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UTILIZATION OF BENTHIC-FEEDING FISH BY INLAND BREEDING BALD EAGLES[1]

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Abstract. Prey utilization was investigated at 11 Bald Eagle (*Haliaeetus leucocephalus*) nests in Arizona over a five-year period beginning in 1978. Visual observations of prey species delivered to the nest and those found in prey remains were in good agreement. Fish, primarily channel catfish (*Ictalurus punctatus*) and other benthic-feeding fish, composed 77% of the prey items found at the nest. Diurnal timing of capture of fish was not found to vary significantly. Measurement of river-bottom profiles at 22 foraging sites yielded similar physical characteristics. Such characteristics indicate a strong relationship between river-bottom profile and acquisition of benthic-feeding fish by Bald Eagles.

Key words: Bald Eagles; prey utilization; Bald Eagle food habits; southwestern Bald Eagles; Arizona Bald Eagles; channel catfish; carp.

INTRODUCTION

A small breeding population of Bald Eagles (*Haliaeetus leucocephalus*) occurs along the Salt and Verde rivers in central Arizona and their associated tributaries. This population is unique because it occupies the southern extent of the species' range and breeds in a desert riparian environment. Prey utilization by inland breeding Bald Eagles is well documented (Lincer et al. 1979); however, little has been published on prey use by this desert-dwelling population. Our objectives were to determine diet composition, to compare prey use with that from other regions, and to examine foraging behavior to determine what aquatic habitat was used in foraging. This study was conducted in order to provide baseline information needed by agencies to evaluate potential effects of proposed construction of water-storage and flood-control dams on major Arizona waterways.

STUDY AREA

The study area was along the Salt and Verde rivers in Arizona, covering approximately 160 km upstream on each river from the Salt-Verde confluence. General locations of the 11 nest sites studied are presented in Figure 1. The Salt River drains the western White Mountain area and the eastern Mogollon Rim. The Verde River drains the western Mogollon Rim and the central mountains. Several water impoundments occur on these waterways, but no active nest site is known to occur at any of these impoundments. Vegetation of the areas surrounding each nest site is that found in the Lower and Upper Sonoran Life Zones (Lowe 1964).

METHODS

Eleven nests, composing the entire Arizona breeding Bald Eagle population known during the course of this study, were observed from the 1976 breeding season through the 1982 breeding season. Two to three observers were stationed at inconspicuous, yet advantageous, lookout points at each nest site. Radio communications between observers at several nest sites aided in visually tracking the eagles. All flight paths, perches, and foraging sites were drawn on 7.5-min USGS topographic maps. Foraging sites were defined as the precise location where a prey capture, or attempted prey capture, was observed.

Preliminary observations indicated that Bald Eagle pairs were habitually foraging from the same general areas of free-flowing water. In order to examine what characteristics of the aquatic habitat may be important to foraging success, we determined river-bottom profiles for 23 foraging sites by recording substrate, bottom depth, and water level at 1.5-m intervals. Substrate was classified into nine categories as defined by Trihey and Wegner (1981).

From 1978 to 1982, prey remains were collected during banding of young, from adult foraging sites, and from in and around all 11 active nests after all birds had dispersed. Prey was identified from characteristic fur, bones, and body parts. When multiple numbers of body parts of a given species were present at one time and place, the greatest number of the same body part was used to determine the number of prey individuals present. This method was evaluated by comparison with recorded observations of adults returning to the nest with prey. At the time of delivery to the

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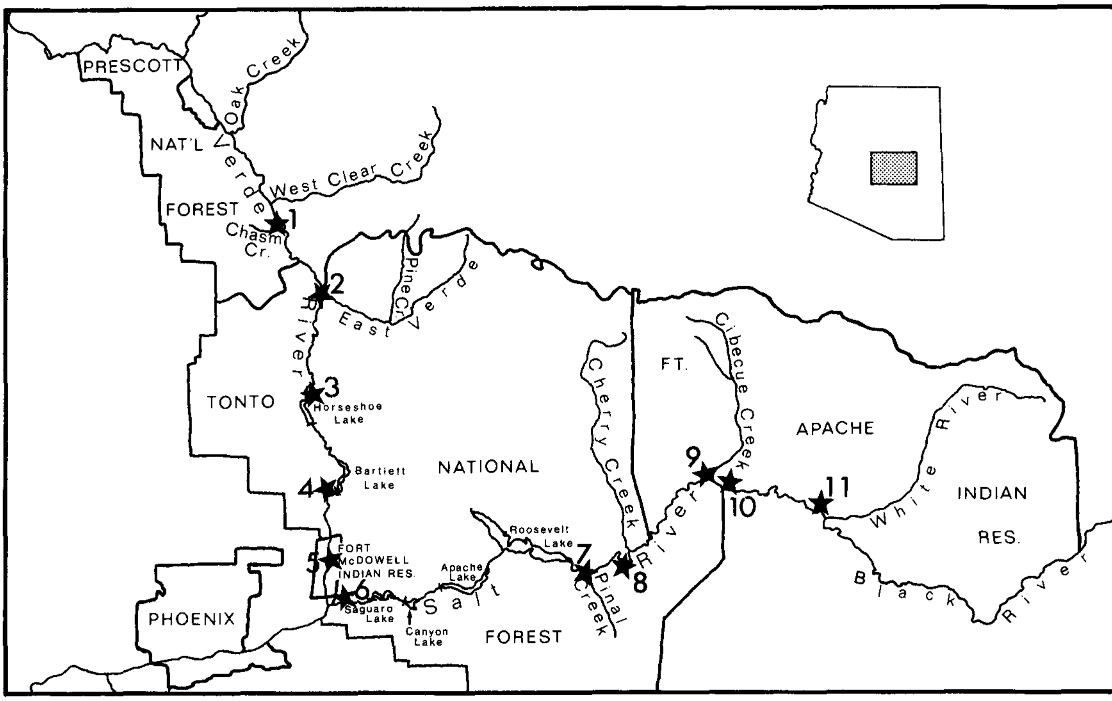

FIGURE 1. Bald Eagle nest sites along the Salt and Verde rivers in Arizona.

nest, prey were visually identified to the lowest possible taxon.

Disparities in biomass of each prey being taken by eagles were accounted for by estimating biomass of each prey species. Body sizes of piscine prey were determined by deriving regression equations between body size and the size of two body parts from known standards. A sample of 45 carp (*Cyprinus carpio*), 38 Sonora suckers (*Catostomus insignis*), and 36 desert suckers (*C. clarki*) were collected from the Salt, Verde, and Gila river systems and from canals in the Phoenix area. Each fish was weighed and measured, and the opercle was extracted and measured for total length (variation of McConnel 1952). A regression equation for opercle length and standard length was calculated. (Standard length is the distance from the most anterior part of the fish to the posterior end of the vertebral column and does not consider tail length.) Standard lengths of carp and suckers delivered to eagle nests were calculated using the retrieved opercle and the standardized regression equation.

A similar regression equation was derived for channel catfish (*Ictalurus punctatus*) by relating pectoral spine diameter to body size (variation of Sneed 1951, DeRoth 1965). The diameter of pectoral spines was measured from a collected sample of 157 channel catfish, in addition to the total length of the fish (data courtesy of W. L. Minckley and P. C. Marsh, Arizona State University). Data were originally collected as total length (including tail length) and were therefore converted to standard length by a factor of 1.201 (Carlander 1969) to ensure conformity. Measurements from this sample of known standards were used to derive a regression equation between spine diameter and body size. Diameters of pectoral spines of 141 individual channel catfish retrieved from eagle prey remains were then measured and standard lengths of channel catfish taken as prey were calculated.

Body weights of remaining prey species were from the literature or unpublished data of specimens from other field studies. We used whole body weight because Stalmaster and Gessaman (1982) reported similar edible proportions for Mallards (*Anas platyrhynchos*), black-tailed jackrabbits (*Lepus californicus*), and chum salmon (*Oncorhynchus keta*). Furthermore, we could not determine whether sequential deliveries to the nest of partial prey bodies were from one or more individuals.

RESULTS

A total of 697 observations were made of prey captures and/or return of an adult to the nest with prey. Of these deliveries, 73% were fish, 17% were unidentifiable, 5% were mammalian, 1% were avian, and 4% were reptilian or amphibian. This differed minimally with the class composition identified from prey remains. Using the latter, we determined that 77% of 481 prey taken by eagles were fish, 12%

TABLE 1. Species composition and biomass of prey remains for Bald Eagles in Arizona 1979–1982.

Species	Number of individuals	Average body weight	Biomass taken (g)	Percent total biomass	Percent total individuals	Source of average body weight
Fish						
Channel catfish	180	263	47,340	21.8	37.4	This study
Sonora sucker	64	293	18,752	8.6	13.3	This study
Carp	59	636	37,542	17.3	12.3	This study
Flathead catfish (*Pylodictis olivaris*)	22	239	5,258	2.4	4.6	Mean of mean lengths from this study; weight calculated from U.S. Bureau of Reclamation (1982)
Desert sucker	21	337	7,077	3.3	4.4	This study
Bullhead catfish (*Ictalurus nebulosus*)	8	239	11,912	0.9	1.7	Estimated from flathead catfish above
Bass spp.	6	556	3,336	1.5	1.2	Mean of mean lengths from this study; weight calculated from U.S. Bureau of Reclamation (1982)
Yellow bass (*Morone mississippiensis*)	5	556	2,780	1.3	1.0	Mean of mean lengths from this study; weight calculated from U.S. Bureau of Reclamation (1982)
Unidentified	3	390	1,170	0.5	0.6	Mean of mean fish weights above
Totals	368		125,149	57.6	76.5	
Birds						
American Coot (*Fulica americana*)	27	654	17,658	8.1	5.6	Fredrickson (1969)
Great Blue Heron (*Ardea herodias*)	5	1,905	9,525	4.4	1.0	Poole (1938)
Unidentified	5	65	325	0.2	1.0	Estimated
Mourning Dove (*Zenaida macroura*)	4	134	536	0.2	0.8	Ivacic and Labisky (1973)
Northern Flicker (*Colaptes auratus*)	2	130	260	0.1	0.4	Anderson and Ohmart (unpubl. data)
Gila Woodpecker (*Melanerpes uropygialis*)	2	62	124	0.1	0.4	Anderson and Ohmart (unpubl. data)
Great Egret (*Casmerodius albus*)	1	899	899	0.4	0.2	Poole (1938)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	1	47	47	0.0	0.2	Pough (1957)
Northern Oriole (*Icterus galbula*)	1	33	33	0.0	0.2	Baldwin and Kendeigh (1938)
Unidentified duck	1	850	850	0.4	0.2	Bureau of Land Management (1979)
Gambel's Quail (*Callipepla gambelii*)	1	173	173	0.1	0.2	Anderson and Ohmart (unpubl. data)
Common Poorwill (*Phalaenoptilus nuttallii*)	1	43	43	0.0	0.2	Lasiewski et al. (1971)
Blue Grosbeak (*Guiraca caerulea*)	1	27	27	0.0	0.2	Anderson and Ohmart (unpubl. data)
Great-tailed Grackle (*Quiscalus mexicanus*)	1	134	134	0.1	0.2	Anderson and Ohmart (unpubl. data)
Totals	53		30,634	14.1	11.0	
Mammals						
Cottontail rabbit (*Sylvilagus audubonii*)	17	1,028	17,476	8.1	3.5	Hall and Kelson (1959)
Black-tailed jackrabbit	14	2,313	32,382	14.9	2.9	Hall and Kelson (1959)
Unidentified mammal	13	587	7,631	3.5	2.7	Mean of average mammal weights
Woodrat (*Neotoma* sp.)	4	150	600	0.1	0.8	Anderson and Ohmart (unpubl. data)
Mouse (*Peromyscus* sp.)	3	20	60	0.1	0.6	Laurenzi (unpubl. data)
Rock squirrel (*Spermophilus variegatus*)	3	817	2,451	1.1	0.6	Burt and Grossenheider (1964)
Antelope ground squirrel (*Ammospermophilus* sp.)	1	150	150	0.1	0.2	Burt and Grossenheider (1964)
Pocket mouse (*Perognathus* sp.)	1	16	16	0.1	0.2	Anderson and Ohmart (unpubl. data)
Pocket gopher (*Thomomys bottae*)	1	200	200	0.1	0.2	Hall and Kelson (1959)
Totals	57		60,966	28.1	11.9	
Reptiles						
Unidentified snake	2	190	380	0.2	0.4	Steenhof (1983)
Unidentified lizard	1	21	21	0.0	0.2	Steenhof (1983)
Totals	3		401	0.2	0.6	
Grand totals	481		217,150			

TABLE 2. Length and weight of four major fish species found in prey remains as estimated from regression on opercle length or pectoral spine diameter. SEM = standard error mean.

Species	*n*	Length (mm)			Weight (g)		
		Mean ± SEM	Min	Max	Mean ± SEM	Min	Max
Channel catfish	141	253.6 ± 5.1	127.8	476.2	263 ± 18	29	1,492
Carp	73	313.3 ± 6.7	160.8	437.5	636 ± 34	106	1,432
Sonora sucker	23	287.5 ± 17.7	165.8	472.9	293 ± 51	49	995
Desert sucker	8	242.4 ± 17.8	162.7	314.4	337 ± 66	103	646
Total	245						

mammalian, 11% avian, and 0.6% reptilian or amphibian.

FISH

In terms of number of individuals, channel catfish were the most frequently utilized fish and the most common prey of any taxon taken by Bald Eagles in Arizona (Table 1). Channel catfish composed 49% of fish prey species and 37% of the total prey items. Other fish species principally taken were Sonora sucker, carp, flathead catfish, and desert suckers. Mean lengths and weights of these four species are presented in Table 2. Flathead catfish ranked fourth in number of individuals found in nests. We did not, however, calculate regression equations to determine length and weight because of difficulties encountered in obtaining fish needed as standards for the derivation. Because of similarity in mean length of the four prey species (channel catfish, carp, desert sucker, and Sonora sucker) examined, we pooled data sets for presentation. In consideration of these major species, 76% of 245 fish that were retrieved as prey remains and possessed an opercle or pectoral spine were from 200 to 350 mm in standard length (Fig. 2). Mean predicted body weights ranged from 263 to 636 g. Regression equations that were used to determine lengths and weights are presented in Table 3.

AVIAN AND MAMMALIAN PREY

Several birds and mammals were common as prey remains (Table 1). American Coots were frequent and ranked fourth in total number. Other birds of small or moderate size were infrequent. The most common mammals found in prey remains were cottontail rabbits and black-tailed jackrabbits, which composed more than 6% of the total number of individuals.

BIOMASS

Estimated body weights of individuals found in prey remains varied greatly (Table 1). Smallest remains were those of a pocket mouse, and the largest prey items were those of black-tailed jackrabbits. However, only 13 species composed approximately 96% of the estimated biomass. These results agree with our findings based on number of individuals, with the exception of carp and black-tailed jackrabbits, both of which demonstrated higher utilization because of larger body size. In reference to biomass, channel catfish, carp, and black-tailed jackrabbits composed approximately 54% of the total estimated biomass.

FORAGING SITES

We were able to observe foraging at 24 locations from seven nest sites. Fish capture success rates and descriptive measurements of each foraging site are presented in Table 4. Capture success rates varied greatly between foraging sites and yielded a total capture success rate of 78%.

Foraging sites at Nest 1 consisted of a riffle and a deep pool below the nest. Sites A and B were in close proximity and were treated as one location since captures occurred at various distances between them as well as specifically at them. Measurements for these and other foraging sites were taken at low stream flows at the end of the breeding season to avoid disturbance of the breeding pair. Therefore, for-

TABLE 3. Regression equations used to determine length and weight of Bald Eagle prey remains from opercles or pectoral spines.

Species	*n*	Length regression equation	*r*	Weight regression equation	*r*
Channel catfish	157	$y = -0.0043 + 0.145(x)$	0.94	$y = (6.03 \times 10^{-6})x^{3.06}$†	0.98
Carp	45	$y = 1.30 + 0.152(x)$	0.97	$\log y = -1.77 + 2.69(\log x)$	0.94
Sonora sucker	38	$y = 1.63 + 0.112(x)$	0.93	$y = (1.97 \times 10^{-5})x^{2.88}$†	0.99
Desert sucker	37	$y = 0.79 + 0.091(x)$	0.95	$\log y = 0.497 + 0.346(\log x)$	0.95

† U.S. Bureau of Reclamation 1982.

aging site B represents a deep pool even though the maximum depth was 0.88 m; at higher stream flow, depths exceeded 1.8 m.

Locations C and D at Nest 2 were a riffle and a shallow backwater, both in sight of the nest. Foraging site E was a deep pool extending to a shallow area.

The outstanding characteristic at Nest 4 was the depth of pools at F, H, and I. Depth ranged from 3 m to >6 m. Each pool was deepest at the outside of a wide, sweeping arc that the river formed below the nest cliff. The pools then developed into broad, sandy shallows along the inner radius of the river arc. In conjunction with these pools, there was a riffle at site G and a broad shallow preceding a riffle at site J.

Foraging sites at Nest 7 were similar. A riffle preceded site K, which was followed by a series of deep pools at L. The same configuration of a deep pool was noted by a sharply deepening wall on the external arc of the river bend and gradual sloping shallows on the internal arc. Immediately downstream of site L was a riffle at M. Foraging sites N, O, and P were located in an area that is popular with sport fishermen, who reported an abundance of catfish. Use of the river by fishermen intensified during May and presumably indicated a catfish run. Site Q consisted of a riffle resulting from a broad sandbar, and immediately preceded the Roosevelt Lake-Salt River delta.

Configuration of the river at Nest 8 foraging sites were similar to those previously discussed. The riverbanks at these sites dropped rapidly on the external arc of a bend in the river and extended to broad shallows of a sandbar.

Site V was a shallow backwater preceding a rapids, and site W was very similar to site E. A large, decadent cottonwood (*Populus fremontii*) provided a foraging perch below which was a pool of moderate depth. A large sandbar was opposite the cottonwood perch and displayed broad shallows.

FEEDING HABITS

Concurrent observations of time of prey capture yielded further insight into the use of prey by eagles. We recorded 733 observations of prey captures, capture attempts, or deliveries of prey to young according to hour of sunrise when they occurred (Fig. 3). The day was divided into four time periods of which Period 1 consisted of hours 1 through 4 and each subsequent period consisted of the following 3 hr. Two peak periods of foraging were evident: between 1 and 4 hr after sunrise and between 8 and 10 hr after sunrise ($\chi^2_{[3]} = 17.2$, $P < 0.01$). When comparing each hour individually, a significant difference between hours was found for all prey classes combined ($\chi^2_{[12]} = 22.7$, $P < 0.05$). However, when examining fish only, no significant difference between hours could be found ($\chi^2_{[12]} = 15.7$, $P < 0.05$).

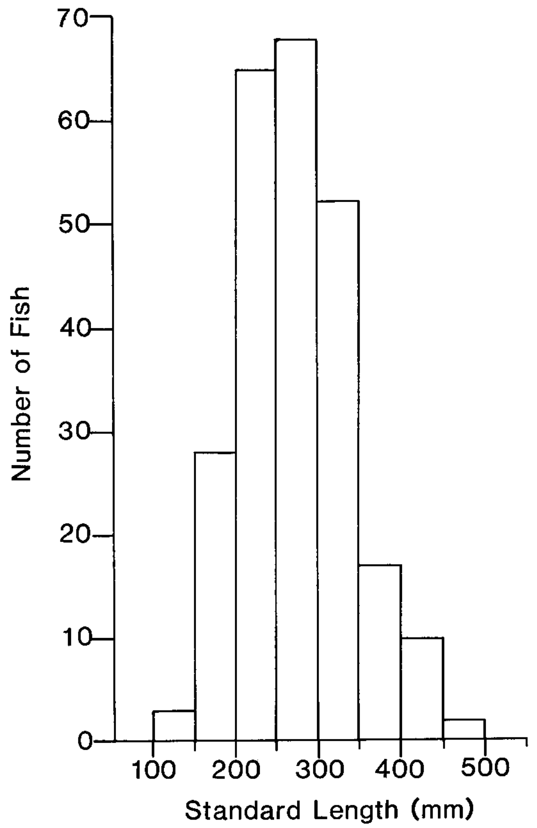

FIGURE 2. Size distribution of four major species found in prey remains: carp, channel catfish, desert suckers, and Sonora suckers.

DISCUSSION

Our results show that the Arizona breeding Bald Eagle population utilizes primarily carp, catfish, suckers, coot, and black-tailed jackrabbit, whether considering biomass or simply number of individuals. Because of their large body size, black-tailed jackrabbits represented nearly 15% of the total biomass taken. One might predict that this eagle population, breeding in a desert riparian habitat, would utilize mammalian prey to a larger extent than populations located in more temperate climates. However, the role that the black-tailed jackrabbit plays in the diet of Bald Eagle nestlings may not be as important as indicated by this estimate. We have observed an adult tearing a jackrabbit carcass in half and returning to the nest laboriously with only part of the carcass. Therefore, transportation of a portion of larger prey items to the nest may occur. The caloric content of the jackrabbit, however, may

TABLE 4. Prey capture success rates and descriptive statistics of observed Bald Eagle foraging sites. N.L. = foraging sites listed as N.L. were from early notes, and locations were not detailed.

Nest site	Foraging site	Captures	Attempts	Percent success	Width (m)	Mean depth (m)	±SEM	Max depth (m)	L/S (cfs)	Distance to nest (km)	Description
1	A	30	5	86	29	0.51	0.06	0.88	1,303 (46)	0.04	Riffle
	B	*	*	*						0.04	Deep pool
	N.L.	2	4	34							
Subtotal		32	9	78							
2	C	10	4	71	56	0.21	0.03	0.66	1,303 (46)	0.04	Riffle
	D	1	3	25	37	0.45	0.06	0.88	1,303 (46)	0.25	Shallow backwater
	E		2	0	49	0.66	0.07	1.59	1,303 (46)	0.68	Deep pool
	N.L.	2	5	29							
Subtotal		13	14	48							
4	F	1		100	49	3.78	0.37	6.28	42,899 (1,515)	0.60	Deep pool
	G	3		100	64	0.38	0.02	0.59	42,899 (1,515)	0.40	Riffle
	H	16	1	94	46	1.66	0.18	2.71	6,201 (219)	0.09	Deep pool
	I	11		100	73	1.50	0.16	3.52	42,899 (1,515)	0.15	Deep pool
	J	4		100	80	0.43	0.03	1.07	42,899 (1,515)	0.23	Riffle
	N.L.	10	6	63							
Subtotal		45	7	87							
7	K	1	1	50	35	0.42	0.05	0.67	9,826 (347)	0.90	Broad shallows
	L	1		100	30	1.49	0.30	4.33	8,495 (300)	0.50	Deep pool
	M	1		100	37	0.37	0.04	0.75	54,622 (1,929)	0.40	Riffle
	N	1		100	27	0.38	0.05	0.60	54,622 (1,929)	1.80	Deep pool
	O	1		100	61	0.58	0.05	1.02	54,622 (1,929)	3.20	Broad shallows
	P	1		100	79	0.76	0.06	1.35	54,622 (1,929)	3.40	Riffle
	Q	1		100	Not measurable					7.50	Shallow sandbar
	N.L.	2		100							
Subtotal		9	1	90							
8	R	5		100	37	0.44	0.08	1.22	10,817 (382)	0.15	Deep pool
	S	9	1	90	43	1.44	0.23	4.08	10,817 (382)	0.03	Deep pool
	T	14	1	93	26	1.04	0.17	2.06	10,817 (382)	0.33	Deep pool
	U	3		100	24	1.20	0.14	1.99	10,817 (382)	0.80	Deep pool
Subtotal		31	2	94							
6	V	1		100	34	0.28	0.03	0.44	7,844 (277)	1.4	Shallow backwater
	W	5	4	56	90	0.78	0.04	1.31	25,456 (899)	12.6	Deep pool
Subtotal		6	4	60							
3	X	7	3	70	Not measurable					0.90	Shallow sandbar
Subtotal		7	3	70							
Total		143	40	78							

* Sites A and B treated as one location (see explanation in text).

be greater than that of the catfish, carp, or suckers and may compensate for waste resulting from partial delivery. Stalmaster and Gessaman (1982) reported wet metabolizable energy available to Bald Eagles from jackrabbit (0.9232 Kcal/g) to be larger than that from salmon (0.6751 Kcal/g). We conclude that mammalian prey is essential to satisfy energy demands of Bald Eagles breeding in Arizona. The large number of catfish, carp, and sucker individuals, however, provide a continued source of forage upon which the population is dependent.

The opportunistic foraging behavior of Bald Eagles is well documented, yet several studies have found that inland eagles prey chiefly on benthic-feeding fish (Table 5). This trend is apparent throughout diverse habitats and climatic regions. Wright (1953) further determined experimentally in New Brunswick that brown bullhead catfish, white suckers, and chain pickerel were preferred by Bald Eagles, with brown bullhead catfish preferred when available. Our results strongly agree with previous findings. Catfish, carp, and suckers composed 74% of all prey remains collected in and around Bald Eagle nests in Arizona.

Swenson (1979) showed that benthic-feeding fish were more vulnerable to predation by Osprey (*Pandion haliaetus*) than were limnetic-feeding fish. He further suggested that the downward visual concentration and slower escape movements make them more vulnerable than piscivorous fish. Todd et al. (1982) argued that the high occurrence of benthic-feeding fish in remains of Maine Bald Eagle prey is due,

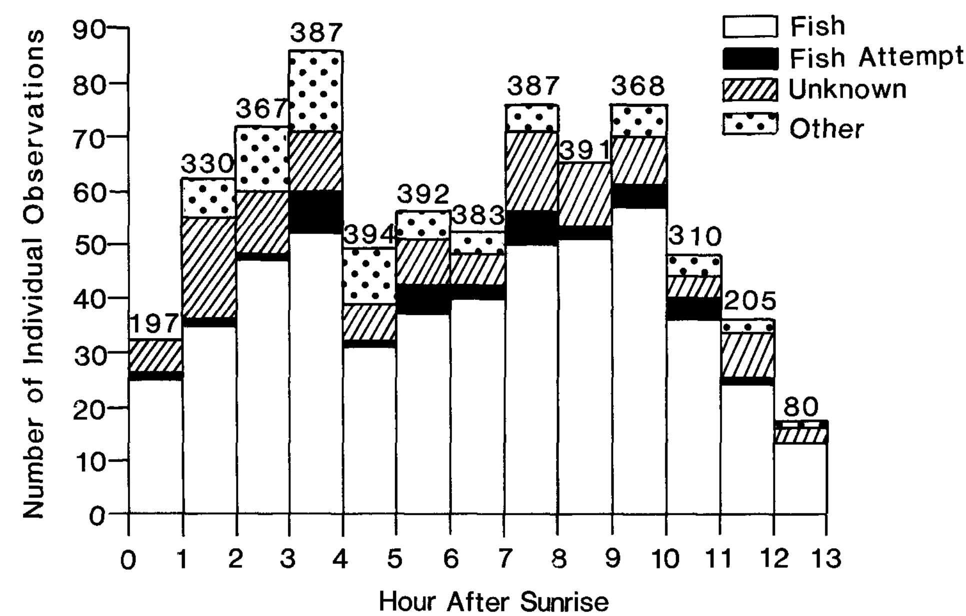

FIGURE 3. Time and frequency of adults returning to the nest with prey. Numbers above bars are hours of observation per hour of day. Total hours of observation = 4,191.

among other reasons, to a greater vulnerability to aerial predation.

We observed several stream characteristics that we believe relate directly to prey vulnerability and availability. Deep pools bounded by riffles and/or sandbars were common at all nest sites. Pool depth was such that at low flow, or even cessation of flow, water depth was maintained in excess of 3 m. Figure 4 presents a cross-section of foraging site I, which was representative of these pools. Each pool was deepest at one side and developed into broad shallows on the opposite bank. Deep pools provide habitat for prey fish species, especially during cessation of river flow. Shallows and riffles that were frequently found immediately upstream or downstream of the pools provided forage for benthic-feeding fish and, simultaneously, brought them nearer to the water surface, thereby increasing vulnerability. Furthermore, we found that of the seven nest sites where foraging was observed (Table 4), six nests were located immediately adjacent to foraging sites and were the most frequently used foraging perches at each nest site. Therefore, an apparent relationship exists between nest placement and physical characteristics of the river. We have shown that there was no significant difference between hour of day and number of fish captured. Thus, prey fish were accessible throughout the day and foraging was a continual process. This demonstrates the im-

TABLE 5. Recent studies indicating the predominance of benthic-feeding fish in inland Bald Eagle diets.

Author	Location	Species	% Diet
Todd et al. (1982)	Maine	Brown bullhead catfish	25
		White sucker (*Catostomus commersoni*)	20
Cline and Clark (1981:20)	Chesapeake Bay, MD	Catfish and carp	77
McEwan and Hirth (1980)	Florida	Brown bullhead catfish Blue catfish (*I. furcatus*) Lake chubsucker (*Erimyson sucetta*)	67
Dugoni (1980)	Louisiana	*Ictalurus* sp.	22
Dunstan and Harper (1975)	Minnesota	Bullhead	
		I. nebulosus *I. natalis* *I. melas*	35
		Suckers	
		C. commersoni *Moxostomer macropidotus*	20
		Northern pike	14

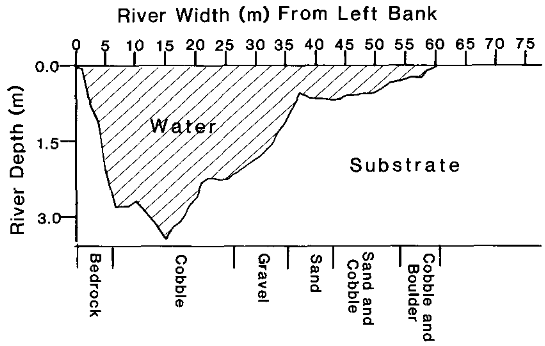

FIGURE 4. River-bottom profile of Site I, a representative foraging site of Arizona breeding Bald Eagles.

portance of nest placement which allowed simultaneous monitoring of young and foraging.

In conclusion, we believe that a much stronger relationship exists between aquatic habitat and Bald Eagle productivity than has been previously indicated by other studies. The dependence of inland breeding Bald Eagles on benthic-feeding fish relates nest site selections to physical characteristics of the stream bottom. A productive river bottom is essential to the life cycle of benthic-feeding fish and, consequently, is essential to nest site establishment and continued productivity of inland breeding Bald Eagles.

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