt behavior of the hawk did not seem to be affected by the strychnine but results indicate that memory and learning may have been degraded. Following three consecutive correct choices (Trials 33–35), the administration of strychnine was discontinued. The hawk then made only three incorrect choices before switching to the correct food chamber, an error rate similar to the pretest situation.

The first attempt to test GHO_1 was terminated because the owl was accumulating strychnine. GHO_1 made five choices during the first test before acquiring toxic levels of strychnine. On Trials 20 and 21, GHO_1 was unable to carry out the test protocol (Fig. 2B), even though lower doses of strychnine were given than in Exps 1 and 2. The toxin was given at 24 hr intervals rather than 48 hr intervals and was apparently accumulating faster than could be eliminated. Administration of the drug to GHO_1 was discontinued on Trial 22. On Trial 29, GHO_1 again established consistent choice behavior. On Trial 32, following three consecutive correct choices, administration of strychnine was again given to GHO_1 but at a reduced level of 0.4 mg. GHO_1 then made seven incorrect choices before meeting contingency, six more than the minimum required and 4.5 more than its pretest mean. We conclude from this experiment that repeated ingestion of strychnine had a modest effect on foraging behavior at dosages of 0.4 mg and a profound effect at dosages of 0.8 mg.

DISCUSSION

Dosages of strychnine alkaloid of 0.8–2.3 mg/kg had substantial effects on behavior of the birds tested. The Red-tailed Hawk appeared less sensitive to strychnine than did the Great Horned Owls, and the two species had markedly different behavioral responses. The Red-tailed Hawk became highly agitated and uncoordinated at doses of 2.3 mg/kg but only once developed tremors. Evans and Lindsey (1984) stated that Red-tailed Hawks are physically affected by 4.5–5.0 mg/kg strychnine. Our results indicate that at least some Red-tailed Hawks can be affected by much smaller doses.

Behavioral responses of the Great Horned Owls were more severe than the hawk's although drug dosage was lower (0.8–1.3 mg/kg). Noticeable loss of coordination and tremors developed. Evans and Lindsey (1984) reported that 2.0–2.5 mg/kg of strychnine has an adverse physiological effect on Great Horned Owls. In our study response to the drug was greatest immediately after prolonged or intense physical exertion. Minimal exertion, such as head-turning, eye-blinking and slow walking, did not trigger tremors. Casarett and Doull (1980) reported that strychnine acts by lowering the threshold for stimulation of spinal reflexes, causing tetanic convulsions. Minimum threshold in our study was exceeded by owls flying across enclosures or flapping their wings vigorously.

Lethal dose (LD_{50}) of strychnine alkaloid has been estimated to be 10.2 mg/kg for Red-tailed Hawks and 7.7 mg/kg for Great Horned Owls (Anthony et

al. 1983). Our results indicate that doses causing a significant behavioral response were 10–16% of the estimated LD_{50} for Great Horned Owls and 28% of the estimated LD_{50} for the Red-tailed Hawk. Experiment 5 revealed that at a dose of 0.86 mg/kg (8.6% of estimated LD_{50}) the Red-tailed Hawk was much less accurate on a choice test than during pre- and post-tests (no drug). At a dose of 0.32 mg/kg (4.0% of estimated LD_{50}), GHO_1 was also less accurate than during pretest (no drug). Thus, sublethal concentrations of strychnine alkaloid have potentially important behavioral consequences for these raptors.

Raptors and other predators may encounter sublethal doses of strychnine in the wild by eating strychnine-poisoned rodents (e.g., Fagerstone et al. 1980; Evans and Lindsey 1984; Barnes et al. 1985; Anthony et al. 1983). Predicting behavioral effects likely to be experienced by wild raptors ingesting strychnine is complicated by a number of factors. First, we observed considerable inter- and intraspecific variation in response to strychnine. Second, feeding behavior appears to influence how strychnine is absorbed by the gastrointestinal tract. Raptors that dismember prey and ingest viscera are likely to absorb the toxin more quickly and over a shorter time period, thus intensifying effects. Whether the predator's susceptibility to strychnine poisoning is increased is not clear. On the other hand, if the raptor rejects viscera, susceptibility to strychnine poisoning should decrease as most of the toxin in strychnine-killed rodents remains in the gastrointestinal tract (Hegdal et al. 1980; Evans and Lindsey 1984). Third, meal size may influence level of toxicity. In our study a given quantity of strychnine in a large meal had much less effect than did the same dose in a small meal. A large amount of food in the gut may dilute the toxin allowing it to be metabolized or eliminated with fewer behavioral consequences. On this basis an otherwise "lethal" dose may be survivable if ingested in a large meal. Fourth, even though strychnine is metabolized or eliminated relatively quickly, complete elimination may take several days. However, if low doses of strychnine are repeatedly ingested over a long period of time, the toxin appears to accumulate in the system faster than it can be eliminated and may eventually influence behavior. Fifth, the physiological impact of a given dose may vary seasonally. Casarett and Doull (1980) reported that cold temperatures have a potentiating effect on strychnine. A given dose of strychnine ingested in winter or early spring will have a greater effect on behavior than the same dose ingested in summer. In addition we found that activity following ingestion contributes to how dramatic the effects will be.

Even though raptors eventually recover from sublethal doses of strychnine with no long-term detrimental effects, ingestion of small doses can have potentially harmful consequences. Birds tested in our study occasionally fell from perches after ingesting low doses of strychnine in food. In the wild a fall from a perch could be fatal or could render birds vulnerable to predation. Further, sublethal doses of strychnine may substantially alter foraging behavior. Effects of strychnine on other aspects of behavior and physiology (e.g., temperature regulation) should also be explored.

Taste aversion to strychnine-contaminated food can have both good and bad consequences. On one hand, it is perhaps fortuitous that a prey base is not removed through aversion, while on the other hand, repeated and frequent ingestion of poisoned items can have serious effects. The ultimate outcome will probably depend upon individual conditions present at time of exposure.

ACKNOWLEDGMENTS

This research was supported by grant #00-84M8-5-698 from the U.S. Forest Service.

LITERATURE CITED

ANTHONY, R. M., G. D. LINDSEY AND J. EVANS. 1983. Hazards to ground squirrels and associated secondary hazard potential from strychnine baiting for forest pocket gophers. *In* Proceedings of 11th vertebrate pest conference. Sacramento, CA.

BARNES, V. G., JR., R. M. ANTHONY, K. A. FAGERSTONE AND J. EVANS. 1985. Hazards to grizzly bears of strychnine baiting for pocket gopher control. *Wilderness Soc. Bull.* 13:552–557.

BROWER, L. P. AND L. S. FINK. 1985. A natural toxic defense system: Cardenolides in butterflies versus birds. *In* N. Braveman and P. Bronstein, EDS. Experimental assessment and clinical applications of conditioned food aversions. *Ann. New York Acad. Sci.*, Vol. 44, New York.

BRETT, L. P., W. G. HANKINS AND J. GARCIA. 1976. Prey-lithium aversions, III: Buteo hawks. *Behav. Bio.* 17:87–98.

CASARETT, L. J. AND J. DOULL. 1980. Toxicology: the basic science of poisons (2nd ed.). Macmillan, New York.

CHENEY, C. D. 1979. A prey chamber for the experimental analysis of raptor hunting. *Behav. Res. Meth. and Instr.* 11:558–560.

EVANS, J. AND G. D. LINDSEY. 1984. Effects of strychnine on behavior of Red-tailed Hawks and Great

Horned Owls. NAPIAP Study Plan, DWRC Work Unit, 901.39.

FAGERSTONE, K. A., V. G. BARNES, JR., R. M. ANTHONY AND J. EVANS. 1980. Hazards to small mammals associated with underground strychnine baiting for pocket gophers. Pages 105–109. *In* Proceedings of 9th vertebrate pest conference. Fresno, CA.

FEDERAL REGISTER. 1983. Intent to cancel registrations of pesticide products containing strychnine. Vol. 48, No. 203, Wednesday, Oct. 19, page 48522.

GARCIA, J., K. W. RUSINIAK AND L. BRETT. 1977. Conditioning food-illness aversions in wild animals: Caveant Canonici. Pages 273–316. *In* H. Davis and H. Hurwitz, EDS. Operant-Pavlovian interactions. Lawrence Erlbaum Associates, Hillsdale, NJ.

——— AND W. HANKINS. 1975. The evaluation of bitter and the acquisition of toxiphobia. Pages 39–45. *In* D. A. Denton and J. P. Coughlan, EDS. Fifth international symposium on olfaction and taste. Academic Press, New York.

GOODMAN, L. S. AND A. GILMAN. 1978. The pharmacological basis of therapeutics. Macmillan, New York.

GUSTAVSON, C. R. 1977. Comparative and field aspects of learned food aversions. *In* L. Barker, M. Best and M. Domjan, EDS. Learning mechanisms in food and selection. Baylor University Press, Waco, TX.

———, L. R. BRETT, D. GARCIA AND J. KELLY. 1978. A working model and experimental solution to the control of predatory behavior. *In* H. Markowitz and V. Stevens, EDS. Behavior of captive wild animals. Nelson-Hall, Chicago.

HEGDAL, P. L. AND T. A. GATZ. 1976. Hazards to wildlife associated with underground strychnine baiting for pocket gophers. Pages 258–266. *In* Proceedings of 7th vertebrate pest conference. Monterey, CA.

———, ——— AND E. C. FITE. 1980. Secondary effects of rodenticides on mammalian predators. *In* Worldwide furbearers conference proc. Pages 1781–1794. Frostburg, MD.

HUDSON, R. H., R. K. TUCKER AND M. A. HAEGELE. 1984. Handbook of toxicity of pesticides to wildlife (2nd Ed.). U.S. Dept. of the Interior, Fish and Wildlife Service, Resource Publication No. 153.

MACKINTOSH, N. J. 1974. The psychology of animal learning. Academic Press, London.

REIDINGER, R. F., JR. AND D. G. CRABTREE. 1974. Organochlorine residues in golden eagles, United States—March 1964–July 1971. *Pest. Monit. Journal,* 8:37–43.

SCHITOSKEY, F., JR. 1975. Primary and secondary hazards of three rodenticides to kit fox. *J. Wildl. Manage.* 39:416–418.

Department of Psychology, Utah State University, Logan, UT 84322. Address second author: Department of Biology, Utah State University. Address third author: Department of Fisheries and Wildlife, Utah State University.

Received 10 February 1987; Accepted 31 August 1987.

J. Raptor Res. 21(3):111–115

A SURVEY OF THE BREEDING FALCONS OF EQALUNGMIUT NUNAAT, WEST GREENLAND IN 1984

JEREMY MOORE

ABSTRACT.—A survey of Peregrine Falcons (*Falco peregrinus*) in continental West Greenland 120 km north of the Arctic Circle found a higher breeding density than reported elsewhere in Greenland. Casual observations of Gyrfalcons (*Falco rusticolus*) during early spring suggested a larger population than was later found. Peregrine hatching dates and productivity were similar to other West Greenland studies, although nest aspect in the present study was less predictable. Interspecific competition for nesting cliffs, asynchronously-hatched broods and the possibility of renesting and 'alternative' nesting sites are discussed.

As a member of the 1984 Greenland White-fronted Goose Study Expedition, I spent the period 1 May–13 August in low arctic Western Greenland. The falcon project arose from a personal interest in raptors and was part of a general ecological investigation of the study area. The aim was to gather information on the location, occupation and breeding success of Gyrfalcon (*Falco rusticolus*) and Peregrine Falcon (*Falco peregrinus*) eyries.

STUDY AREA

Eqalungmiut Nunaat is an essentially triangular area of upland tundra adjoining the western edge of the Greenland ice sheet (Fig. 1) bounded on two further sides by broad (1–3 km), flat, melt-river valleys which join at its western extremity to form the southern arm of Nagsuggtoq (Nordre Strømfjord). Central co-ordinates of 50°30′W, 67°30′N, place the area approximately 120 km north of the Arctic Circle, and 65 km north of Kangerlussuaq (Søndre Strømfjord).

Eqalungmiut Nunaat is a region approximately 750 km^2 of often bare gneissic plateau with whaleback ridges, small, broken crags, lakes and damp gullies rising from sea level to a maximum altitude of 631 m. The region is part of a tract of apparently similar terrain stretching far to the north and south, intersected by valleys, minor and major, sometimes flanked by high cliffs, and occasionally forming deep gorges with sheer, rocky sides. The glacial melt-rivers are particularly cliff bound in places, with sheer rock dropping up to 250 m from the plateau.

METHODS

The survey period was between 23 May and 10 August 1984. Visits were made to sites occupied by falcons in 1979 (Fox and Stroud 1981) as time and weather conditions allowed. Reports of calling falcons were followed up, and speculative visits were made to previously unknown areas. A cliff thought suitable for an eyrie was observed from a distance until the presence or absence of falcons was confirmed. Signs such as old stick nests, patches of 'whitewash' and orange lichen (*Caloplaca* sp.) were useful in locating potential nest sites, but the exact location of the scrape was confirmed only after use by falcons was seen.

On each visit the stage in the breeding cycle was assessed, and an attempt was made to count and age young when present. Hatching dates were estimated by backdating from the estimated age of nestlings (see Anderson and Hickey 1970). Nesting ledges were not visited, nor were prey remains collected. Time constraints restricted the area which could be covered, but the survey is thought to be complete over an area of 560 km^2. The study area can conveniently be regarded as an island for determining mean territory size.

RESULTS

Peregrine Falcon. Thirteen Peregrine territories were found, one of which was later deserted, and another of which held just a single adult; eleven pairs were thought to have reared young (Table 1). However, distribution was by no means uniform, and a large (125 km^2) discrete area appeared to be unoccupied by Peregrines. At least one pair held territory in the unoccupied area in 1979, but a recent rock fall on the then occupied cliff may have destroyed the nesting ledge; however, no sign of occupancy was found on numerous, apparently suitable, cliffs nearby. Other sheer rockfaces were discovered in the 'empty quarter' which were apparently unoccupied during incubation. Eyries may have been missed during this, the 'quiet' period at these latitudes, but the nature of the cliffs suggested that nesting sites were not numerous there. Any additional eyries would, of course, increase the breeding density given below.

In Table 2 the mean territory size and mean inter-eyrie distance are given for Eqalungmiut Nunaat and compared with those for several parts of the Arctic and of the British Isles. The use of the term 'territory size' does not imply an area defended or used exclusively by one pair of falcons. The density of breeding Peregrines in Eqalungmiut Nunaat is similar to that in 'prime' British habitat (i.e., an area thought by Ratcliffe (1980) to have abundant prey

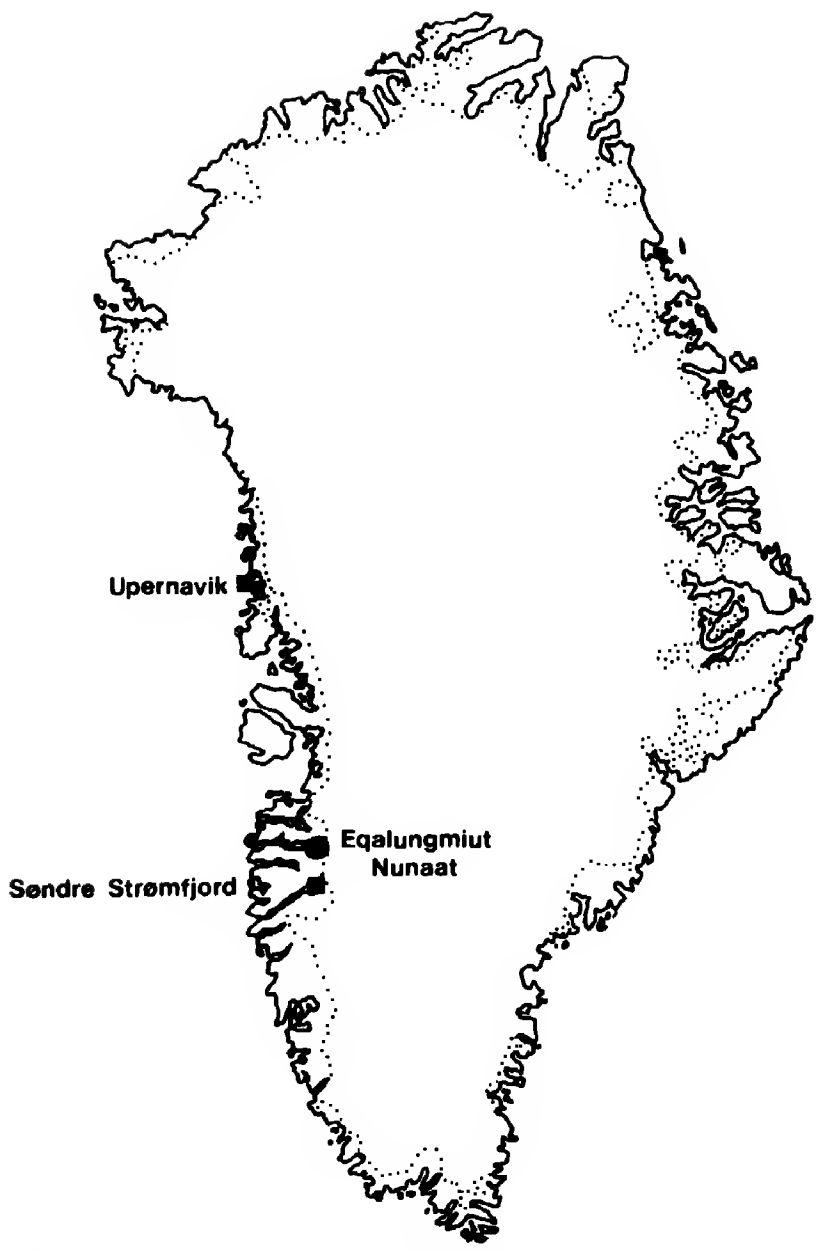

Figure 1. Map of Greenland showing approximate location of Eqalungmiut Nunaat study area.

and nesting places), higher than that in the Søndre Strømfjord area (Burnham and Mattox 1984) and considerably higher than that for Southern Greenland (Falk and Moller 1986). In Table 3, I have given densities for Eqalungmiut Nunaat as a whole (A), and the area actually occupied (B). It is recognised that the latter may be, to some extent, an arbitrary measurement, given that Peregrines nesting there may have hunted in the unoccupied area. Nevertheless, some idea results of the high density reached there. I have compared these figures with densities discovered in the Søndre Strømfjord area (Mattox 1984). Density in area (B) approaches that in Northwest England in recent years but is considerably lower than that found in the Canadian tundra west of Hudson Bay (Court et al. in press).

High Peregrine breeding density in Eqalungmiut Nunaat is not easy to explain. Basic requirements would be an abundance of suitable nesting sites and of prey. All prey items seen being taken to an eyrie were small in size; Peregrine diet is likely to have been similar to that discovered by Burnham and Mattox (1984) in their nearby study area—more than 90% Lapland Longspur (*Calcarius lapponicus*), Snow Bunting (*Plectrophenax nivalis*), Wheatear (*Oenanthe oenanthe*), and Redpoll (*Carduelis flammea*). Mattox (pers. comm.) has found that Peregrine density is lower towards the West Greenland coast as reflected in the density calculations for his larger study area. Likely, an increase in Peregrine density had taken place since 1979, but the 1984 survey was very much more thorough, rendering a meaningful comparison difficult. This study confirms the finding of high productivity of young Peregrines in West Greenland (Burnham and Mattox 1984).

Cliff aspect was estimated for each eyrie, and in contrast with the findings of Burnham (1975), both north- and northwest-facing cliffs were occupied. Burnham discovered a mean aspect of almost due

Table 1. Comparison of Peregrine Falcon breeding success in Western Greenland and Great Britain.

AREA	PAIRS HOLDING TERRITORY	SUCCESSFUL PAIRS	BREEDING SUCCESS	BROOD SIZE ($\bar{x}$)	YOUNG/ PAIR
Eqalungmiut Nunaat (1984)[a]	12	11	92%	2.3	2.1
West Greenland (1972–84)[b]	—	—	83%	2.8	2.3
West Greenland (1984)[b]	30	22	73%	3.2	2.3
Great Britain (1976–80)[c]	—	—	56%	2.3	1.3

[a] Mean brood size (and therefore young/pair) may have been under-estimated as nesting ledges were not visited. Note also small sample size—7 broods.
[b] From Mattox (1984).
[c] From Ratcliffe (1984). Young/pair in an increasing but non-migratory population.

Table 2. Comparison of mean inter-eyrie distance and mean territory size (all pairs) for some Peregrine Falcon populations.

AREA	MEAN INTER-EYRIE DISTANCE (km)	MEAN TERRITORY SIZE (km^2)[f]
Eqalungmiut Nunaat (A)[f] (1984)	5.2	46.7
Eqalungmiut Nunaat (B)[f] (1984)	5.2	36.2
West Greenland (1984)[a]	7.7	86.3
South Greenland[b]	—	240
Northwest Territories, Canada (west coast of Hudson Bay)[c]	3.3	17
Inland Northwest England (1930–60)[d]	5.0	42.3
Inland Northwest England (1982)[e]	4.6	32.0

[a] Figures from Mattox (1984) but see also Burnham and Mattox (1984).
[b] See Falk and Moller (1986).
[c] See Court (1986) and Court et al. (1987).
[d] An inland area thought by Ratcliffe (1980) to have abundant nesting places and prey, and therefore maximum Peregrine density.
[e] Increased density since recovery from pesticide crash (Ratcliffe 1984).
[f] See text.

south, while that for the present study was approximately 240°, or west-southwest. One north-facing eyrie in Eqalungmiut Nunaat had a late hatch date of 22 July. The majority of nesting cliffs were high and sheer, and at medium elevation. Eyrie elevation was between 150 m and 500 m, with a mean of 340 m. Eight successful cliff eyries were on sheer faces 60–120 m high, while a ninth was on a 20 m face at the bottom of an 80 m broken rocky slope. Two unsuccessful eyries were on 150 and 180 m sheer faces. Cliff height above the surrounding area was usually accentuated by a steep talus slope, which in many cases effectively doubled the height. The majority of eyries overlooked areas of flat terrain, often a lake or melt-river valley, with two exceptions: one eyrie on the sheer side of a deep (150 m) and narrow gorge was enclosed by the opposite wall, while a second pair nesting in another gorge had a limited view over the lower eastern wall.

Table 3. Mean territory size of Peregrine Falcons in West Greenland 1984.

AREA	MEAN TERRITORY SIZE (km^2)[a]		
	SUCCESSFUL PAIRS	PAIRS IN TERRITORY	TOTAL TERRITORIES
Eqalungmiut Nunaat A[a]	50.9	46.7	43.1
Eqalungmiut Nunaat B[a]	39.5	36.2	33.5
West Greenland[b]	117.3	86.3	66.4

[a] See text.
[b] From Mattox (1984).

Hatching took place between 2 and 22 July (8 broods) with a mean hatch date of 9 July compared with Mattox's (1984) mean for the same year of 7 July and a 1983 mean of 12 July (Burnham and Mattox 1984). The two day difference in 1984 mean hatch dates cannot be adequately addressed in view of this study's small sample size and different method of estimation. At one eyrie with a late hatch date (18 July), a Peregrine pair had been present since at least 23 May. Behaviour of the pair on that date, including courtship feeding and the sluggish behaviour of the female in particular, suggested that egg-laying was about to take place or had perhaps even commenced (the first casual sighting of a Peregrine in the area had been on 5 May). Activity took place at both the cliff eventually used (a 20 m face), and a sheer 120 m face with a Common Raven (*Corvus corax*) nest and copious white-wash, facing northwest, about 1 km away. The late estimated start of incubation (18 June) suggests that renesting may have taken place. Inclement weather during late May could have led to the loss of an unusually early first clutch at a more exposed but more secure alternative nesting site within the same territory. The larger cliff was occupied by Peregrines in 1979. Replacement clutches and the use of alternative cliffs are well-known phenomena at lower latitudes (in the British Isles, for example), but have not been proven in the Arctic, to my knowledge. W. G. Mattox (pers. comm.) believes that a 're-lay' may have taken place on one occasion in the Greenland Peregrine Falcon Survey area.

Gyrfalcon. Two successful pairs were found, rearing two and three young, while a third pair

deserted territory during or after incubation. All three occupied eyries were on south-facing cliffs, one at 450 m, two at 200 m. One additional eyrie occupied by Gyrfalcons in 1979 was used by ravens in 1984.

A large number of casual Gyrfalcon sightings during May and early June suggested a larger population than was eventually found. On the evidence of this survey, it is difficult to agree that numbers of Gyrfalcon and Peregrine nesting sites are similar in inland West Greenland (Burnham and Mattox 1984). It is known, however, that Gyrfalcon breeding populations fluctuate widely according to the availability of prey (Burnham and Mattox 1984). Late winter and early spring were exceptionally severe in central West Greenland which may have had a direct or indirect effect on Gyrfalcon numbers.

Seven unused eyries (identified by white-wash on cliffs), were found, mainly on lesser (<40 m), medium to high elevation (300–500 m) cliffs of varying aspect. Possibly Gyrfalcons occupied a proportion of perhaps less than ideal sites in more favourable years, or in fact some cliffs that were later occupied by Peregrines. At one south-facing 150 m cliff, nesting attempts by both Gyrfalcons and Peregrines took place. Observations at the cliff on 1 and 3 June suggested that Peregrines had recently arrived, evicted a pair of ravens and established a territory. Gyrfalcons were incubating about 600 m away and were driven off violently by the Peregrines when approaching too closely. Peregrine courtship displays and copulation were observed; there was no evidence of egg-laying, although this may have taken place elsewhere. Both pairs subsequently deserted the cliff, although the male Gyrfalcon was seen at the cliff in early August (interestingly, an identically plumaged male Gyrfalcon was seen on three occasions in mid-July at another cliff about 15 km away, and not previously or subsequently). Possibly inter-specific aggression contributed to the desertion of the cliff by both species. The two species were not known to have bred on the same cliff in Greenland until 1984 but do so in Alaska (White and Cade 1971). In 1984 two cliffs in the Søndre Strømfjord area held successful pairs of both species (Mattox 1984). However, unsuccessful attempts such as the one under discussion may have taken place on other occasions.

Asynchronously-hatched broods of both Peregrines (one brood of four) and Gyrfalcons (one brood of three) were recorded. The last-hatched in each brood had survived into the final third of the nestling period, and seemed healthy and vigorous in each case, despite appearing at least one week younger than its siblings. Burnham and Mattox (1984) have found small 'odd-age' young in several West Greenland eyries, but the smallest nestling has never survived to fledging. Court (1986) found that the last hatched Peregrine chicks in broods of four grew at the same rate as the first, second and third hatched chicks—if they survived the first week.

ACKNOWLEDGMENTS

I would like to thank Peter Davis, Robin Payne and Adrian Fowles for their help in the preparation of this paper, and William G. Mattox, Gordon S. Court and M. Alan Jenkins for their comments and advice on its first draft. Thanks also to Suzanne Edwards for the typing. Particular thanks also go to Tony Fox, David Stroud and Phil Davies for allowing me time enough to complete the fieldwork.

LITERATURE CITED

ANDERSON, D. W. AND J. J. HICKEY. 1970. Oological data in eggs and breeding characteristics of Brown Pelicans. *Wilson Bull.* 82:14–28.

BURNHAM, W. A. 1975. Breeding biology and ecology of the Peregrine Falcon (*Falco peregrinus*) in West Greenland. M.Sc. Thesis, Brigham Young University. Provo, UT. Unpublished.

——— AND W. G. MATTOX. 1984. Biology of the Peregrine and Gyrfalcon in Greenland. *Meddelelser om Grønland, Bioscience* 14, Copenhagen.

COURT, G. S. 1986. Some aspects of the reproductive biology of tundra Peregrine Falcons. M.Sc. Thesis, University of Alberta. Unpublished.

———, D. M. BRADLEY, C. C. GATES AND D. A. BOAG in press). The population biology of Peregrine Falcons (*Falco peregrinus tundrius*) in the Keewatin District of the Northwest Territories, Canada. *In* T. J. Cade, J H. Enderson, C. M. White and C. Thelander, EDS. Peregrine Falcon populations: their management and recovery. Proc. 1985. Intl. Peregrine Conf., Sacramento.

FALK, K. AND S. MOLLER. 1986. Status of the Peregrine Falcon in South Greenland: population density and reproduction. M.Sc. Thesis, Roskilde University, Denmark. Unpublished.

FOX, A. D. AND D. A. STROUD. 1981. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunaat, West Greenland. GWGS, Aberystwyth, 1981.

MATTOX, W. G. 1984. Greenland Peregrine Falcon Survey, 1984. Field Report, submitted to Commission for Scientific Research in Greenland.

RATCLIFFE, D. A. 1980. The Peregrine Falcon. Poyser, Calton. 1980.

———. 1984. The Peregrine breeding population of the United Kingdom in 1981. Bird Study Vol. 31, pp. 1–18, March 1984.

WHITE, C. M. AND T. J. CADE. 1971. Cliff-nesting raptors and ravens along the Colville River in arctic Alaska. *The Living Bird,* 10th Annual, pp. 107–150, 1971.

Greenland White-fronted Goose Study, School of Biological Sciences, University College of Wales, Aberystwyth, Dyfed, United Kingdom..

Received 5 January 1987; Accepted 8 July 1987.

Wildlife Rehabilitation Conference for Wildlife Professionals and Volunteers. The International Wildlife Rehabilitation Council is sponsoring a three day conference on Wildlife Rehabilitation in North America on 29–31 January 1988 at the Holiday Inn in Foster City, CA. Featured speakers include David M. Bird of McGill University in Montreal and Patrick T. Redig of the University of Minnesota. Highlights of the conference include basic and advanced general sessions, scientific papers, workshops, commercial exhibits, poster sessions and wildlife center displays, skill seminars, tours, guest speakers, and much more. Issues in wildlife rehabilitation, veterinary medicine and pathology in wildlife, management and administration of wildlife centers, rehabilitation techniques and a presentation of the California Condor Project are but a few of the many topics to be covered. **For information and registration contact: International Wildlife Rehabilitation Council, Conference Registration, % Sue Kelly, 1915 Kentucky Avenue, Redwood City, CA 94061; or call Curt Clumpner (206) 743-1884 or Margie Comstock (415) 697-8531.**

J. Raptor Res. 21(3):116–118

SHORT COMMUNICATIONS

NESTING CHRONOLOGY OF THE GREAT GRAY OWL AT AN ARTIFICIAL NEST SITE IN THE SIERRA NEVADA

THOMAS W. BECK AND RANDALL A. SMITH

The California Great Gray Owl (*Strix nebulosa*) population is centered in the Yosemite region of the Sierra Nevada (Winter 1980). Efforts were initiated in 1980 to enhance breeding habitat at Ackerson Meadow in the Stanislaus National Forest by providing artificial nests at 1400 m elevation, the lower elevational range for Great Gray Owl breeding in this part of California (Winter 1984). Artificial nests made of wire and sticks were successfully used by Great Gray Owls in Manitoba (Nero et al. 1974). Most nests reported for North America have been in old stick nests made by hawks (Bent 1938, telecon Dec 1986 with Evelyn L. Bull, USDA Forest Service Research Station, La Grande, OR 1987), whereas nests in the Sierra Nevada have been in the tops of broken conifer trees near large meadows (Winter 1980).

In September 1984 ten artificial nest structures were constructed at Ackerson Meadow by topping large conifers to simulate broken-topped snags. Trees with a dbh of 76–137 cm ($\bar{x}$ = 109 cm) were cut 8.5–20 m high ($\bar{x}$ = 12.2 m), and tops were then hollowed into a bowl shape with a drain hole for removal of rain water. All nest construction was performed by a climber using a bar-equipped chainsaw. On 18 April 1985 a female Great Gray Owl was found incubating at one of the artificial sites, an Incense Cedar (*Calocedrus decurrens*) 11 m high with a dbh of 94 cm. The diameter at the top of the tree was 58 cm; the nest bowl was 46 cm across and 18 cm deep. The nest tree was 158 m from the closest meadow and received partial shade briefly during early afternoon.

On 1 May a Canon 512-XL 8-mm movie camera adapted for automatic, time-lapse photography was positioned 37 m from the nest and used to record nesting behavior and chronology (see Temple 1972). Nocturnal photographic equipment was not available. The camera was equipped with a 47.5 mm telephoto lens and was operated by a photoelectric sensor which activated the timing device. Timing intervals were 90, 96, and 105 sec, and the period recorded each day was 14–15 hr. Photo intervals were lengthened as days became longer to ensure seven days coverage with each roll of film. Dates monitored were 1–27 May and 6–19 June. Personal visits were made on 29 and 31 May. Daily temperatures were obtained from U.S. Weather Bureau records taken at Cherry Lake located 13 km distant at the same elevation as Ackerson Meadow.

Behavior of the female owl indicated that the first egg hatched on 14 May. On that date she began repositioning, looking down, and reaching her head down into the bottom of the nest. On this basis we estimated that egg laying began at the Ackerson Meadow nest on or close to 14 April (see Craighead and Craighead 1956; von Haartman et al. 1963–1972). In northern Finland the incubation period at one Great Gray Owl nest studied closely was at least 36 d (Pullainen and Loisa 1977). von Haartman et al. (1963–1972, in Pullainen and Loisa 1977) assumed the incubation period to be about one month. Craighead and Craighead (1956) reported the earliest egg laying date in Wyoming to be 1 April and the earliest hatching date to be 30 April. Little variation in behavior of the female occurred during late incubation (i.e., 1–14 May). In the daytime (ca 14 hr) the female was away from the nest 0.8% of the time, which usually involved one absence of 5–10 min/d in the late afternoon or early evening close to the nest. Feeding visits by the male occurred at night and began at dusk, but none were recorded by the camera. Pullainen and Loisa (1977), based on nine 24 hr periods, reported that the female was absent an average of 3.1 times/d, all <5 min in duration, for a total absence of 0.63% during incubation. Food was brought by the male mainly between 2000 and 0200 H. In Sweden only the male brought prey to the nest during incubation and the number varied from three to five vole-sized items/d (Hoglund and Lansgren 1968).

During early brooding from 15–27 May, the female was absent from the nest an average of 2.0% of the time monitored and the male made feeding visits to the nest during the day. On 22, 24 and 25 May the male was seen at the nest once/d for 1–2 min at 1000, 1945 and 1825 H, respectively. Other feedings by the male could have occurred and been missed by the camera. On the night of 23 and 24 May, the male brought food to the nest at 2040, 2330, 0110, 0235 and 0550 H. In Finland the female was absent 1.0% of the time and the male began bringing food to the nest during the daytime in the first two weeks after hatching (Pullainen and Loisa 1977).

During late brooding from 6–15 June (age of older chick = 23–32 d), the female was absent from the nest an average of 43.8% (range 27–58%/d) of the time recorded (ca 6.6 hr of 15 hr/d). Absences averaged 3.4/d

(range two to four). Time off the nest was spent hunting and roosting as far away as 100 m. The female was observed bringing a Pocket Gopher (*Thomomys bottae*) to the nest on 31 May in the early afternoon. In Finland Pullainen and Loisa (1977) reported that the female stopped warming the young at 14 d old and with young 15–24 d old the female was absent from the nest 13.1% of the time. During 0600–2100 H in Finland, comparable to our study, the female was absent 6.1% and most of that time sat quietly in the vicinity of the nest, occasionally bringing food to the nestlings (Pullainen and Loisa 1977). In Swe den Hoglund and Lansgren (1968) reported that the female began bringing prey to the nest 11 d into the nestling period. Winter (telecon Dec 1986) suggests that while off the nest the female generally roosts and only occasionally hunts.

Hatching date of the second egg was uncertain. Based on the behavior of the female, hatching could have been on 15 or 16 May, but small size of the second young at the end of the nestling period suggested that second hatching might have been several days to a week after the first. Small clutches are usually laid at a rate of one egg/d, but six to 12 d may elapse between later eggs in larger clutches; since incubation begins with the first egg, young in a large brood may differ greatly in size and development (Blair 1962). Broods of more than two have not been recorded in California. Food scarcity and/or delayed hatching may have caused the small size of the younger chick. Hoglund et al. (1968) noted that in a nest of several young it is not unusual for the youngest to develop slowly and to die before reaching fledgling size. Winter (1982, 1984) concluded that irregular breeding in the Sierra Nevada reflects year-to-year abundance of primary prey species.

The first young was observed on 23 May at 9 d old. On 6 June both young were visible, and the older chick at 23 d old was at least twice the size of the younger. From 6–15 June the older chick was quite mobile about the nest, especially during absences of the female. During 13–15 June and when the female was absent the older chick perched much of the time outside (within 1–2 m) of the nest. On 13 June the younger chick was mysteriously found in a weakened condition on the ground below the nest and was returned to the nest a few hours later. During the evening of 15 June or morning of 16 June before dawn, the older nestling left the nest at 32 d old. Visual observations of the nest during the final week when both young were present showed that midday heat caused stress on the female and on the young when the female was absent as evidenced by gular flutter behavior. Hoglund and Lansgren (1968) reported that in Sweden the departure of the young from the nest at 20–29 d old was caused by heat from the sun.

On 16, 17 and 18 June, when only the underdeveloped younger chick remained, the female was absent from the nest 99.8% of the time. On 17 June the chick showed signs of extreme heat stress and a sun shade was erected. On 18 June the chick disappeared from the nest at 1845 H. Ground search on 20 June proved unsuccessful and we assumed the chick was taken from the nest or the ground by a predator. On 17, 20 and 25 June the female and fledgling were observed day-roosting about 65 m from the nest tree.

The amount of time the female was absent from the nest during late brooding seems excessive and was considerably greater than that reported by Pullainen and Loisa (1977) for the same daytime hours. Daytime average maximum temps, based on Cherry Lake records, were: 1–14 May, 20°C (range = 12–26°C); 15–27 May, 23°C (range = 21.5–28°C); 6–15 June, 31°C (range = 28.5–33.2°C); 16–18 June, 34°C (range = 33.2–34.5°C). Behavior of the female may have been affected by heat which would explain absence during late brooding and virtual abandonment of the younger nestling.

On 21 April 1987 a female Great Gray Owl was found using an artificial nest site ca 100 m from the one used in 1985 which was similar except for the presence of more shade canopy. We could not determine if it was the same owl which nested in 1985, and on or about 24 May the nest was abandoned. No sign of young were seen and the cause of abandonment is unknown. Several natural nest sites were also abandoned in 1987 in Yosemite National Park for unknown reasons (telecon with Jon Winter May 1987).

Our observations indicate that artificial nest structures simulating broken-topped snags are accepted by Great Gray Owls. At lower elevations in the Sierra Nevada such structures should be constructed only where shading can be provided. Time-lapse photography of owl nests can yield useful data on nesting chronology and behavior but should include nocturnal recording capability.

ACKNOWLEDGMENTS

We thank Steve Brougher, Kirk Ford, Bill Kiger, Steve Laymon and Jon Winter for providing observations and assistance at the nest site, Mike Webb for photographs and Jared Verner and Jon Winter for their valuable comments on the draft manuscript.

LITERATURE CITED

BENT, A. C. 1938. Life histories of North American birds of prey. Part 2. U.S. Nat. Mus. Bull. 170:482 pp.

BLAIR, H. M. S. 1962. Studies of less familiar birds (Great Gray Owl). *Br. Birds* 55:414–418.

CRAIGHEAD, J. J. AND F. C. CRAIGHEAD, JR. 1956. Hawks, owls and wildlife. Dover Publ. Inc., New York. 443 pp.

HOGLUND, N. E. AND E. LANSGREN. 1968. The Great Gray Owl and its prey in Sweden. *Viltrevy* 5:363–421.

NERO, R. W., S. G. SEALY AND H. W. R. COPELAND. 1974. Great Gray Owls occupy artificial nest. *Loon* 46(4):161–165.

PULLIAINEN, E. AND K. LOISA. 1977. Breeding biology and food of the Great Gray Owl, *Strix nebulosa,* in northeastern Finnish Forest Lapland. *Aquilo Ser. Zool.* 17:23–33.

TEMPLE, S. A. 1972. A portable time-lapse camera for recording wildlife activity. *J. Wildl. Manage.* 36:944–947.

VON HAARTMAN, L., O. HILDEN, P. LINKOLA, P. SUOMALAINEN AND R. TENOVUO. 1963–1972. Pohjolan linnut varikevin. Helsinki. 1092 pp.

WINTER, J. 1980. The status and distribution of the Great Gray Owl in California. State of California, Dept. of Fish and Game. Project W-54-R-12, Job II-9. Final report (April 1980).

———. 1982. Further investigations on the ecology of the Great Gray Owl in the central Sierra Nevada. USDA Forest Service, Region 5, Stanislaus National Forest contract #43-2348. Final Report (February 1982).

———. 1984. Great Gray Owl survey, 1984. State of California, Dept. of Fish and Game. Project W-65-R-2, Job II-3. Progress Report (January 1985).

USDA Forest Service, Stanislaus National Forest, 19777 Greenley Road, Sonora, CA 95370. Address of second author: USDA Forest Service, Coronado National Forest, 300 W. Congress, Tucson, AZ 85701.

Received 1 February 1987; Accepted 12 August 1987

J. Raptor Res. 21(3):118–120

AGONISTIC ENCOUNTERS BETWEEN BALD EAGLES AND OTHER RAPTORS WINTERING IN WESTCENTRAL UTAH

NEIL SABINE AND KIRK GARDNER

Each year 200–300 Bald Eagles (*Haliaeetus leucocephalus*) winter in Rush Valley, 70 km southwest of Salt Lake City, Tooele Co., Utah (Edwards 1969). Golden Eagles (*Aquila chrysaetos*), Ferruginous Hawks (*Buteo regalis*), and Red-tailed Hawks (*Buteo jamaicensis*) also winter in the area and may compete with Bald Eagles for food. In January–March 1982, 1983 and 1984 we compiled over 1500 hr of field observations on Bald Eagles wintering in Rush Valley. We noted seven interspecific encounters involving adult Bald Eagles and one of the above raptors. As far as we know, these are the only reported observations of agonistic interactions between Bald Eagles and Golden Eagles or Ferruginous Hawks.

We observed two interspecific encounters between Bald and Golden Eagles near Black-tailed Jackrabbit (*Lepus californicus*) carcasses during 1984. On 17 January K.G. saw an adult Bald and an adult Golden Eagle involved in an aerial confrontation 50 m above the ground. Both birds made several passes at one another but no contact was made, and within two min both had landed on the ground. Three min later the Bald Eagle flew directly at, dove, and struck on the back another adult Golden Eagle perched on the ground 50–100 m away. A struggle ensued in which each bird struck the other repeatedly with open talons. Most attacks were initiated with short hops, but rushes along the ground were also seen. The encounter lasted for about one min and ended when the Golden Eagle flew away. The Bald Eagle returned to the carcass site and dragged a freshly killed jackrabbit to an area free of vegetation but was supplanted by another adult Bald Eagle before feeding. Later, similar fights took place between several Bald Eagles that attempted to secure the carcass.

On 24 January an adult Golden Eagle was seen feeding on a jackrabbit while one adult Bald and one adult Golden Eagle stood nearby. After 10 min the Bald Eagle supplanted the feeding bird with a short rush to the carcass. Seven min later the second Golden Eagle displaced the Bald Eagle by momentarily landing on its back with closed talons. The Bald Eagle responded by flying and landing about five m from the carcass. A third adult Golden Eagle closer to the feeding site faced the Bald Eagle and lowered its head each time the latter attempted to approach the carcass. Eight min later the Bald Eagle successfully supplanted the feeding eagle by flying to the carcass; all Golden Eagles flew away within five min after the Bald Eagle began to feed.

Overall, interspecific confrontations between eagles at feeding sites were rare. Golden Eagles were seen at only 25% (N = 87) of the carcasses visited by Bald Eagles and were present <22% of the time (N = 239 hr) at feeding sites of marked birds. Based on the incidents of 17 and 24 January, we believe that Bald Eagles may occasionally steal prey from Golden Eagles, which contrasts with the dominant position Golden Eagles appear to have in some Bald Eagle winter roosts (Lish 1973).

Aggressiveness shown by both species of eagles may have

been a response to a declining food supply. Jackrabbits are the principal food of eagles in Rush Valley (Edwards 1969; Platt 1976) and our surveys indicated decreasing jackrabbit population levels in 1982–1984. Each January subjective assessments of jackrabbit numbers were made in particular sections of the study area during hunts to secure bait for trapping Bald Eagles. A conservative estimate of two to three times more rabbits were seen in 1982 than in 1983; rabbits were so scarce during 1984 that those used for trapping were acquired outside Rush Valley. Annual counts in Rush Valley by the U.S. Army indicated peak jackrabbit numbers during fall 1980 were followed by continual declines through 1985 (R. LeClerc, pers. comm.). Reduction in rabbit numbers was further quantified by data collected during 28 prey transects in 1983 and 1984. Each 0.8 km transect was walked three times in 1983 and twice in 1984 at randomly selected dates and times during March. Significantly more rabbits were seen in 1983 than in 1984 (0.88 rabbits/km and 0.07 rabbits/km, respectively, Mann-Whitney U-Test, $U_{(14,14)} = 24$, $P < 0.01$). Swingland (1975) noted that limited food availability led to more confrontations in captive Rooks (*Corvus frugilegus*).

A second indicator of prey availability was the condition of captured eagles subjectively assessed by palpating fat reserves below the sternum. Eagles captured in both 1983 and 1984 had significantly less fat deposits than those captured in 1982 (Mann-Whitney U-Test, $U_{(6,7)} = 34$, $P < 0.005$, and $U_{(6,13)} = 77$, $P < 0.001$, respectively). Lastly, less competition for food in 1982 was suggested by the presence of fewer Golden Eagles at carcasses with Bald Eagles (7%, N = 14) than in succeeding years (16%, N = 79).

Encounters between Bald Eagles and raptors other than Golden Eagles were rare and only five incidents were observed during 1628 hr of observation. Though hawks were never seen near feeding eagles, three instances involving Ferruginous Hawks were probably motivated by food.

On 29 March 1983 an adult Bald Eagle attempted to kleptoparasitize adult Ferruginous Hawks on two occasions. The first began when the eagle flew directly at a hawk carrying an unidentified ground squirrel about 20 m above the ground. Upon intercepting the hawk, the eagle made four quick passes from 5–10 m above but made no contact. The hawk dropped the ground squirrel after the fourth pass and the eagle immediately flew to where the carcass fell but could not be seen on the ground. About one min later the eagle flew back to its original perch without the squirrel. Within an hour the same eagle pursued another Ferruginous Hawk carrying another ground squirrel. This apparent attempt at kleptoparasitism, however, was unsuccessful; the hawk remained above the eagle as both gained altitude and after several attacks from below, the eagle abandoned its pursuit.

Bald Eagles commonly steal food from Ospreys (*Pandion haliaetus*) (Howell 1932; Bent 1937; Brown and Amadon 1968) and Common Mergansers (*Mergus merganser*) (Grubb 1971). Occasionally Bald Eagles kleptoparasitize vultures (*Cathartes* sp.) (Meinertzhagen 1959; Brown and Amadon 1968) and Northern Harriers (Baldwin 1940). Ferruginous Hawks are probably seldom attacked by Bald Eagles, however, because each usually winters in different habitats (Bent 1937).

We observed hawks attacking adult Bald Eagles on three occasions. On 18 February 1983 a Ferruginous Hawk stooped three times in broad, shallow arcs from a height of roughly 30 m at a Bald Eagle standing on the desert floor. The eagle lowered its head during each pass but on the last pass also raised a wing, presumably to keep its balance, as the hawk passed within one m. The hawk then ceased the attack and landed on the ground about 300 m away. Three min later the hawk made another stoop at the eagle which again responded by ducking its head. Although the eagle was not feeding, the presence of five Common Ravens (*Corvus corax*) and a Northern Harrier nearby suggested that a carcass may have been present.

Two attacks on a radio-tagged adult Bald Eagle were initiated by hawks for no apparent reason. On 7 March 1983 an adult Ferruginous Hawk dove from about 50–80 m above a soaring Bald Eagle. The eagle eluded the attack by first swerving and then quickly landing. The hawk flew away after the incident and the eagle remained perched for another 50 min. The next day the same eagle was soaring at 100–150 m when it was attacked by an adult Red-tailed Hawk. The Red-tail initiated the attack from 50–80 m above the eagle and displayed its talons during a dive. As the hawk passed the eagle rolled over and presented its talons but no contact was seen. Both birds then continued to soar and slowly drifted apart.

LeDuc (1970) saw a Red-tailed Hawk near its nest strike a Bald Eagle in flight in Minnesota. Our encounters were probably not directly associated with nest defense because both occurred over open desert far from any probable breeding sites. The onset of breeding behavior, however, may have prompted the hawks to attack; tolerance of large raptors, recognized as threats by hawks, may diminish during hawk breeding periods and lead to the type of attacks we observed.

Klem et al. (1985) described a series of observations where raptors killed other raptors and proposed such encounters were initiated by self-defense, territorial defense or predation. Our observations suggest that defense of food and attempts at kleptoparasitism also lead to interspecific confrontations in raptors and that the frequency and severity of such encounters appear to be related to food availability.

LITERATURE CITED

BALDWIN, W. P. 1940. Bald Eagle robbing Marsh Hawk. *Auk* 57:413.

BENT, A. C. 1937. Life histories of North American birds of prey. U.S. Natl. Mus. Bull. 167.

BROWN, L. AND D. AMADON. 1968. Eagles, hawks, and falcons of the world. Vol. 1. Hamlyn Publishing Co., Ltd. Middlesex.

EDWARDS, C. C. 1969. Winter behavior and population dynamics of American Eagles in Utah. Ph.D. dissertation. Brigham Young Univ., Provo, UT. 142 pp.

GRUBB, T. C., JR. 1971. Bald Eagles stealing fish from Common Mergansers. *Auk* 88:928–929.

HOWELL, A. H. 1932. Florida Bird Life. Tallahassee: Florida Dept. Game and Freshwater Fish.

KLEM, D., JR., B. S. HILLEGASS AND D. A. PETERS. 1985. Raptors killing other raptors. *Wilson Bull.* 92:230–231.

LEDUC, P. V. 1970. Red-tailed Hawk attacks Bald Eagle. *Auk* 87:586.

LISH, J. W. 1973. Status and ecology of Bald Eagles and nesting Golden Eagles in Oklahoma. M.S. Thesis. Oklahoma State University, Stillwater, OK. 99 pp.

MEINERTZHAGEN, R. 1959. Pirates and predators. Oliver and Boyd Publishing Co., London.

PLATT, J. B. 1976. Bald Eagles wintering in a Utah desert. *Am. Birds* 30:783–788.

SWINGLAND, I. R. 1975. The influence of weather and individual interactions on the food uptake of captive Rook (*Corvus frugilegus*). *Physiol. Zool.* 48:295–302.

Department of Zoology, Brigham Young University, Provo, UT 84602. Address of second author: Bureau of Land Management, 2370 South 2300 West, Salt Lake City, UT 84401.

Received 16 December 1987; Accepted 8 July 1987

J. Raptor Res. 21(3):120–121

OCCURRENCE AND FIRST NEST RECORD OF FLAMMULATED OWLS IN MONTANA

DENVER W. HOLT, JUDY A. HOY AND PHILIP L. WRIGHT

The Flammulated Owl (*Otus flammeolus*) is reported to occur in Montana during annual migration (AOU 1983). Wright (1976) reported the first specimen record of a Flammulated Owl for Montana (UMZM 15231) and listed two other site records for the state. Skaar et al. (1985) reported five verified and one questionable Flammulated Owl records for Montana which included all previous records. In 1985 and 1986 calling Flammulated Owls

Table 1. Reports of Flammulated Owls for Montana, 1962–1986.

DATE	LOCATION	COMMENTS
Summer 1962	Flathead Co., Head of Lake McDonald, Glacier National Park	First state record; road kill
January 1965[a]	Lewis and Clark Co., west of Helena	Found helpless in snowstorm; later died
October 1971	Ravalli Co., at Darby game bird farm	First specimen record; found injured; later died
4 September 1975	Missoula Co., downtown Missoula	First nesting evidence; recently fledged bird; injured; later released
4 September 1979	Ravalli Co., Cow Creek, Woodside	Found injured; later died
27 September 1980	Missoula Co., Grant Creek, Missoula	Road kill
21 November 1981[b]	Flathead Co., east of Bigfork	Observed perched in tree with vole in talons
20 December 1981[c]	Flathead Co., West Glacier	Observed chasing passerines at bird feeder
11 August 1982	Missoula Co., west of Missoula	Fledgling found by logger; later released
20 August 1985	Granite Co., Rock Creek road, 8 miles from I-90	Found injured; later released
15 July 1986	Missoula Co., Blanchard Lookout, Blanchard Creek	First nest record; snag felled by logger

[a] Reported by Pat McKinney.
[b] Reported by Robin Magadino.
[c] Reported by B. Reilly McClelland (2nd hand).

(presumably males) were heard in Missoula County (R. Escano and S. Reel, pers. comm.). We report the first confirmed nest record, previous evidence of nesting and additional sight records which include four winter records of Flammulated Owls in Montana.

On 15 July 1986 a Ponderosa pine (*Pinus ponderosa*) snag was cut for firewood near Blanchard Lookout, Blanchard Creek, Missoula County. A cavity in the snag contained three nestling Flammulated Owls. Two of the nestlings were partially feathered and approximately equal in size and age, while the third nestling was smaller and mostly in downy plumage. No information concerning habitat surrounding the nest area was noted.

Table 1 lists all known previous Flammulated Owl records for Montana. The Flammulated Owl is considered to be strictly insectivorous (Ross 1969; Winter 1974; Marshall 1967, 1978) and is generally believed to winter south of the United States. Four previous sight records (October, November, December, January) in Montana (Table 1) are of particular interest because of seasonal occurrence and as an indicator that vertebrate prey may be taken given the time of year. The fact that owls reported here were seen at midday during late fall/early winter and associated with a vole spp. and small passerines (Table 1), help to support the previous statement.

To our knowledge there are no published records of Flammulated Owls preying on vertebrates nor wintering in the northern Rocky Mountains. Likely, these small owls occur throughout western Montana in suitable habitat but have simply been overlooked because of their habits.

ACKNOWLEDGMENTS

We thank Robin Magadino, Joe T. Marshall and B. Riley McClelland for information and personal records. We also thank Richard Reynolds and Jon Winter for comments on the draft manuscript. Pete Bloom and Richard J. Clark made helpful comments on the final manuscript.

LITERATURE CITED

AMERICAN ORNITHOLOGISTS' UNION. 1983. Check-list of North American birds, 6th edition. American Ornithologists' Union (Washington DC).

MARSHALL, J. T. 1967. Parallel variation in North and Middle American screech-owls. *West. Found. Vert. Zool. Monog.* 1:1–72.

———. 1978. Systematics of smaller Asian night birds based on voice. Am. Ornithol. Union, Wash. D.C., *Ornithol. Monog. No.* 25:1–58.

ROSS, A. 1969. Ecological aspects of the food habits of insectivorous screech-owls. *Proc. West. Found. Vert. Zool.* 1:301–344.

SKAAR, D., D. FLATH AND L. S. THOMPSON. 1985. Montana bird distribution. *Mont. Acad. Sci. Monog. No. 3* 44:1–70.

WINTER, J. 1974. The distribution of the Flammulated Owl in California. *West. Birds* 5:25–44.

WRIGHT, P. L. 1976. Further bird records from western Montana. *Condor* 78:418–420.

P.O. Box 8335, Missoula, MT 59807. Address of second author: 2858 Pheasant Lane, Stevensville, MT 59870. Address of third author: Department of Zoology, University of Montana, Missoula, MT 59812.

Received 8 April 1987; Accepted 12 August 1987

J. Raptor Res. 21(3):121–124

NEST SITE COMPETITION BETWEEN OSPREYS AND CANADA GEESE AT LAKE ALMANOR, CALIFORNIA

DANIEL A. AIROLA

The Osprey (*Pandion haliaetus*) and the Canada Goose (*Branta canadensis*) nest in broken-top trees near water through much of northwestern North America. Canada Geese have been reported using Osprey nests (Yocum 1952; Geis 1956; Gabrielson and Lincoln 1959; Craighead and Stockstad 1961; Garber 1972) and artificial platforms constructed for Ospreys (Henny et al. 1978; W. D. Carrier, pers. comm.) in many areas.

Reports of interactions at nest sites between the two species are few. Fannin (1894) reported an unusual case in which both Ospreys and Canada Geese defended a nest containing eggs of both species. Flath (1972) observed conflicts at Osprey nest sites, including one case in which Ospreys apparently evicted geese that had begun nesting before Ospreys returned from migration. Another Osprey nest received double usage during a year with mild spring

weather, and geese fledged young prior to the Ospreys' return; Flath (1972) suggested that competition may be common during years with cool spring weather when delay in nesting by geese results in overlap in nesting seasons.

Yocum (1952) and Craighead and Stockstad (1961) suggested that at different times Ospreys may or may not successfully defend nests from Canada Geese but gave no supporting evidence. Garber (1972) reported use of an Osprey nest site by Canada Geese and subsequent use by Ospreys in two consecutive years at Eagle Lake, California. The Ospreys were unsuccessful, but whether nesting geese were disrupted was unknown.

Paucity of records presents difficulty in evaluating the importance and causes of nest site competition. Here, I report additional observations of interspecific interactions observed at nest sites at Lake Almanor, California. I also compare nest site characteristics for Ospreys and Canada Geese in the area and analyze the effect on Osprey reproduction of Osprey nest usurpation by geese.

Lake Almanor is a hydroelectric reservoir at 1450 m elevation in the northern Sierra Nevada, Plumas Co., California. Surrounding habitats are mixed-conifer and Jeffrey pine (*Pinus jeffreyi*) forests and mountain meadows (Verner and Boss 1980). Osprey nesting has been monitored since 1969 (Airola and Shubert 1981; Airola 1987). About 30 Osprey and 100 Canada Goose pairs nest annually at the lake.

I located and checked occupation of Osprey nests during annual ground searches of shoreline areas in April 1980–1984. Young were counted in nests from a helicopter in early July (within one to three wk of fledging). Only nests known to be occupied during early surveys were included in later calculations (see Postupalsky 1977). Effect on Osprey reproduction of Canada Goose occupation of Osprey nest sites was determined by comparing observed reproductive success with that expected if geese had not usurped nests. I located Canada Geese nesting at Osprey nests and other sites during early Osprey nest surveys. Other goose nests were found during incidental work and by confirming cooperator reports.

Extent of observations of interspecific interactions varied at nests. At one nest (#52), I made 37 short visits (340 min total) on 32 d while one or both species were present (4 April–27 May 1981). Other sites were visited only a few times during the nesting season. Nest heights were measured with a clinometer; mean heights (±SD) were compared using *t*-Tests (Zar 1974).

I observed an Osprey flying near nest 52 (which had been used in 1980 by Ospreys) on 4 April 1981. The nest was at the dead top of a 36 m live incense cedar (*Calocedrus decurrens*). Geese nested 200 m away in 1980 in a snag which had fallen during the subsequent winter. I checked the Osprey nest and found a Canada Goose apparently incubating on 5 April.

At 0800 H on 6 April, nest 52 was occupied by a pair of geese and two Ospreys were perched in a tree 50 m away. The Ospreys began diving on the geese, who stood and defended the nest. The Ospreys made about 15 dives, but did not strike either goose which remained on the nest. At 1700 H I found both geese sitting on the nest (one presumably on eggs) and one Osprey perched in the tree used that morning. The Osprey again dove repeatedly at the geese; no contact was made and the geese defended the site. During brief morning visits the next three d (18 min total observation) both geese were on the nest site and one Osprey was at the same perch, but no harassment occurred.

On 11 April an Osprey began building a nest on a nearby snag not previously used. I observed no further harassment during 13 d (105 min total observation time) from 11–30 April when the goslings apparently fledged successfully. An Osprey worked sporadically on the new nest throughout this period (seen on eight of 13 visits) but was unsuccessful because the tree top was small and broken diagonally and would not support a nest.

On the day of gosling fledging, an Osprey perched 30 m from the nest in the main perch tree used by the pair during previous years. Ospreys were not observed using the perch while geese occupied the nest. Between 30 April and 8 May, an Osprey was irregularly present at the nest and perch tree (on six of 12 visits, 100 min). On numerous subsequent visits from 16 May–22 June no Ospreys were seen. On 4 August a new Osprey nest with two adults and no young was found further from the lake in the vicinity of the contested site and may have been a "frustration nest" (Postupalsky 1977) constructed by the displaced pair.

In 1982 the geese again occupied and fledged young from the same nest, but no Ospreys were observed in the immediate area (18 visits on 13 d during the early nesting season). Ospreys reoccupied the presumed frustration nest early and eventually fledged three young. The usurped nest tree toppled in winter 1982–83.

Canada Goose occupation at another Osprey territory apparently caused reproductive failure. On 15 April 1980 a goose incubated at an artificial nest-platform used by Ospreys during at least two of the three previous years (A. Camerena, pers. comm.). The Ospreys were apparently prevented from using the nest by the geese and constructed a nest at least two wk later than usual in a tree that provided poor nest support. Reproduction was unsuccessful, producing only one egg which failed to hatch. Nest failure may have resulted from the delay in nesting or disturbance by a nearby construction project. Geese did not occupy the platform nest in 1981 and Ospreys transported sticks from their previous year's nest to the original site. Successful nesting occurred at the site the next three yr.

Geese nested at one other Osprey nest site during 1980–84. In 1982 a goose pair used an alternate nest 150 m from an occupied Osprey nest (K. S. Kahre, pers. comm.). Ospreys had frequently used the alternate site as a perch during the eight yr use of the nearby nest. Aggression occurred between the geese and Ospreys during nest ini-

tiation in 1982. Ospreys frequently harassed the geese and once struck a goose in midair. Both species fledged three young. The alternate Osprey nest collapsed in winter 1982–83. The site was not reused by geese, while Ospreys nested successfully at their nest site in 1983 and 1984.

Three other instances of geese nesting at Osprey sites were recorded in the area from 1975–78 prior to my study (A. Camerena and G. Davis, pers. comm.). However, monitoring was insufficient to determine if Osprey reproduction was affected.

Overall, during five yr of intensive study three Osprey nests were occupied by geese (one occupied two yr) but only two of 132 Osprey nesting attempts were disrupted. Osprey reproductive success averaged 1.54 young fledged/occupied nest (see Airola and Shubert 1981; Airola 1987).

Mean (±SD) Osprey nest height at Lake Almanor was 38 (±7.7) m (N = 67). Mean height of Osprey nests used by Canada Geese (including pre-1980 sites) was 42 (±7.3) m (N = 5) and did not differ significantly in height from the mean for all Osprey nests (t = 1.12, df = 65; P > 0.10). Mean height of five non-Osprey tree nests used by Canada Geese at Lake Almanor was 20 (±7.9) m, significantly less than the means for all Osprey nests (t = 6 57, df = 70; P < 0.001) and for those used by geese (t = 4 57, df = 8; P < 0.01).

My observations show that Canada Geese can appropriate and successfully defend a nest site from Ospreys, causing Osprey reproductive failure. Results support Flath's (1972) conclusion that conflicts are most likely to occur during years with cold spring weather. Canada Geese may begin nesting at Lake Almanor in early March (two to three wk before Ospreys arrive from migration) unless nesting is delayed or disrupted by weather. Flath (1972) reported observations in which Ospreys were dominant over geese, including eviction of geese from Osprey nests. In contrast geese that nested early in Osprey nests at Lake Almanor successfully defended nests from Ospreys. If adverse weather prevents early goose nesting, Ospreys are apparently able to reclaim and maintain their nests sites. I did not observe geese displace Ospreys from nests once Ospreys had established occupation.

Geese may prefer shorter trees for nesting; non-Osprey sites used by geese at Lake Almanor were substantially lower than Osprey nests. Similarly, seven goose nests found in 1954 by E. G. Hunt (pers. comm.) at nearby Mountain Meadows Reservoir, Lassen County were in 6–12 m snags. Such preference would not be surprising because the precocial goslings must drop to the ground soon after hatching (Craighead and Stockstad 1958, 1961; Hornocker 1969). Geese hatched from taller trees may suffer greater mortality from falls. However, data are lacking on availability of nest sites of various heights and goose use of shorter natural sites could reflect site availability. Nest area fidelity may prompt geese that lose nest trees to use nearby tall Osprey nests; at least once, geese used an Osprey nest following loss of a nearby, shorter nest tree.

Several factors may influence nest site selection by Ospreys. Ospreys at Lake Almanor appear to select tall sites that provide easy flight access and a view of foraging areas (Airola and Shubert 1981). Use of taller nest sites may also reduce predation by mammals on altricial young. Avoidance of interspecific competition for nest sites may also influence nest height selection by both species.

Effects of nest site competition on reproduction by both species appear to be minimal. Canada Goose occupation of Osprey nests over the five yr study reduced Osprey production by 1.3% and the Osprey populations increased (Airola 1987). Geese disrupt Osprey reproduction too seldom to substantially affect the Osprey population at Lake Almanor. No nesting geese were observed displaced by Ospreys; my Osprey nest checks, however, began in April and I could have missed some early Osprey evictions of geese. Earlier checks would be needed to fully assess effects on geese of nest site competition.

ACKNOWLEDGMENTS

I thank K. S. Kahre, G. Rotta, E. G. Hunt, A. Camerena, and G. Davis for providing unpublished information, and R. D. Harris, D. A. Hammer, J. S. Castrale, R. E. Eckstein and R. D. Marcotte for comments. Fieldwork was supported by USDA Forest Service, Lassen National Forest. W. S. Swanson and T. L. Rhodes provided administrative support.

LITERATURE CITED

AIROLA, D. A. AND N. SHUBERT. 1981. Reproductive success, nest site selection, and management of Ospreys at Lake Almanor, California, 1969–1980. *Cal-Neva Wildl. Trans.* 1981:79–85.

AIROLA, D. A. 1987. Current status of the Osprey on National Forests of California. Proc. Osprey Sympos., 1984 and 1985. Int. Osprey Found., Sanibel, FL.

CRAIGHEAD, J. J. AND D. S. STOCKSTAD. 1958. Goslings descend from aerial nest. *J. Wildl. Manage.* 22:206–207.

——— AND ———. 1961. Evaluating the use of aerial nesting platforms by Canada Geese. *J. Wildl. Manage.* 25:363–372.

FANNIN, J. 1894. The Canada Goose and Osprey laying in the same nest. *Auk* 11:322.

FLATH, D. L. 1972. Canada Goose-Osprey interactions. *Auk* 89:446–447.

GABRIELSON, I. N. AND F. C. LINCOLN. 1959. Birds of Alaska. Stackpole Co., Harrisburg, PA.

GARBER, D. P. 1972. Osprey nesting ecology in Lassen and Plumas Counties, California. M.S. Thesis. Calif. St. Univ. Humboldt, Arcata.

GEIS, M. B. 1956. Productivity of Canada Geese in the Flathead Valley, Montana. *J. Wildl. Manage.* 20:409–419.

HENNY, C. J., J. A. COLLINS AND W. J. DEIBERT. 1978. Osprey distribution, reproduction, and status in west-

ern North America: II. The Oregon population. *Murrelet* 59:14–25.

HORNOCKER, M. G. 1969. Goslings descend from aerial nest, attacked by Bald Eagle. *Auk* 86:764–765.

POSTUPALSKY, S. 1977. A critical review of problems in calculating Osprey reproductive success. Pages 1–12. *In* J. C. Ogden, ED. Trans. N. Amer. Osprey Res. Conf. USDA Nat. Park Serv., Ser. No. 2.

VERNER, J. AND A. S. BOSS. 1980. California wildlife and their habitats: western Sierra Nevada. USDA Forest Service Gen. Tech. Rep. PSW-37. Pacific SW Forest and Range Exp. Sta. Berkeley, CA. 439 pp.

YOCUM, C. F. 1952. Techniques used to increase nesting of Canada Geese. *J. Wildl. Manage.* 16:425–428.

ZAR, J. H. 1974. Biostatistical Analysis. Prentice Hall. Englewood Cliffs, NJ. 620 pp.

Jones and Stokes Associates, Inc., 1725 23rd St., Sacramento, CA 95816.

Received 15 March 1987; Accepted 20 August 1987

J. Raptor Res. 21(3):124

AMERICAN SWALLOW-TAILED KITE USES MISSISSIPPI KITE NEST

JOHN EMMETT CELY

On 28 May 1985 I found an American Swallow-tailed Kite (*Elanoides forficatus*) nest at the Webb Wildlife Center, Hampton County, South Carolina. The nest was in a 36 m high, 52 cm dbh loblolly pine tree (*Pinus taeda*) located within a five ha thinned (basal area = 11.5 m^2/ha) pine stand surrounded by a laurel oak (*Quercus laurifolia*)-switch cane (*Arundinaria gigantea*) forest interspersed with overcup oak (*Q. lyrata*)-swamp tupelo (*Nyssa sylvatica* var. *biflora*) sloughs. The nest was 390 m north of the Savannah River floodplain and 1.3 km north of the river itself. An active Mississippi Kite (*Ictinia mississippiensis*) nest was found within the same stand and near the top of a similar-size loblolly pine 72 m northeast of the Swallow-tailed Kite nest. The Swallow-tail pair fledged one young about 15 July while the Mississippi Kite pair fledged one young during the last week of July.

On 26 May 1986 I returned to the area and found a pair of Swallow-tailed Kites (presumably the same as last year) nesting on top of the previous year's Mississippi Kite nest. New nest material, primarily Spanish moss (*Tillandsia usneoides*) and some twigs, had been added to the top of the old nest.

I have found or observed 28 Swallow-tailed Kite nests in South Carolina between 1980–1986 of which six cases represent probably the same bird(s) reusing the same area in two consecutive years. Average distance between consecutive-year nests is 175 m (range 72–275 m). In no case has a Swallow-tailed Kite been found reusing the same nest. New Swallow-tail nests do not appear very substantial although some nests appear bulkier than others (pers. obs.). Nest deterioration is obvious during winter months, but the basic foundation is usually intact the following spring when kites arrive from their wintering grounds. Although Bent (Life Histories of North American Birds of Prey, Part I. Dover Reprint, New York. 1961) reported that Swallow-tailed Kites do build on an old nest, I have found nothing in the literature to support this claim. Snyder (Breeding biology of Swallow-tailed Kites in Florida, *Living Bird* 13:73–97, 1974) found no evidence of nest reuse by Swallow-tailed Kites in southern Florida, but one nest was built in the same tree fork as a previous year's nest.

In coastal South Carolina Swallow-tailed Kites and Mississippi Kites usually occupy similar habitat (riparian woodland and mixed pine-swamp forests) and often cooccur in mixed feeding flocks (pers. obs.). However, Swallow-tails arrive on South Carolina breeding grounds in late March, about three to four wks earlier than Mississippi Kites. Both species place their nests near the top of tall trees (usually loblolly pine); Swallow-tailed Kites observed to date (N = 28) liberally use Spanish moss in nest construction while Mississippi Kites use only twigs (N = 8).

Nongame & Heritage Trust Section, South Carolina Wildlife & Marine Resources Department, P.O. Box 167, Columbia, SC 29202.

Received 15 November 1986; Accepted 31 August 1987

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.