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FOOD HABITS OF BALD EAGLES WINTERING IN NORTHERN ARIZONA

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ABSTRACT.—We used pellets collected from roosts to supplement incidental foraging observations to identify prey species of Bald Eagles (*Haliaeetus leucocephalus*) and to evaluate spatial and temporal trends in their food habits while wintering in northern Arizona between 1994–96. We analyzed 1057 pellets collected from 14 roosts, and identified five mammal and 13 bird species. American Coot (*Fulica americana*, N = 447) and elk/deer (*Cervus elaphus/Odocoileus hemionus*, N = 412) were the most common prey remains we identified and they varied annually and inversely with each other (11–58% for coots and 21–78% for elk/deer). Diving ducks (92%) were more heavily represented in pellets with identifiable bird prey (N = 701) than dabblers (1%), although Christmas Bird Counts indicated 64% divers and 36% dabblers in the study area (N = 18 202; χ^2 = 46.3, df = 1, $P < 0.01$). Almost all pellets consisted mostly of mammal or bird remains (N = 366 and 689, respectively). The overall ratio of mammal to bird pellets was 59:41, with relative class frequencies varying between years (χ^2 = 118.29, df = 2, $P < 0.01$). At roosts <3 km from water (N = 752), 90% of the pellets contained birds; whereas, at roosts >3 km from water (N = 303), 96% of the pellets contained mammals (χ^2 = 698.54, df = 1, $P < 0.01$). In three successive winters of varying weather conditions, wintering eagles foraged primarily on mammals, fish, and waterfowl, respectively; but only mammals and waterfowl were accurately represented in pellets.

KEY WORDS: *Bald Eagle;* Haliaeetus leucocephalus; *pellets; diet; food habits; winter roosts; winter habitat.*

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RESÚMEN.—Utilizamos las egragópilas recolectadas en sitios de perchas para complementar las observaciones de forrajeo e identificar las especies de presas de *Haliaeetus leucocephalus* como tambien para evaluar las tendencias espaciales, temporales y sus habitos alimenticios durante su estadía de invierno en Arizona entre 1994–96. Analizamos 1057 egragópilas recolectadas en 14 sitios de perchas, identificamos 5 especies de mamíferos y 13 de aves. *Fulica americana* (N = 447) y *Cervus elaphus/Odocoileus hemionus* (N = 412) fueron los restos de presas mas comunes identificados. Estos variaron anualmente e inversamente entre ellos (11–58% para *Fulica americana* y 21–78% para *Cervus elaphus/Odocoileus hemionus).* Diving ducks (92%) fueron mas representados en las egagrópilas como aves presa (N = 701) que los Dabblers (1%), aunque los Conteos de Navidad indicaron una representatividad de 64% para Olivers y 36% para Dabblers en el área de estudio (N = 18 202; χ^2 = 46.3, df = 1, $P < 0.01$). Casi todas las egagrópilas fueron restos de mamíferos o aves (N = 366 y 689 respectivamente). La proporción total de egagrópilas de mamíferos y aves fue de 59:41, con frecuencias relativas de clase entre años (χ^2 = 118.29, df = 2, $P < 0.01$). En los sitios de perchas <3 km del agua (N = 752), el 90% de las egagrópilas contenían aves, mientras que los sitios de perchas a > 3km del agua (N = 303), el 96% de las egagrópilas contenían mamíferos (χ^2 = 698.54, df = 1, $P < 0.01$). En tres inviernos subsecuentes con variaciones climáticas, las águilas forrajearon principalmente mamíferos, peces, y aves acúaticas respectivamente, pero solo los mamíferos las aves fueron representadas con certeza en las egagrópilas.
[Traducción de César Márquez]

Food habits of nesting Bald Eagles (*Haliaeetus leucocephalus*) in Arizona are well-documented (Haywood and Ohmart 1986, Hunt et al. 1992, Grubb 1995), but information on the diet of winter migrants is limited (Grubb and Coffey 1982, Grubb and Kennedy 1982, Brown 1993). As part of a long-term study of wintering Bald Eagles in northern Arizona (Grubb et al. 1989, Grubb et al. 1994, Grubb 1996), we collected pellets from beneath roost trees during three winters from 1994–96. Typically, pellets effectively supplement direct observations and prey remains in determining local diets (Grubb and Kennedy 1982, Stalmaster and Plettner 1992, Isaacs et al. 1993). Fish and large mammals, for example, can be underrepresented in pellets, and small mammals overrepresented. However, the overall proportion of birds and mammals in pellet analyses tends to reflect actual diet (Mersmann et al. 1992). In northern Arizona, mid-winter foraging on fish is rare (Grubb and Lopez 1997), and prey remains of waterfowl and large ungulate carrion are often difficult to find. In addition, the relatively-small, ephemeral population of wintering eagles limits foraging observations (Grubb and Kennedy 1982, Grubb et al. 1989). Therefore, to supplement limited, incidental foraging observations, we relied primarily on pellets to identify prey species and to evaluate spatial and temporal trends in the food habits of Bald Eagles wintering in northern Arizona.

STUDY AREA AND METHODS

Our study area was the Coconino National Forest, surrounding the town of Flagstaff, Arizona, in Coconino and Yavapai counties. Habitat is dominated by ponderosa pine (*Pinus ponderosa*) forest transitioning into forests of pinyon pine-juniper (*P. edulis-Juniperus* spp.) at lower elevations (Brown 1982). Elevation ranges between 1524–2439 m in semimountainous terrain. The only permanent water bodies in the vicinity of our study roosts were several small lakes (<1000 ha). Winter weather in northern Arizona varies within and between years with occasional heavy snows (<0.6 m) and cold temperatures (lows exceeding −18°C), interspersed with dry periods of mild temperatures (highs to 10°C) and general loss of snow cover.

We collected pellets during three winters: 1993–94, 1994–95, and 1995–96, referred to hereafter as the winters of 1994, 1995, and 1996, respectively. We used daily minimum low temperatures (°C) measured at the Flagstaff airport (National Oceanographic and Atmospheric Administration, on-line data) to contrast winter weather conditions between study years (October through March, 1994–96). We measured the distance from each roost to the nearest permanent water on U.S. Geological Survey, 7 5-min quadrangle maps.

We collected pellets from beneath roost trees in 14 previously-identified night roosts (Grubb et al. 1989, Dargan 1991). Bald Eagle use of winter roosts was highly variable, ranging from one eagle in a single tree to >40 eagles in >25 trees. Pellets were collected by walking around roost trees clockwise then counter-clockwise, 2- and 5-m away from the base of the tree, or farther if necessary to accommodate tree lean. We removed pellets from each roost prior to the next field season. We were unable to collect pellets from every 1994 roost during the following two winters because of weather and scheduling limitations. Because 42% of all the pellets collected, and 68% of the 1996 pellets resulted from an exceptional concentration of >40 eagles foraging on waterfowl and using a single roost (hereafter referred to as Roost 8) in 1996, we evaluated annual variation and calculated overall class composition with and without data from this roost.

We dissected pellets in the laboratory to determine their contents. Identification of prey items was made to the lowest taxonomic level possible by comparison to avian study skins and mammalian hair samples. Visual estimates of percent volume were made for each taxon. Pellets comprised of >50% mammal or >50% bird remains by volume were classified by predominant class to facilitate comparisons between years, roosts, and habitat Adorjan and Kolenosky (1969) and Moore et al. (1974) facilitated hair identification, but we could not differentiate elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) hair. However, based on our field observations of available large ungulate carrion, we estimated elk comprised >85% of the elk/deer hair sample. Similarly, Redhead (*Aythya americana*) and Canvasback (*A. valisineria*) feathers in pellets could not be differentiated. Because Redheads greatly outnumbered Canvasbacks on local lakes (Morrall and Coons 1996; National Audubon Society Christmas Bird Counts 1994–96, Laboratory of Ornithology, Cornell University, on-line data; pers. obs.), we estimated they comprised >80% of this feather sample.

We used SPSS 7.5 for Windows (SPSS 1997) to calculate frequencies and descriptive statistics, and chi-square tests for evaluating variation in frequencies of mammal and bird pellets among years and between lake and upland roosts. Sample sizes and percentages are not always additive because some pellets contained more than one class or species. We used the frequency of occurrence (i.e., the number or percent of pellets containing a class or species) as the measure of relative abundance.

RESULTS

We collected 1057 Bald Eagle pellets (Table 1). Of the 885 pellets with distinguishable prey species, 823 (93%) contained only a single species, but 61 (7%) had two species and one (<1%) had three species. We identified five mammal and 13 waterfowl species (Table 2). American Coot (*Fulica americana*, $N = 447$) and elk/deer ($N = 412$) were the most common prey items. Relative frequencies of these two species varied annually and inversely with each other (11–58% for coots and 21–78% for elk/deer). Diving ducks were more heavily represented (92%, including American Coots) than dabblers (1%) in eagle pellets with identifiable avian prey ($N = 701$). However, National Audubon Society Christmas Bird Counts for northern Arizona between 1994–96 (Laboratory of Ornithology, Cornell University, on-line data), indicated much less difference in the numbers of divers (64%) and dabblers (36%) during our study ($N = 18\ 202$; $\chi^2 = 46.3$, df $= 1$, $P < 0.01$). Nine of 12 locally-common species of divers (75%) were identified in our pellet analysis, and four of seven dabblers (57%).

Based on the most prevalent prey species in pellets, we identified 366 mammal, 689 bird, and 2

Table 1. Number of pellets collected each year and the relative frequency (% total number) of mammalian and avian prey by roost and by year, for 1057 pellets collected beneath 14 winter Bald Eagle roosts in northern Arizona, 1994–96.

ROOST (TREES)	DISTANCE TO WATER (km)[a]	NO. PELLETS (% MAMMAL/% BIRD) 1994	1995	1996	TOTAL
1 (4)	0.05	2[b] (50/0)	1 (0/100)	1 (0/100)	4[b] (25/50)
2 (19)	0.25	30 (13/87)	0	6 (0/100)	36 (11/89)
3 (14)	0.4	51 (69/31)	15 (40/60)	29 (41/59)	95 (56/44)
4 (9)	0.5	22 (0/100)	0	0	22 (0/100)
5 (13)	0.85	14 (7/93)	5 (0/100)	23 (9/91)	42 (7/93)
6 (6)	1.7	2 (0/100)	—	—	2 (0/100)
7 (18)	1.9	0	0	98 (2/98)	98 (2/98)
8 (27)	2.2	5 (60/40)	—	449 (2/98)	454 (3/97)
9 (1)	3.5	1 (100/0)	—	—	1 (100/0)
10 (27)	5.0	38 (100/0)	19 (100/0)	4 (100/0)	61 (100/0)
11 (5)	6.5	12 (100/0)	—	0	12 (100/0)
12 (3)	7.6	1 (100/0)	—	—	1 (100/0)
13 (2)	13.0	12 (100/0)	—	—	12 (100/0)
14 (31)	18.2	110 (91/9)	61 (97/3)	46[b] (96/2)	217 (94/6)
Totals:					
14[c] (179)	8L/6U	300 (69/30)	101 (83/17)	656 (11/89)	1057 (35/65)
Totals without Roost 8[d]					
13[c] (152)	7L/6U	295 (69/30)	101 (83/17)	207 (31/69)	603 (59/41)

[a] Roosts <3.0 km ($\bar{x}$ = 1.0, SD = 0.8) from permanent lakes were classified as lake (L), and roosts >3.0 km ($\bar{x}$ = 9.0, SD = 5.1) were classified as upland (U).
[b] One pellet was entirely fish remains.
[c] Total number of roosts.
[d] Since 42% of all the pellets collected, and 68% of the 1996 sample, came from an unusual concentration of >40 eagles foraging on waterfowl and using Roost 8 in 1996, both typical annual variation and overall class composition were more accurately represented without Roost 8 data.

fish pellets. The overall ratio of mammal to bird pellets, excluding Roost 8, was 59:41, with relative class frequencies varying between years (χ^2 = 118.3, df = 2, P < 0.01). The overall ratio with Roost 8 included was 35:65. Class frequencies were generally consistent at individual roosts from year to year; only Roosts 3 and 8 varied among years (Table 1). However, class frequencies varied between roosts and appeared related to roost distance from permanent water. At roosts <3 km from water (classified as lake roosts), 90% of the pellets contained mostly bird remains (N = 752), whereas at roosts >3 km from water (classified as upland roosts), 96% of the pellets contained mammalian remains (N = 303, χ^2 = 698.5, df = 1, P < 0.01). Conversely, 98% of all bird pellets occurred in lake roosts and 79% of all mammal pellets occurred in upland roosts.

Weather conditions varied among the three years of our study. Temperatures generally declined from October through mid-December with repeated, brief cold cycles throughout the winter of 1994. During the winter of 1995, generally cold temperatures in November and early December with shorter warming periods than the previous year led to a freeze-over of local lakes by late December. January also had nearly two weeks of unseasonable cold before temperatures began to increase through March. The winter of 1996 was generally mild and characterized by only three, 10–14 d cold cycles between mid-December and late February.

In the relatively-typical winter of 1994, pellets confirmed that Bald Eagles fed primarily on large mammal carrion (69%, Table 1). In 1995, waterfowl numbers were again minimal after freeze-over and, although the number of pellets was down, dependence on mammalian carrion was evident

Table 2. Relative class and species abundance in 1057 pellets collected beneath 14 Bald Eagle winter roosts in northern Arizona, 1994–96.

	No. Pellets (% Annual Total[a])			
Class/Species	1994 (N = 300)	1995 (N = 101)	1996 (N = 656)	Total (N = 1057)
Mammal	217 (72)	86 (85)	146 (22)	449 (42)
Elk/mule deer[b] (*Cervus elaphus/Odocoileus hemionus*)	198 (66)	78 (78)	136 (21)	412 (39)
Cottontail rabbit (*Sylvilagus* spp.)	27 (9)	4 (4)	6 (1)	37 (4)
Black-tailed jackrabbit (*Lepus californicus*)	3 (1)	2 (2)	0	5 (<1)
Coyote (*Canis latrans*)	2 (1)	1 (1)	0	3 (<1)
Unknown mammal	27 (9)	11 (11)	21 (3)	59 (6)
Bird	96 (32)	17 (17)	588 (90)	701 (66)
American Coot (*Fulica americana*)	59 (20)	11 (11)	377 (58)	447 (42)
Ruddy Duck (*Oxyura jamaicensis*)	11 (4)	0	93 (14)	104 (10)
Ring-necked Duck (*Aythya collaris*)	7 (2)	0	26 (4)	33 (3)
Redhead/Canvasback[b] (*Aythya americana/Aythya valisineria*)	6 (2)	1 (1)	23 (4)	30 (3)
Northern Shoveler (*Anas clypeata*)	1 (<1)	0	1 (<1)	2 (<1)
Mallard (*Anas platyrhynchos*)	4 (1)	0	0	4 (<1)
Northern Pintail (*Anas acuta*)	0	0	1 (<1)	1 (<1)
Green-winged Teal (*Anas crecca*)	0	0	1 (<1)	1 (<1)
Lesser Scaup (*Aythya affinis*)	0	0	1 (<1)	1 (<1)
Western Grebe (*Aechmophorus occidentalis*)	11 (4)	5 (5)	6 (1)	22 (2)
Pied-billed Grebe (*Podilymbus podiceps*)	1 (<1)	0	4 (<1)	5 (<1)
Eared Grebe (*Podiceps nigricollis*)	0	0	3 (<1)	3 (<1)
Unknown bird	10 (3)	4 (4)	275 (42)	289 (27)
Unknown fish	1 (<1)	0	2 (<1)	3 (<1)
Other material[c]	6 (2)	3 (3)	27 (4)	36 (3)

[a] Numbers and percentages of pellets are not additive because some pellets contained >1 class or species.
[b] Species were grouped because hair or feathers present in pellets were not distinguishable.
[c] Vegetation, seeds, soil, sand, small stones; monofilament line was also found in one pellet.

(83%). However, the harsh weather conditions caused an extensive die-off of feral fathead minnows (*Pimephales promelas*) which became the primary food we observed Bald Eagles eating that winter (Grubb and Lopez 1997). During 1996, waterfowl remained locally abundant all winter, with large flocks of several hundred birds concentrated in small openings in lake ice during cold periods. Very few road- or winter-killed elk were observed and pellets confirmed our observations that Bald Eagles fed primarily on birds (89%).

Discussion

The 59:41 frequency ratio of mammal to bird pellets, excluding Roost 8, was consistent with our combined local field experience over the past 24 yr. Bald Eagles wintering in northern Arizona typically depend on elk carrion as their primary food, beginning in late fall when visceral piles left during hunting season are abundant. Waterfowl provide an opportunistic, alternative food source when available. In similar habitat around Navajo Lake in northern New Mexico, pellets indicated Bald Eagle use of deer and elk carrion varied inversely with small mammal and waterfowl consumption, depending on weather and prey availability (Grubb 1984). Mild weather permits waterfowl to remain on northern Arizona lakes, whereas harsher winter conditions force them to leave and large ungulates to become more vulnerable to road- and winter-kill. Therefore, there is a weather-driven, relatively-stable food base for visiting, winter eagles even though prey classes vary (Grubb and Kennedy 1982). The 35:65 overall ratio of mammal to bird pellets we obtained by including Roost 8 was more representative of a mild winter with abundant-waterfowl, such as in 1996.

Differential foraging by wintering Bald Eagles on diving and not dabbling waterfowl may be a function of winter icing conditions and differing response behaviors to hunting eagles. Since dabbling ducks can launch into flight quickly, they are vulnerable for only a brief period. Divers, on the other hand, require a stretch of open water to get airborne, increasing their exposure to eagle predation. Diving to escape can also leave them vulnerable to foraging Bald Eagles. We have observed eagles circling overhead, singly (Brattstrom 1989) and in cooperative groups (Sherrod et al. 1976), to repeatedly drive their prey back underwater until exhausted. Icing of lake surfaces exacerbates diving duck vulnerability by concentrating large numbers of waterfowl in small areas, precluding flight by reducing take-off space, and limiting the diving area for underwater maneuvering.

In the three successive winters of our study, different weather conditions resulted in Bald Eagles foraging primarily on mammals, fish, and waterfowl, respectively. However, only the 1994 dependence on mammals and 1996 dependence on waterfowl were accurately represented by pellets. Nonetheless, our results suggest that pellets can provide effective assessments of long-term trends in mammal and bird use, and an indication of the relative abundance of prey within each class (Mersmann et al. 1992, Stalmaster and Plettner 1992). Pellet analyses need not be avoided in winter diet assessment (Stalmaster and Plettner 1992), especially under limiting circumstances such as those that we encountered. As demonstrated by our winter 1995 results, pellet analyses should be substantiated with observations as much possible, and the general absence of fish representation should be taken into account. In addition, the variation we recorded in wintering Bald Eagle diet, both annually and among roost locations, mandates a large pellet sample well-distributed over time and space.

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