

## FOOD HABITS OF BALD EAGLES BREEDING IN THE ARIZONA DESERT

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ABSTRACT.—Of 1814 foraging attempts, prey captures, or nest deliveries by Bald Eagles (*Haliaeetus leucocephalus*) in 14 Arizona breeding areas during 1983–1985, 1471 observations were identifiable to at least class: fish (76%), mammal (18%), bird (4%), and reptile/amphibian (2%). Forty-five species were recorded: catfish (*Ictalurus punctatus*, *Pylodictis olivaris*), suckers (*Catostomus insignis*, *C. clarki*), and carp (*Cyprinus carpio*) were most common. Mean population dietary heterogeneity was 2.03 (SD = 0.43). During 1983–1985, 22 successful sites had a wider dietary breadth than nine unsuccessful ones (3.73 vs 1.92). Fish and mammal classes varied by month ( $P < 0.001$ ) and breeding area ( $P < 0.001$ ) and were negatively correlated ( $R = -0.993$ ,  $P = 0.001$ ). Of 484 discrete foraging locations, only four (<1%) were frequented in more than one year. Within-season shifts in foraging locations were typical within breeding areas to accommodate changing prey availability. Foraging activity varied hourly and among prey classes, peaking 08:00–10:00 and 16:00–19:00 h MST ( $P < 0.001$ ). Perches east (NE-E-SE) of foraging sites were used more often before 13:00 h MST (59.3%,  $N = 118$ ), while perches west (SW-W-NW) were used more often after 13:00 h (58.4%,  $N = 113$ ;  $P = 0.013$ ). Most foraging occurred near shore in shallow river waters. The mean straight-line distance between Verde River nest sites was 14.4 km (SD = 3.5) with a ratio of river: straight-line distance of 1.4:1. Opportunistic and breeding area-specific foraging was evident throughout the population. Received 2 May 1994, accepted 11 Nov. 1994.

Bald Eagles (*Haliaeetus leucocephalus*) typically nest along marine coastlines and large interior lakes and rivers where they have evolved as a fish-eating sea eagle. Food habits have been studied extensively throughout the Bald Eagle's range (Grubb and Hensel 1978, McEwan and Hirth 1980, Cash et al. 1985, Brown et al. 1991); their opportunistic foraging habits are well known (Brown and Amadon 1968). Hunt et al. (1992) summarized the progressive accumulation of food habits data in Arizona through the mostly unpublished research of Rubink and Podborny (1976), Hildebrandt (1981), Haywood and Ohmart (1986) and Grubb (unpubl. data). The purpose of this paper is to document more fully the food habits results of interagency cooperative research led by the USDA Forest Service on Bald Eagles breeding in central Arizona during 1983–1985 (Grubb, unpubl. data), which was an extension and expansion of previous Arizona studies. In this study observations of food habits (foraging attempts, prey captures, nest deliveries), supplemented by prey remains collected from nests, were used to determine dietary composition

and variability, foraging habits, and foraging habitat for breeding Bald Eagles in central Arizona.

#### METHODS

The study area in Gila, Maricopa, and Yavapai counties of central Arizona primarily is within the Verde and Salt river drainages, which flow from the north and east of Phoenix, respectively (Fig. 1). This area lies within the transitional Central Highlands Province, characterized by more closely clustered mountain ranges and smaller, less numerous desert basins than the Basin and Range Province to the south, and by generally lower elevation and greater topographic relief than the Colorado Plateau to the north (Chronic 1983). Study area elevations ranged between 500–1500 m, with most Bald Eagle nests (9–11 of 13 during any year) located on 50–100 m cliffs. All sites were associated with riparian vegetation—Cottonwood-Willow (*Populus fremontii*-*Salix goodingii*) Series and Mixed Broadleaf (*Platanus wrightii*, *Fraxinus pennsylvanica*, *Alnus oblongifolia*) Series. However, Sonoran Desert-scrub—Arizona Upland or Palo Verde-Mixed Cacti (*Cercidium* spp.-*Opuntia* spp.) Series—was the prevalent vegetative classification. Higher elevation sites ranged into Pinyon-Juniper (*Pinus edulis*-*Juniperus* spp.) and Ponderosa Pine (*P. ponderosa*) Associations (Brown 1982).

This study was based on more than 51,000 h of field observation by 71 nest watchers deployed near nest sites (Forbis et al. 1985) in 14 Bald Eagle breeding areas in 1983–1985. Species lists were compiled primarily from identifications made during observations (see Forbis et al. for specific techniques) of prey captures and deliveries to the nest. Unquantified prey remains collected at nests during the banding of 6–8-week-old eaglets were used to augment observational species lists. Comparisons among years, months, and breeding areas were facilitated by simultaneous sample days of data collection standardized across all breeding areas (4 days/2 weeks, 20–24 sample days/area/year, i.e., late incubation through fledging, February/March through early June). Each sample day consisted of dawn-to-dusk observation by two nest watchers typically stationed 300–500 m from and with good views of the nest and surrounding foraging/perching habitat.

Locations of foraging attempts and captures were recorded with the Universal Transverse Mercator (UTM) planar coordinate system. Repetitive use of foraging locations was evaluated with both exact ( $\leq 20$ -m accuracy) and truncated (100-m block) UTM's (Grubb and Eakle 1988). Observation times were recorded exactly, but data were partitioned into 15 hour classes for temporal analysis: <06:00, 06:00–06:59 . . . 18:00–18:59,  $\geq 19:00$  h MST. Size of fish prey (<15, 15–30, 31–45, >45 cm) was estimated from comparison with adult features or reference points of known dimension at the nests. Species identification and occasional recovery of dropped prey items also facilitated size estimation. Hunting and capture methods, characteristics of foraging perches (type, direction, and distance from foraging area and height above), activity at initiation of foraging attempts/captures, type of foraging habitat (river/reservoir/upland, proximity to shore, and estimated depth) and flight direction of prey deliveries also were recorded whenever possible. Most measurements were recorded indirectly from topographic maps.

Straight-line and river distances were measured between five traditional and three new nest sites on the Verde River to evaluate the amount of riverine habitat required for Bald Eagle breeding areas in central Arizona. For this analysis, nest sites were arbitrarily assumed to be at the center of linear, riverine breeding areas. The Verde River was used because in contrast to the Salt River, (a) it is free flowing over most of its length; (b) it has only two reservoirs at its lower end, one of which is typically little more than a river channel; (c) it has no major or extensive canyons along its course; (d) all of its breeding areas are located

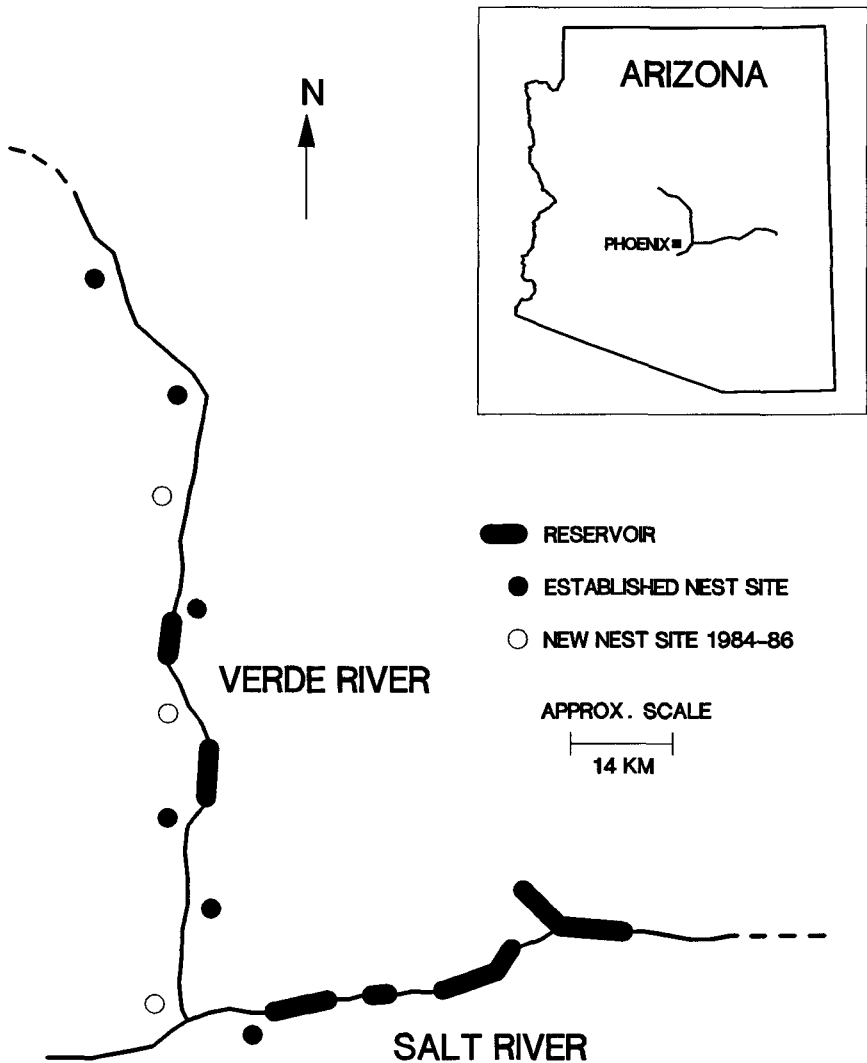


FIG. 1. Central Arizona study area (inset) and spacing of established (pre-1977) and new (1984–1986) Bald Eagle nest sites along the Verde River, as an indication of minimum linear, riverine breeding area size.

along the main river; (e) three new breeding areas were established among five traditional sites during and immediately following this study; and (f) breeding areas were evenly distributed along its course.

Frequency, descriptive, and cross-tabulation programs within SPSS PC+ Version 4.0 (No-

rusis/SPSS Inc. 1990) were used initially to explore and summarize data. Statgraphics Version 5 (STSC, Inc. 1991) was used to compare frequencies among years, breeding areas, prey and size classes (contingency table), and for assessing hourly foraging activity (Chi-square goodness of fit). A nonparametric permutation test (Mielke 1984) enabled comparison of dietary breadth indices between successful and unsuccessful nests. Sample sizes occasionally varied throughout the analyses due to missing data.

Population dietary breadth (PDB), an index to number of prey taxa in the diet, and population dietary heterogeneity (PDH), an index to dietary variation among breeding areas within a given year (Steenhof and Kochert 1988), were used for comparisons within- and between-breeding areas and years. PDB was calculated with the formula,  $PDB = [\sum(P_i^2)]^{-1}$ , where  $P_i$  was the proportion of the diet contributed by the  $i$ th of  $N$  prey taxons. Values of this index range from 1 to  $N$ . Breadth measures were based on frequencies of individual species when known; otherwise, genus or class groups were used. Calculation of dietary breadth (DB) for individual breeding areas followed the same procedure as PDB. PDH was calculated from contingency tables of prey taxa grouped similarly to PDB for each breeding area. The resultant  $G$ -statistic (Sokal and Rohlf 1981) was then divided by degrees of freedom, i.e., the product of (prey taxa - 1)  $\times$  (breeding areas - 1) for the appropriate year.

## RESULTS

*Prey composition and variability.*—Of 1814 food habits observations during 1983–1985, 1471 (81%) were distinguishable to at least class and represented a minimum of 45 separate prey species (Table 1). Fish were the most frequently recorded prey, followed by mammals, with only limited numbers of bird and reptile/amphibian prey evident in the diet. The most common species or groups by prey class were catfish (*Ictalurus punctatus*, *Pylodictis olivaris*), suckers (*Catostomus insignis*, *C. clarki*), and carp (*Cyprinus carpio*); cottontail (*Sylvilagus audubonii*), jackrabbit (*Lepus* spp.), squirrel (*Spermophilus* spp.), and woodrat (*Neotoma* spp.); American Coot (*Fulica americana*); other waterfowl (*Anas* spp.); and Sonora mud turtles (*Kinosternon sonoriense*), spiny softshell turtles (*Trionyx spiniferus*), and snakes (Serpentes). Many smaller birds were identified from single occurrences in prey remains. No snake remains were found in nests. Foraging on frogs (Salientia) was observed once, and a partial exoskeleton of a crayfish (*Camberus* sp.) was found in one nest.

Relative frequencies of prey classes in the population diet did not vary significantly across years ( $\chi^2 = 3.046$ ,  $df = 6$ ,  $P = 0.803$ ); however, the proportions of fish ( $\chi^2 = 28.793$ ,  $df = 4$ ,  $P < 0.001$ ) and mammals ( $\chi^2 = 21.687$ ,  $df = 4$ ,  $P < 0.001$ ) in the diet differed from month to month. Bird ( $\chi^2 = 4.175$ ,  $df = 4$ ,  $P = 0.383$ ) and reptile/amphibian ( $\chi^2 = 1.020$ ,  $df = 4$ ,  $P = 0.907$ ) variation was negligible (Fig. 2). The relative frequencies of fish and mammal prey were highly and negatively correlated ( $R = -0.993$ ,  $P = 0.001$ ): fish increased in the diet as the nesting season progressed, while occurrence of mammalian prey declined. The proportions of fish ( $\chi^2 = 110.586$ ,  $df = 11$ ,  $P < 0.001$ ), mammal ( $\chi^2 = 128.452$ ,  $df = 11$ ,  $P < 0.001$ ), bird ( $\chi^2 = 88.197$ ,  $df = 11$ ,  $P < 0.001$ ), and reptile/

TABLE 1  
 FREQUENCY AND RELATIVE PROPORTION (%) OF PREY TAXA IDENTIFIED DURING CAPTURES/  
 DELIVERIES BY BREEDING BALD EAGLES AT 14 ARIZONA NEST SITES, 1983–1985.<sup>a</sup>

Prey taxa	1983	1984	1985	Total
FISH <sup>b</sup>	203 (73)	235 (71)	680 (79)	1118 (76)
Catfish	33	13	75	121
Sucker	13	20	69	102
Carp ( <i>Cyprinus carpio</i> )	28	28	44	100
Bass	—	3	21	24
Unidentified fish	129	171	471	771
Mammal <sup>c</sup>	56 (20)	65 (19)	142 (16)	263 (18)
Cottontail ( <i>Sylvilagus audubonii</i> )	13	8	29	50
Black-tailed jackrabbit ( <i>Lepus californicus</i> )	2	2	3	7
Unidentified lagomorph	0	5	9	14
Squirrel	0	8	10	18
Woodrat ( <i>Neotoma</i> ) spp.	0	7	9	16
Unidentified mammal	41	35	82	158
Birds <sup>d</sup>	11 (4)	24 (7)	24 (3)	59 (4)
Waterfowl	0	10	12	22
Other birds	11	14	12	37
Reptile/amphibian <sup>e</sup>	9 (3)	9 (3)	13 (2)	31 (2)
Turtle spp. (Cryptodira)	6	5	1	12
Snake spp. (Serpentes)	2	6	4	12
Unidentified reptile/amphibian	1	2	4	7
Totals	279	333	859	1471

<sup>a</sup> 343 observations of unknown prey class were excluded; additional species identified from prey remains are listed in footnotes.

<sup>b</sup> Channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), Sonora sucker (*Catostomus insignis*), desert sucker (*C. clarki*), Yellow bass (*Morone mississippiensis*), smallmouth bass (*Micropterus dolomieu*), bass spp. (*Micropterus* spp.), and sunfish spp. (*Lepomis* spp.).

<sup>c</sup> Rock squirrel (*Spermophilus variegatus*), ground squirrel spp. (*Spermophilus*) spp., mouse (*Peromyscus*) spp., muskrat (*Ondatra zibethicus*), ringtail (*Bassariscus astutus*), striped skunk (*Mephitis mephitis*), collared peccary (*Tayassu tajacu*), beaver (*Castor canadensis*), and hereford calf (*Bos taurus*).

<sup>d</sup> Mallard (*Anas platyrhynchos*), Green-winged Teal (*A. crecca*), Cinnamon Teal (*A. cyanoptera*), Common Merganser (*Mergus merganser*), American Coot (*Fulica americana*), White-winged dove (*Zenaida asiatica*), Mourning Dove (*Z. macroura*), Greater Roadrunner (*Geococcyx californicus*), Violet-green Swallow (*Tachycineta thalassina*), Gambel's Quail (*Callipepla gambelii*), Northern Mockingbird (*Mimus polyglottos*), Wild Turkey (*Meleagris gallopavo*), Whip-poor-will (*Caprimulgus vociferus*), Northern Flicker (*Colaptes auratus*), Gila Woodpecker (*Melanerpes uropygialis*), Cactus Wren (*Campylorhynchus brunneicapillus*), Great-tailed Grackle (*Quiscalus mexicanus*), jay spp. (Corvidae), and blackbird spp. (Emberizidae).

<sup>e</sup> Sonora mud turtle (*Kinosternon sonoriense*), spiny softshell turtle (*Trionyx spiniferus*), racer (*Coluber constrictor*), lizard spp. (Sauria), and frog spp. (Salientia).

amphibian ( $\chi^2 = 23.411$ ,  $df = 11$ ,  $P = 0.015$ ) varied among 12 breeding areas (Fig. 3); two areas with insufficient sample size ( $N \leq 8$  observations) were excluded from this analysis.

The range in DB was 2.66–7.51 (ADB) for individual breeding areas across years and 4.88–7.94 (PDB) for years across breeding areas (max-

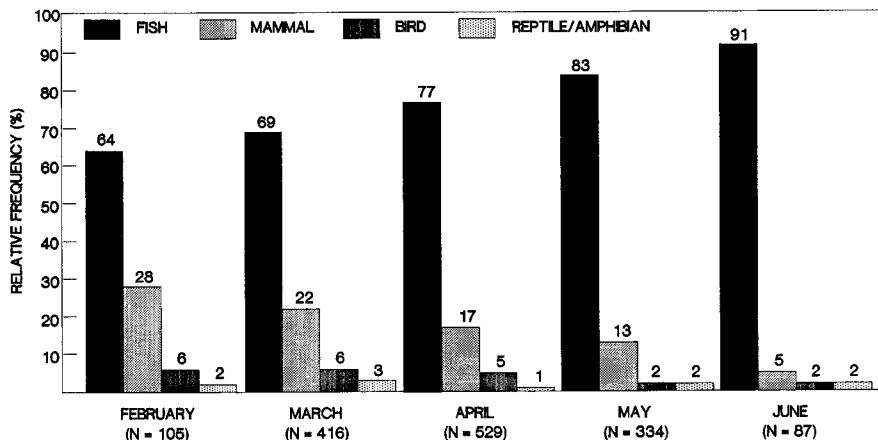


FIG. 2. Monthly variation in relative frequency (%) of breeding Bald Eagle prey classes observed in Arizona, 1983-1985.

imum potential value = 12, Table 2). During 1983-1985, the 22 sites that successfully produced young eagles had a mean DB nearly twice that of nine unsuccessful ones (3.58 vs 1.89;  $P = 0.0432$ ). Mean PDH over the three-year study period was 2.03 (SD = 0.43).

Prey class representation in the diet did not vary significantly between food habits observations and prey remains ( $\chi^2 = 3.846$ ,  $df = 3$ ,  $P = 0.278$ ). Ten of 11 breeding areas (91%) where both fish foraging was observed and prey remains were collected contained fish remains in or below the nests. Mammals were evident in prey remains at eight of nine breeding areas (89%) with recorded mammal foraging. Bird remains were in seven of nine areas (78%) with recorded avian foraging. In contrast, evidence of reptile/amphibian prey was found only in one of five areas (20%) where such foraging was observed.

*Foraging habits.*—Over the three-year study period, 484 discrete foraging locations were identified from 743 observations of prey attempts or captures in 14 breeding areas (Table 3). Within the same breeding season, 103 foraging locations (21%) were used more than once (median = 2, range = 2-25). However, only four (<1%) of the 484 locations were frequented in more than one year. Each of the four locations was used only once in either 1983 or 1985, with all repetitive use (range = 2-6) occurring in the alternative year. Using 100-m blocks instead of exact locations in the analysis resulted in 23 (6%) of 363 discrete blocks repetitively used between years. None of the repeat blocks was used all

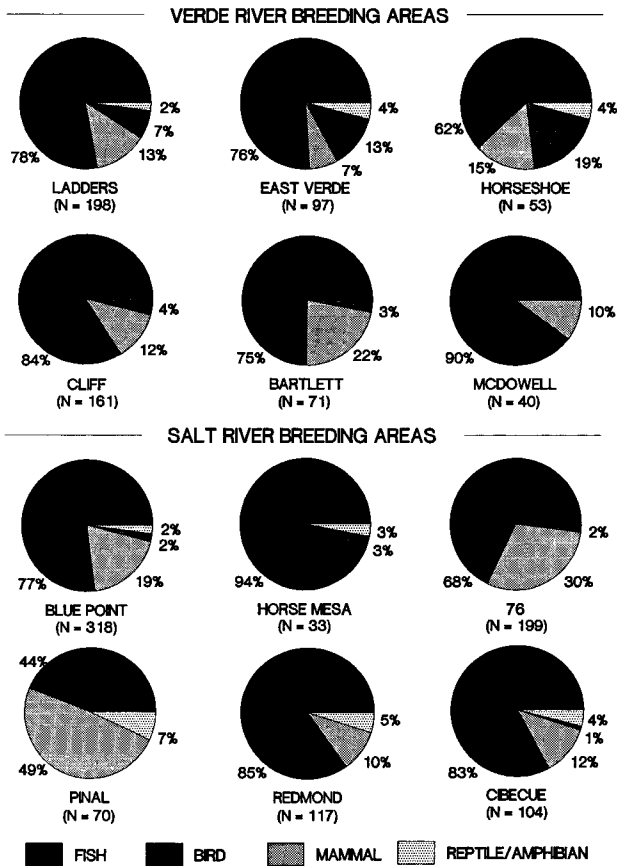


FIG. 3. Variability in the relative frequency (%) of prey classes among 12 Bald Eagle breeding areas in Arizona, 1983-1985.

three years, but 12 were used in consecutive years. Only three blocks had more than one repetition in both years.

The 76 and Blue Point breeding areas illustrate typical between- and within-year variation in foraging patterns. The 76 site had 77% of the 1983 foraging in the northeast quadrant from the nest, 9% northwest, and 14% southwest (N = 22). In 1984 foraging shifted: 25% northeast, 63% northwest, and 12% southwest (N = 16;  $\chi^2 = 17.944$ ,  $df = 2$ ,  $P < 0.001$ ). At Blue Point in 1983 frequencies for predominant direction of prey delivery flights (east, west, other; N = 83) varied as the season progressed: February and March 52% east, 48% west, 0% other; April 10%, 50%, 40%; May 35%, 0%, 65%;  $\chi^2 = 197.396$ ,  $df = 6$ ,  $P < 0.001$ ).

TABLE 2  
POPULATION (P), AREA (A), AND YEARLY DIETARY BREADTH (DB) AND YEARLY POPULATION  
DIETARY HETEROGENEITY (PDH) FOR 14 BALD EAGLE BREEDING AREAS IN ARIZONA,  
1983–1985

Breeding area	1983 DB	1984 DB	1985 DB	ADB
Ladders	3.69	—	3.05	4.39
East Verde	1.80	6.55	3.33	6.08
Horseshoe	1.00	2.81	4.23	4.36
Bartlett	—	1.00	3.84	4.40
McDowell	—	—	4.08	—
Blue Point	1.00	7.06	6.75	7.51
Horse Mesa	2.00	1.00	2.67	3.76
76	2.57	4.08	3.32	4.11
Sheep	2.00	—	—	—
Pinal	1.92	3.01	—	3.57
Redmond	2.38	2.00	2.86	2.85
Cibecue	—	3.80	5.41	5.19
Cliff	—	3.51	2.14	2.66
Pleasant	—	—	1.00	—
Yearly PDB	4.88	7.94	6.25	
Yearly PDH	2.11	1.57	2.41	

Foraging activity occurred throughout daylight hours (Fig. 4). It increased to a morning peak between 08:00–10:00 h MST, then dropped off to remain relatively steady through midday. A second peak of activity occurred in late afternoon between 16:00–19:00 h MST ( $\chi^2 = 198.967$ ,  $df = 14$ ,  $P < 0.001$ ). Foraging for both fish ( $\chi^2 = 120.514$ ,  $df = 14$ ,  $P < 0.001$ ) and mammals ( $\chi^2 = 58.294$ ,  $df = 14$ ,  $P < 0.001$ ) followed a similar pattern, although mammal foraging showed more of a down-up cycle through midday. Avian foraging fluctuated throughout the day but generally tended to increase toward a peak between 16:00–17:00 h MST ( $\chi^2 = 25.250$ ,  $df = 13$ ,  $P = 0.021$ ). Reptile/amphibian hourly variation was not significant ( $\chi^2 = 14.333$ ,  $df = 11$ ,  $P = 0.215$ ); however, a tendency toward increased midday activity is apparent in Fig. 4. No reptile/amphibian predation was observed before 06:00 or after 18:00 h MST.

The distribution of fish size during 1983–1985 was similar to that recorded by Haywood and Ohmart (1986) for 1979–1982. Of 1000 estimated fish prey sizes, 13% were <15 cm; 56%, 15–30 cm; 26%, 31–45 cm; and 4%, >45 cm. Relative frequencies of size varied between Verde (12, 50, 33, 5%;  $N = 439$ ) and Salt river (15, 61, 21, 3%;  $N = 454$ ) breeding areas ( $N = 5$  for each river), with higher proportions of fish >30 cm on the Verde River and <31 cm on the Salt River ( $\chi^2 = 9.967$ ,



TABLE 3  
FORAGING OBSERVATIONS<sup>a</sup>

Nest	Discrete foraging locations				Locations <sup>b</sup> reused within year	Distrib. of reuse <sup>c</sup>	Locations reused >1 year
	1983	1984	1985	Total			
Ladders	5	9	15	28	9	13, 10, ≤5	0
East Verde	3	6	11	20	2	≤3	0
Horseshoe	4	10	2	16	1	2	0
Cliff	—	13	35	48	14	23, 15, 6, ≤4	1
Bartlett	3	4	22	29	2	2	0
McDowell	—	—	5	5	1	4	—
Blue Point	80	9	74	163	49	25, 7, 6, 6, ≤5	2
Horse Mesa	4	11	9	24	1	2	0
76	15	10	44	69	10	6, ≤4	1
Sheep	2	—	—	2	1	2	—
Pinal	12	6	0	18	1	3	0
Redmond	9	2	24	35	8	6, ≤4	0
Cibecue	—	9	17	26	5	≤3	0
Pleasant	—	1	0	1	0	—	—
Totals	137	89	258	484	103 (21%)	2–25	4 (<1%)

<sup>a</sup> As represented by attempts or captures by year, including the number reused within years, range of repetitive use, and the number used more than one year.

<sup>b</sup> For Ladders, nine of the 28 total foraging locations were used more than once in the same year.

<sup>c</sup> For Ladders, one of nine foraging locations was reused 13 times, another 10 times, and the remaining seven were used ≤ five times.

df = 3,  $P = 0.019$ ). The greater relative frequencies of carp (15–45 cm) at Verde River sites and of bass (primarily yellow bass [*Morone mississippiensis*] <15 cm) at Salt River sites (Fig. 5) probably accounted for most of the size variation between rivers in 1983.

Most hunting forays appeared to be initiated from perches (70%) rather than while in flight (30%,  $N = 468$ ;  $\chi^2 = 16.000$ ,  $df = 1$ ,  $P < 0.001$ ). However, flying in to pick up prey was the primary capture technique (76%), followed by landing/walking or wading (19%), and pursuit or pirating (5%,  $N = 435$ ;  $\chi^2 = 85.7273$ ,  $df = 2$ ,  $P < 0.001$ ).

Mean number of prey deliveries/day at 11 successful breeding areas on 328 sample days in 1984–1985 was 2.2 (SD = 0.86,  $N = 729$ ). The ratio of male:female deliveries ( $N = 152$ ) at three successful sites was 1.9:1, while the ratio of male:female time spent feeding young at those sites was 1:1.8 (15 and 26 min/day, respectively).

*Foraging habitat.*—Generally, foraging perches were in southerly directions from forage sites (51% SE-S-SW and 78% E-SE-S-SW-W,  $N = 351$ ; Fig. 6). However, perches east (NE-E-SE) of foraging sites were used more often before 13:00 h MST (59.3%,  $N = 118$ ), while perches

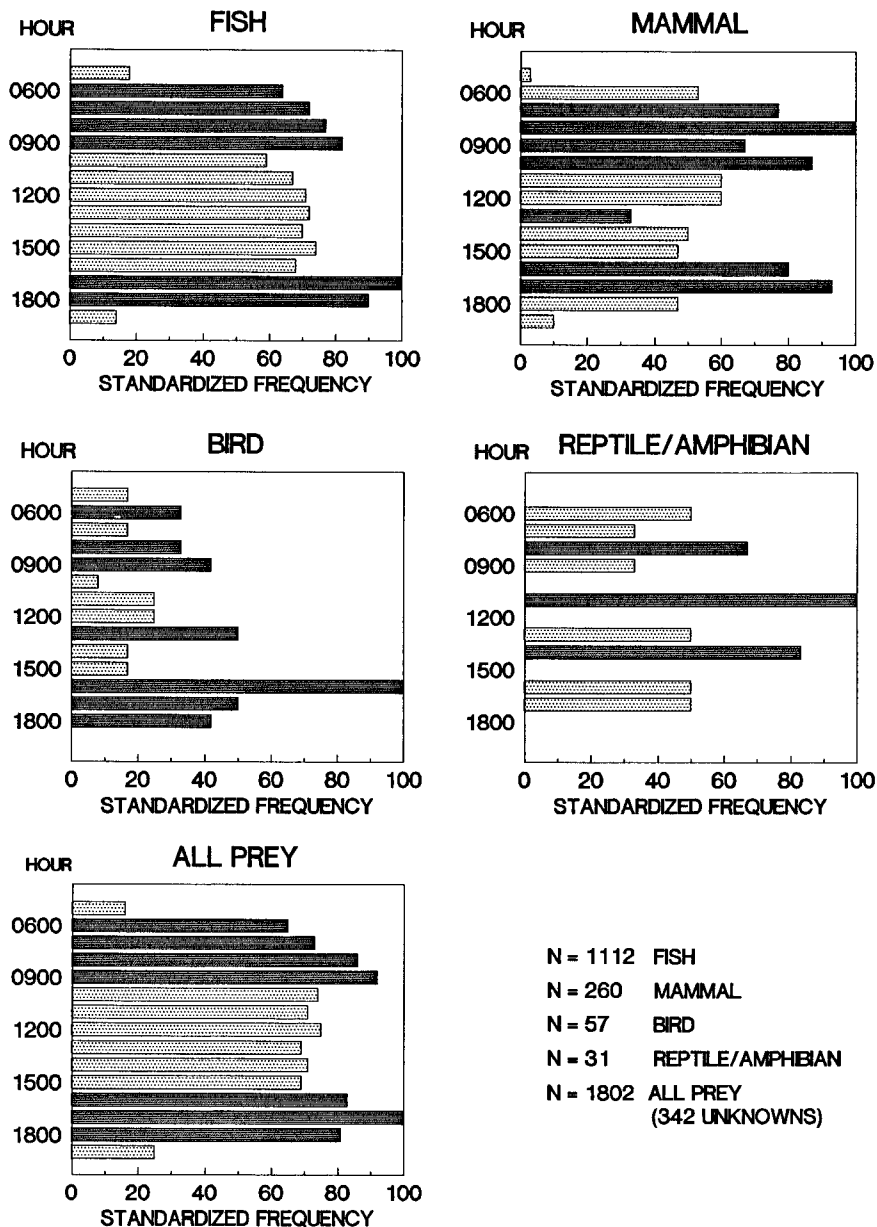
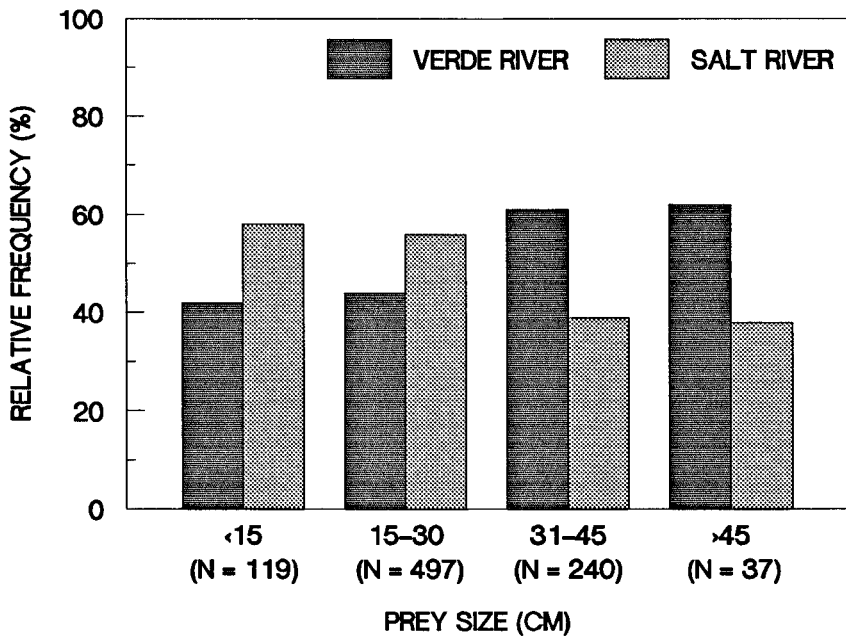
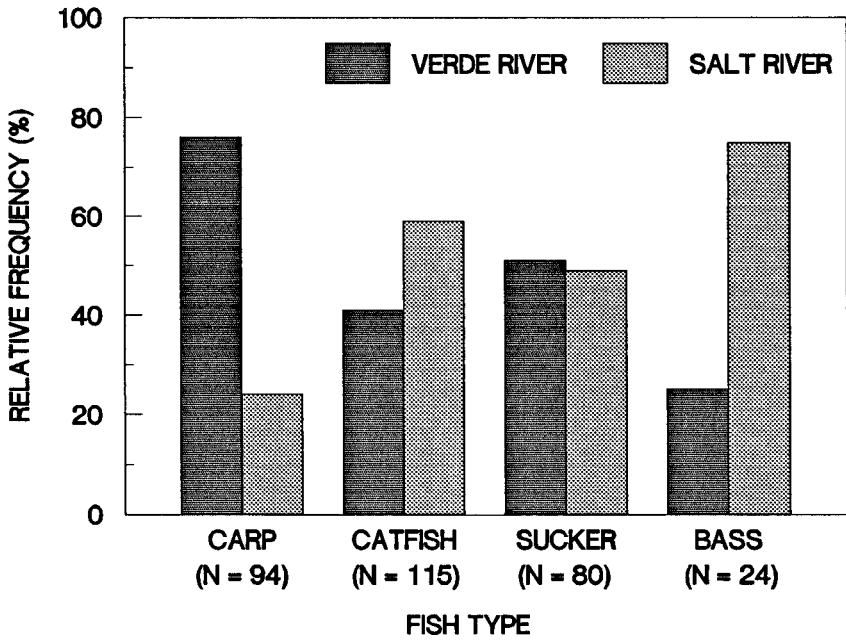


FIG. 4. Temporal patterns of foraging for all prey combined and individual prey classes by breeding Bald Eagles in Arizona, 1983–1985. Frequencies were standardized for comparison by dividing each hourly frequency by the highest frequency in its prey class and multiplying by 100. Shaded bars highlight peaks or trends.



west (SW-W-NW) were used more often after 13:00 (58.4%,  $N = 113$ ;  $\chi^2 = 6.162$ ,  $df = 1$ ,  $P = 0.013$ ). Foraging perches averaged 22 m in horizontal distance from the foraging sites ( $SD = 3.1$ , range 6–73 m,  $N = 320$ ) and 47 m in vertical height above them ( $SD = 2.6$ , range 9–87 m,  $N = 344$ ). Most foraging perches (60%) were on cliffs, the dominant habitat feature of the study area. Perches in trees (28%: 15% live and 13% dead) and on the ground (12%) were less frequent ( $N = 367$ ;  $\chi^2 = 16.818$ ,  $df = 2$ ,  $P < 0.001$ ).

Of 317 water-oriented foraging attempts or captures 20% were along the shoreline, 43% were between shore and the middle third of the water body, and 37% were in the middle ( $\chi^2 = 8.636$ ,  $df = 2$ ,  $P = 0.013$ ). Sixty-one percent of this foraging occurred at approximate depths of <1.2 m; 20% between 1.2–2.4 m; and 19% deeper than 2.4 m ( $\chi^2 = 34.818$ ,  $df = 2$ ,  $P < 0.001$ ). River foraging predominated (78%), supplemented by 8% reservoir and 14% upland foraging ( $N = 465$ ;  $\chi^2 = 91.242$ ,  $df = 2$ ,  $P < 0.001$ ).

The mean straight-line distance between Verde River nest sites was 14.4 km ( $SD = 3.5$ ); mean river distance was 18.9 km ( $SD = 4.8$ ). The ratio of river: straight-line distance was 1.4:1. New sites were located approximately midway in the three longest, straight-line spans (29.0, 26.4, 24.6 km) between established sites (Fig. 1).

#### DISCUSSION

In support of the observational study of food habits, Mersmann et al. (1992) and Stalmaster and Plettner (1992) found observation to be the least biased means of portraying diets. Todd et al. (1982) and Knight et al. (1990) recommended direct observation to validate prey remains in determining diet because prey remains favored avian over fish classes; this bias was reversed for observed food habits. Despite minor differences noted in their Arizona study, Haywood and Ohmart (1986) felt the two methods were comparable. Collopy (1983) also found no differences ( $P > 0.05$ ) between observation and prey remains in estimating species composition in the diet of golden eagles (*Aquila chrysaetos*) in Idaho.

*Prey composition and variability.*—Species composition and relative frequency were generally comparable to other breeding Bald Eagle food habits studies in Arizona (see Table 4). Related data on species, size, and number of prey were insufficient for biomass calculations. However, the

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FIG. 5. Comparison of fish prey types and sizes from observations of foraging Bald Eagles along the Verde and Salt rivers in Arizona, 1983–1985.

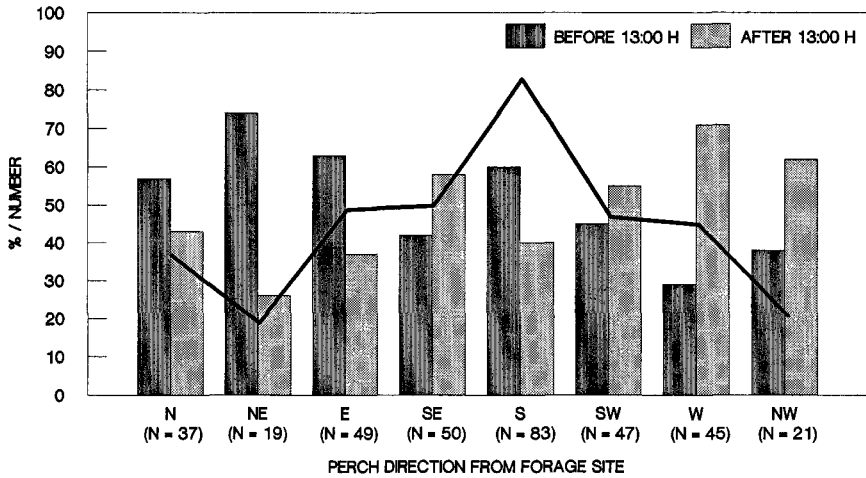


FIG. 6. Breeding Bald Eagle foraging perch directions from foraging sites before and after 13:00 h (relative frequency, bars) and actual perch frequency by direction (line) in Arizona, 1983–1985.

high proportion of mammals recorded in the population diet during this study, along with the unlikelihood of over-estimating mammal frequency in an observation-based study (Stalmaster and Plettner 1992), suggest an unusual dependence on this prey class during 1983–1985. Between 1986–1990, Hunt et al. (1992) noted a higher proportion of birds in the population diet than mammals, yet they found the same seasonal, inverse relationship between primary and secondary prey classes (Fig. 2).

TABLE 4  
COMPARISON OF PREY COMPOSITION RESULTS (%) FROM FORAGING STUDIES ON BREEDING BALD EAGLES IN ARIZONA

Study/years		Fish	Mammal	Bird	Reptile	Species	Number of items
Rubink & Podborny (1976)/1972–1975	R <sup>b</sup>	87.3	3.2	6.4	3.2	7	63
Hildebrandt (1981)/1977–1978	R	82.3	9.9	7.2	0.0	20	192
	O	76.2	13.8	10.0	0.0	—	130
Haywood & Ohmart (1986)/1979–1982 <sup>a</sup>	R	76.4	12.0	11.0	0.6	30	484
	O	88.0	6.0	1.2	4.8	—	579
Present study/1983–1985 <sup>a</sup>	O	76.0	17.9	4.0	2.1	45	1471
Hunt et al. (1992)/1986–1990	R	79.9	7.4	11.8	0.9	72	1847

<sup>a</sup> Based on Grubb (unpubl. data).

<sup>b</sup> R = remains, O = observations.

These inverse relationships between fish and mammals or birds, like those recorded for wintering Bald Eagles in Arizona and New Mexico (Grubb and Kennedy 1982, Grubb 1984), may reflect the opportunistic foraging associated with fluctuating prey and marginal habitat conditions characteristic of the periphery of a species' range. Increased turbidity during spring runoff may have reduced fish availability for eagles early in the nesting season, while improving water conditions with associated spawning likely accounted for the later increase.

Low annual variation in prey composition may have been partially a result of population averages dampening individual variation, and/or the consistent weather and stream-flow patterns during the 1983–1985 nesting seasons. A year of relatively high precipitation, compared with low to average years like those observed during this study, would likely result in greater annual fluctuations of prey use. In contrast to population diet, DB among individual breeding areas from year to year was sufficiently variable to indicate both opportunistic and site-specific foraging activity.

The wider DB of successful sites suggests either a greater reliance on alternate prey or a more diverse variety of prey at those sites. Arizona's breeding Bald Eagles (PDH = 2.03) showed more variation in diet than Prairie Falcons (*Falco mexicanus*, PDH = 1.63), and less than Golden Eagles (PDH = 2.62), and Red-tailed Hawks (*Buteo jamaicensis*, PDH = 2.44) in southwestern Idaho (Steenhof and Kochert 1988).

*Foraging habits.*—Shifts in foraging location and variable prey composition suggest opportunistic use of habitat for foraging, both within- and between-years. Variation in foraging directions was likely a result of changing water conditions, spawning cycles, and human recreational activity. Different flow rates and turbidity levels in the stream running through the 76 breeding area in 1983 and 1984 may have affected fish prey availability and caused the recorded shift in primary foraging areas. At Blue Point, the April shift to the east corresponded to carp spawning in the adjacent upstream reservoir, whereas the shift back west in May and the increase in off-river flight directions was apparently related to the end of spawning and the seasonal increase in water-oriented human recreational activity.

Hourly foraging results for 1983–1985 generally confirmed previously reported peaks and trends (Haywood and Ohmart 1986) and further supported temporal variability in foraging for all prey classes, including fish. Haywood and Ohmart (1986) identified two peak periods of foraging, 1–4 h and 8–10 h after sunrise (N = 733). Afternoon peaks in 1983–1985 appeared later, but this was probably an artifact of differential time measurement between the two studies. Haywood and Ohmart (1986) also observed a significant difference between individual hours for all prey

classes combined but not for fish alone. Given the variety of prey and range in foraging times recorded during these two studies, it appears that Bald Eagles breeding in Arizona will take most any kind of prey at any time of day as the need and/or opportunity arises.

Feeding rates were within the ranges reported for two nests in Ohio (2.5–4.0 feedings/day, Herrick 1924) and for three nests in southeast Alaska (2.3–3.6 feedings/day, Cain 1985). However, both these studies noted nearly 1:1 ratios of male:female prey deliveries. In Arizona, males appeared to do more prey gathering and less nest attending, although behavior of individual pairs varied. Cain (1985) observed an overall male:female ratio of time spent feeding of 1:1.9, similar to Arizona results, with male participation in feedings declining as the nestling period progressed.

*Foraging habitat.*—Given the abundance of cliffs throughout the study area and the distribution of riparian vegetation on either side of drainages where it occurred, the availability of potential perching habitat was not directionally biased. Thus, foraging perch use appeared related to position of the sun, with a selection for those sites or times that placed the sun behind the eagle as it viewed the foraging area. Such relative positioning improved visibility above as well as into bodies of water; it also hindered potential prey from detecting the approaching predator (Grubb 1977). In addition, the benefits of shade for thermoregulation at cliff sites may have been a factor in midday perch selection, particularly later in the season when temperatures often rose above 100°F.

Steep, canyon-walled shorelines, and frequent water level fluctuations that limit littoral zones and their ability to support prey species are characteristic of Arizona reservoirs. These factors probably contribute to the predominantly river and upland foraging recorded during this study. Additionally, because most nests were along rivers and observations were usually centered on nest sites, reservoir foraging may have been underrepresented. Foraging in shallow, near-shore habitat was consistent with the documented importance of shallows and riffles in providing forage for benthic-feeding fish and simultaneously increasing their vulnerability to foraging Bald Eagles (Haywood and Ohmart 1986).

Foraging habitat is one of the primary determinants of raptor breeding area distribution (Newton 1979). The even distribution of breeding areas along the Verde River is strong evidence for a minimum linear, riverine breeding area size for Arizona of approximately 14 km, straight-line distance. The establishment of three new sites midway in each of the three widest gaps between traditional sites further substantiates this trend. Presumably this distribution is driven by prey availability, since Bald Eagles nest much closer together (<0.8 km) in regions of abundant prey (Dzus

and Gerrard 1993). The straight-line river distance ratio of 1:1.4 was calculated on total nest distribution and river distance, yet it compared to the 1:1.5 ratio determined by Grubb (1988) within 3.2 km radii of 18 nest sites. Thus, the indication is that approximately 20 km of riverine habitat may be necessary to support a breeding pair of Bald Eagles in Arizona (14 km straight-line distance  $\times$  1.4 straight-line:river distance ratio).

In summary, breeding Bald Eagles in central Arizona opportunistically used a wide variety of prey, although fish, primarily catfish, suckers, and carp, were consistently the most frequent and important prey, especially later in the nesting season. Like wintering Bald Eagles in the Southwest, the breeding population has adapted to variable and ephemeral sources of prey. Consistent with this foraging behavior were within- and between-season shifts in foraging locations and variations in diet among breeding areas.

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