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WINTER FORAGING ECOLOGY OF BALD EAGLES ON A REGULATED RIVER IN SOUTHWEST IDAHO

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ABSTRACT.—We studied Bald Eagle foraging ecology on the South Fork Boise River, Idaho, during the winters of 1990–92. We compared habitat variables at 29 foraging sites, 94 perch sites, and 131 random sites. Habitat variables included river habitat (pool, riffle, run), distance to the nearest change in river habitat, distance to nearest available perch, number and species of surrounding perches, and average river depth and flow. Eagles foraged more at pools than expected, and closer (<15 m) to changes in river habitat than expected. Where eagles foraged at riffles, those riffles were slower than riffles where they perched or riffles that were available at random. Where eagles foraged at runs, those runs were shallower than runs at either perch or random sites. Eagles perched less at riffles and more at sites where trees were available than expected. Changes in river habitat represent habitat edges where river depth and flow change, making fish more vulnerable to eagle predation. Fish are more susceptible to predation at shallower river depths and slower flows. Slower river flows may be related to decreased surface turbulence, which also increases vulnerability of fish to aerial predation.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *wintering ecology*; *foraging ecology*; *dams*; *rivers*; *Idaho.*

Ecología del forrajeo de invierno de águilas Calvas en un rio regulado del suroeste de Idaho

RESUMEN.—Estudiamos la ecología de forrajeo de águilas Calvas en el Río South Fork Boise en Idaho, durante los inviernos de 1990–1992. Comparamos las variables de habitat en 29 sitios de forrajeo, 93 perchas y 131 sitios al azar. Las variables de habitat incluyeron habitats del río (pozos, escorrentias, otros), la distancia al cambio de habitat mas cercano del río, la distancia mas cercana a una percha disponible, el número y especies de perchas alrededor y el promedio de profundidad y escorrentia. Las águilas forrajearon mas en los pozos de lo esperado, y mas cerca (15 m) a los cambios de habitat en el río de lo esperado. En los sitios poco profundos en donde las águilas forrajearon, estos fueron mas lentos que aquellos en donde las águilas utilizaron perchas disponibles al azar. En los sitios en donde las águilas se percharon en escorrentias, estas fueron menos profundas que las de las perchas o sitios al azar. Las águilas utilizaron menos perchas en sitios de escorrentias y mas en sitios en donde los árboles estaban mas disponibles de lo esperado. Los cambios de habitat en el río estaban representados por las orillas en donde la profundidad y el flujo variaban, haciendo a los peces mas vulnerables a la depredación de las águilas. Los peces son mas susceptibles a la depredación en los niveles menos profundos y en escorrentias mas lentas los cuales pueden estar relacionados con la disminución de la turbulencia en la superficie, lo que aumenta la vulnerabilidad de los peces a la depredación aerea.

[Traducción de César Márquez]

The winter diets of Bald Eagles (*Haliaeetus leucocephalus*) differ depending on locale, habitat, weather conditions, and prey availability, but fish are selected most often when available (Stalmaster 1987). Bald Eagles may concentrate during winter near dams where open water and fish are readily available (Steenhof et al. 1980). Dams can keep downstream areas from freezing and can provide a reliable source of fish that have been killed or stunned while passing through dam turbines (Steenhof 1978, Brown et al. 1989). In rivers, benthic-feeding fish are the most commonly taken

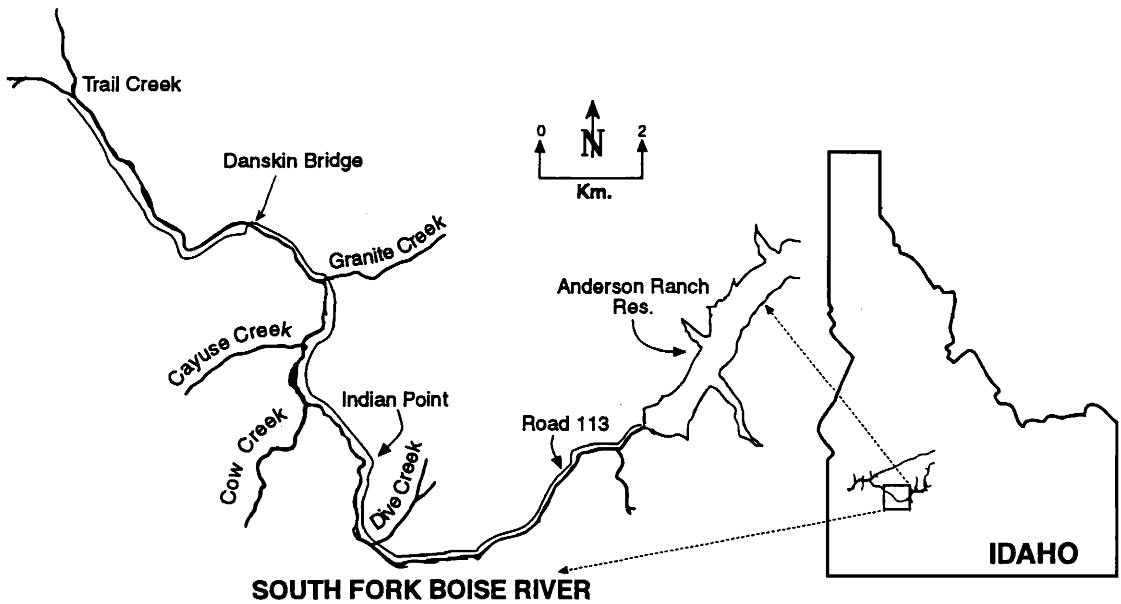

Figure 1. South Fork Boise River, Idaho, studied during winters 1990–92; Anderson Ranch Dam to Trail Creek.

prey (Dunstan and Harper 1975, McEwan and Hirth 1980, Todd et al. 1982, Haywood and Ohmart 1986, Hunt et al. 1992), but eagles may also take rainbow trout (*Oncorhynchus mykiss*) if available (Brown et al. 1989, Spahr 1990, Brown 1993). The Boise River, a tributary of the Snake River, is a major drainage containing free-flowing and regulated river reaches and three reservoirs. Mammal carrion and fish are the main prey of Bald Eagles wintering in the Boise River System (Kaltenecker and Bechard 1995, Kaltenecker 1997). We studied foraging ecology of Bald Eagles on the South Fork Boise River during the winters of 1990–92, and present results which identify and describe foraging and perching habitat.

STUDY AREA AND METHODS

The South Fork Boise River flows from the Sawtooth Mountain Range in southwestern Idaho and drains an area of approximately 1568 km^2 (Gebhards 1964). Anderson Ranch Dam, a U.S. Bureau of Reclamation power-generating and irrigation facility, is 19 km downstream from the town of Pine. Our study area included approximately 20 km of river located between Anderson Ranch Dam and Trail Creek and was easily accessible by vehicle along U.S. Forest Service road #113 (Fig. 1). Both the river and Bald Eagles perching along it could be seen from our observation points on the road. The South Fork flowed through a steep-sided valley dominated by shrub-steppe vegetation consisting of sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), native perennial grasses (*Poa secunda, Pseudoregnaria spicata, Aristida longiseta*), and exotic annuals cheatgrass (*Bromus tectorum*) and medusahead rye (*Taeniatherum caput-medusae*). Cottonwood/willow riparian vegetation (*Populus trichocarpa, Salix* spp., *Betula* spp., *Alnus* spp.) dominated the river bottom and other riparian areas. Some mixed-conifer stands (*Pinus ponderosa, Pseudotsuga menziesii*) were present on north-facing slopes. Elevations ranged from 1100–1220 m, and temperature extremes varied from $-30°C$ to 16°C during December–March. River flows were regulated by Anderson Ranch Dam and were maintained at the standard winter minimum flow (approx. 91 m^3/s) throughout both winters. Drought conditions prevailed during both years of the study.

We conducted a total of 224 hr of foraging observations on 28 d between 15 December–1 March (12 days during the first winter, and 16 days during the second winter). Observations were conducted by one person from a vehicle using 8 × 30 binoculars and 45× spotting scope. We began observing at dawn, and continued throughout the day until all eagles left the river or returned to night roosts. Observation points were selected so that perched or flying eagles and the river were in full view between 150–500 m away from the observer. We recorded foraging activity as successful or unsuccessful attempts at fish prey. A foraging site was defined as the exact point in the river where a foraging attempt was made. Foraging attempts were initiated either from the wing or nearby perch locations. We identified fish species taken by eagles from observation of prey captures or feeding, or by analysis of prey remains collected from feeding sites immediately after eagles departed. Remains used to identify fish species included scales, opercular bones, and mandibles. During observations, we also recorded all perches used by eagles within 75 m of the river. Perch sites were defined as any tree, cliff, or rock outcrop where we observed eagles perching. Perches from which prey strikes were initiated were included in the sample of perch sites.

Once a foraging site had been identified, we returned to it during late February or March of the same winter and measured surrounding habitat. Because river flows were regulated at a constant level throughout both winters, we assumed that surrounding habitat did not change significantly between observation of prey captures and measurement of habitat. We used a line-transect method modified from Bovee (1982) and Platts et al. (1983) to measure physical habitat parameters associated with each foraging site. At each foraging site, we recorded predominant river habitat (three categories: pool, riffle, run), distance to nearest change in river habitat, and distance to the nearest perch. Furthermore, a transect was established across the river perpendicular to flow, and river depth, stream flow, and bottom substrate were recorded at five equidistant points (verticals) along the transect. At each vertical, we measured depth and flow using a Price AA flowmeter. At each end of the transect, we recorded the number of surrounding perches and predominant species of tree within a 75 m arc. At all eagle perch sites located within 75 m of the river, we measured surrounding habitat as described above for foraging sites. Lastly, we selected an additional sample of sites by converting random numbers into distances (m) downstream from Anderson Ranch Dam. After locating random sites using a metric tape, we measured surrounding habitat similar to foraging and perch sites.

Habitat variables associated with foraging, perch, and random sites were analyzed using logistic regression (LOGIST procedure, SAS 1990), which determines the effects of several different independent variables on a single dependent variable (Harrell 1986, Trexler and Travis 1993). The dependent variable in our analyses was site type (three categories: foraging, perch, or random). We conducted three separate logistic regression analyses, comparing foraging to random sites, foraging to perch sites, and perch to random sites. We used stepwise logistic regression, with the significance level to enter the model and to remain in the model set at 0.15. Independent variables entered into the analyses were river habitat (pool, riffle, run), distance to nearest change in river habitat, presence of available perches, distance to nearest perch, and number of surrounding perches. River habitat is a nominal variable, and was therefore transformed into a set of 0,1 variables that were used in the analysis. To prevent over specification of the model, we considered the variable "run" as the base state and did not include "run" in the model; thus, we determined if being a pool or riffle increased the chance of, for example, being a foraging site. Distance to the nearest perch was placed in a category of 1 to 6, with 1 = 0–10 m, 2 = 11–25 m, 3 = 26–50 m, 4 = 51–75 m, and 5 = >75 m. Number of perches was placed in a category of 0–5, with 0 = no surrounding perches, 1 = less than 5, 2 = 6–10, 3 = 10–20, and 4 = >20 perches available within 75 m. We further explored relationships of variables contributing significantly to logistic regression models using Chi-square goodness-of-fit tests (Zar 1984; FREQ procedure, SAS 1990). We calculated average stream flow and depth for each transect, and compared means using analysis of variance (ANOVA; GLM procedure, SAS 1990) to determine if flow or depth characteristics varied significantly between foraging, perch, or random sites by river habitat type.

RESULTS

Counts of Bald Eagles from 18 aerial surveys conducted every two weeks during both winters of our study ranged from 0–17 ($\bar{x}$ = 7.8) eagles. We observed 31 attempted prey captures of fish (17 successful) at 29 different sites, identified 94 eagle perch sites, and collected habitat data from 131 random sites. Fish species taken by eagles included largescale suckers (*Catostomus macrocheilus*, N = 10), mountain whitefish (*Prosopium williamsoni*, N = 4), and rainbow trout (N = 3).

Due to low sample sizes, and because stream flows were similar during both winters, we lumped habitat data collected during both years of the study for analyses. Significant differences existed between foraging and random sites, foraging and perch sites, and perch and random sites. Foraging sites differed from random sites with regard to river habitat and distance to the nearest change in river habitat (Table 1). Further analysis using Chi-square goodness-of-fit tests revealed that eagles foraged at pools more than expected (number expected = 3.63, actual number = 8, χ^2 = 6.1, P = 0.013, df = 1), and that foraging sites were closer (<15 m) to changes in river habitat more than expected (number expected = 5.6, actual number = 12, χ^2 = 9.5, P = 0.002, df = 1). Where eagles foraged at runs, those runs were shallower than runs available at random (Table 2). Where eagles foraged at riffles, those riffles had slower stream flows than riffles available at random.

Perch sites were similar to foraging sites, but differed with regard to distance to the nearest change in river habitat and the number of surrounding perches (Table 1). As with foraging sites compared to random, foraging sites were closer to changes in river habitat (χ^2 = 9.5, P = 0.002, df = 1) than perch sites. Foraging sites also had fewer surrounding perches than perch sites. Perch sites differed from random with regard to the presence, number of, and distance to surrounding perches. Not all random sites had potential eagle perches available within 75 m. No differences existed between perch and random sites with regard to either river depth or flows (Table 2).

Table 1. Results from three separate stepwise logistic regression procedures comparing habitat between foraging and random, foraging and perching, and perching and random sites for Bald Eagles. Sample sizes are in parentheses.

	Parameter Estimate	Standard Error	Wald Chi-Square	P Value	Odds Ratio
FORAGING (29) vs. RANDOM (131)[a,b]					
Intercept	−1.682	0.583	8.331	0.004	
Pool	1.423	0.549	6.768	0.009[e]	4.175[f]
Distance to Habitat Change	−0.018	0.007	5.736	0.017[e]	0.983
Perch	0.967	0.548	3.115	0.078	2.630
FORAGING (29) vs. PERCHING (94)[c]					
Intercept	4.751	1.584	8.999	0.003	
Distance to Habitat Change	−0.015	0.007	4.514	0.034[e]	0.985
Perch	−1.987	1.234	2.591	0.108	0.137
Number of Surrounding Perches	−2.463	0.631	15.194	0.0001[e]	0.085
PERCHING (94) vs. RANDOM (131)[d]					
Intercept	−8.833	1.469	36.15	0.0001	
Pool	0.955	0.606	2.486	0.115	2.599
Distance to Nearest Perch	0.801	0.334	5.731	0.017[e]	2.227
Perch	2.978	1.031	8.332	0.004[e]	19.65
Number of Surrounding Perches	3.812	0.643	35.15	0.0001[e]	45.24

[a] The first of the two listed site types was the modeled state, thus the sign (+ or −) of the parameter estimate indicates whether an increase in the independent variable was associated with a higher (if +) or lower (if −) probability of being a site of the modeled state.

[b] Model statistics: overall $G = 19.74$ with 3 df ($P = 0.0002$); concordance/discordance: 73.6%/22.8%. Concordance is determined as follows. All possible pairings of foraging and random sites are created. A pair of sites is defined as concordant if the foraging site of that pair is also the site predicted by the logistic regression model (based on predictor variables, e.g., habitat) to be the site more likely to be the foraging site. A pair is discordant if the model predicts (incorrectly) that the random site is more likely to be the foraging site. Percents of the total number of pairs that are concordant or discordant are presented. Ties are not presented.

[c] Model statistics: overall $G = 45.22$ with 3 df ($P = 0.0001$); concordance/discordance: 85.6%/12.2%.

[d] Model statistics: overall $G = 153.86$ with 4 df ($P = 0.0001$); concordance/discordance: 85.1%/3.7%.

[e] Denotes variables contributing significantly to stepwise logistic regression models at $P < 0.05$ level (analyses performed using SAS, procedure logist).

[f] A pool site has an approximately four-fold greater probability of being a feeding site than does a non-pool site.

DISCUSSION

Fish species captured by Bald Eagles can influence foraging behavior and foraging site selection in rivers. Many authors have discussed increased vulnerability of bottom-feeding fish to avian predators (Swenson 1979, Todd et al. 1982, Haywood and Ohmart 1986). In our study, eagles took more benthic-dwelling than pelagic fish. River habitat also may influence Bald Eagle foraging site selection. In our study, eagles foraged more from pools than other river habitats. Hunt et al. (1992) reported that eagles foraged more from pools than other habitats in California's Pit River. In Arizona, nesting Bald Eagles also foraged most at pools (Haywood and Ohmart 1986). On the Boise River, Spahr (1990) reported that eagles were observed at pools more than expected. During winter, most fish species, especially salmonids, seek pools or other areas of low stream velocity to maintain position with minimal energy expenditure (Allen 1969, Cunjak and Power 1986, 1987, Hillman et al. 1987). Because of winter temperatures and low stream flows on the South Fork Boise River, it is likely that during our study, pools were areas of high fish abundance.

Changes in river habitat, especially from pool to riffle or pool to run, usually indicate decreasing water depth and a change in stream flow, both found to be important parameters at foraging sites during our study. We found that eagles foraged at sites which were closer to river habitat changes than were random sites. This suggests that changes in river habitat may be important to foraging Bald Eagles as habitat edges. The edges of habitats containing higher prey densities may represent areas where fish become vulnerable to predation due to

Table 2. Results from ANOVA procedures on average depth and average velocity by river habitat type. *P*-values are from ANOVA, means with different letters are different by Tukey's Studentized Range (HSD) tests at $P < 0.05$ level.

	MEAN DEPTH (m)			MEAN FLOW (m/s)		
HABITAT TYPE	*N*	$\bar{x}$	SE	*N*	$\bar{x}$	SE
POOLS						
Foraging	8	0.80a	0.10	8	0.32a	0.05
Perch	13	0.84a	0.10	13	0.33a	0.05
Random	12	0.92a	0.10	12	0.32a	0.05
F, (df), *P* Value		0.33, (2), 0.72			0.10, (2), 0.90	
RIFFLES						
Foraging	8	0.41a	0.04	8	0.62a	0.05
Perch	16	0.40a	0.04	16	0.80b	0.05
Random	38	0.41a	0.04	38	0.71b	0.05
F, (df), *P* Value		0.02, (2), 0.98			3.54, (2), 0.04	
RUNS						
Foraging	13	0.47a	0.03	13	0.57a	0.03
Perch	64	0.57ab	0.03	64	0.54a	0.03
Random	81	0.61b	0.03	81	0.50a	0.03
F, (df), *P* Value		4.76, (2), 0.01			2.96, (2), 0.06	

decreasing water depth. Haywood and Ohmart (1986) reported that eagles foraged from pools bounded by shallows or riffles where benthic feeding fish were vulnerable to predation. Hunt et al. (1992) also showed that eagles foraged from shallow areas of pools. Wintering Bald Eagles in Grand Canyon, Arizona, foraged more in creeks (i.e. smaller, shallower streams) than rivers (Brown 1993). We found that eagles foraged at runs which were shallower than those available at random. Though water depth influences fish vulnerability, foraging site selection by Bald Eagles also may be influenced by stream flow. We found that eagles foraged at riffles with lower stream flows. Water turbulence is related to stream flow; the faster the flow, the greater the turbulence. Low surface turbulence may be an important component of Bald Eagle foraging sites (Hunt et al. 1992), enabling eagles to better detect fish.

We concur with other authors that physical habitat parameters of rivers or streams are important to Bald Eagle foraging site selection and foraging success. Eagles commonly took prey from habitats where fish were likely most abundant, but concentrated foraging efforts at the edges of those habitats where water was shallower and slower, suggesting that vulnerability of prey also may be important.

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