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WINTER BALD EAGLE DISTRIBUTION IS INVERSELY CORRELATED WITH HUMAN ACTIVITY ALONG THE COLORADO RIVER, ARIZONA

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ABSTRACT.—Helicopter surveys for Bald Eagles (*Haliaeetus leucocephalus*) were conducted along the Colorado River through Glen Canyon National Recreation Area and Grand Canyon National Park, Arizona, U.S.A., during winter 1990–91. Eagle abundance and distribution were examined for a possible correlation with human activity levels as documented in National Park Service recreational use reports. Twenty-two times more eagles were detected in river reaches with low human use compared to river reaches with high to moderate human use. Eagle distribution did not correspond to prey abundance, biomass patterns, or habitat conditions frequently associated with eagle foraging habitat. Moderate to high levels of human activity may have been responsible for lower eagle abundance in some reaches of the river, reinforcing the need for continued management of some areas as refugia where species sensitive to human disturbance can be protected from higher levels of human activity.

KEY WORDS: *Bald Eagle; Colorado River; Arizona;* Haliaeetus leucocephalus; *human disturbance.*

La distribución invierna de el *Haliaeetus leucocephalus* esta correlacionada inverso con actividad humana enseguida del Río Colorado, Arizona.

RESUMEN.—Inspecciones de helicóptero para *Haliaeetus leucocephalus* fueron conducidas a lo largo del Río Colorado por el área Nacional de Recreación del Glen Canyon y el Parque Nacional del Grand Canyon, Arizona, U.S.A., durante el invierno de 1990–91. La abundancia y distribución del *H. leucocephalus* fueron examinados por una posible correlación con niveles de actividad humana como fueron documentado en reportes de el Servicio Nacional de Parques. Vieinte-dos veces mas fueron los *H. leucocephalus* descubiertos en tramos del río con uso bajo de humanidad comparado con tramos del río con uso alto y moderado. La distribución de *H. leucocephalus* no correspondió con la presa abundante, patrón de distribución de materia biológica, y condiciones de hábitat frecuentemente asociada con hábitat de forraje de *H. leucocephalus*. Niveles altos a moderado de actividad humana puede ser responsable por la baja cantidad de *H. leucocephalus* en tramos de el río, reforzando la necesidad para la continuación de administración de unos área de refugio donde especie delicadas a molestos humanos pueden ser protegidos de niveles alto de actividad humana.

[Traducción de Raúl De La Garza, Jr.]

Human activities can influence Bald Eagle (*Haliaeetus leucocephalus*) behavior and distribution (Stalmaster 1987). Numerous studies have shown that eagle distribution and foraging behavior can be detrimentally affected by unmanaged human recreational activities such as hiking (Stalmaster and Newman 1978), fishing (Knight et al. 1991, Skagen et al. 1991), and boating (Knight and Knight 1984, McGarigal et al. 1991), and by physical developments within eagle habitat (Buehler et al. 1991). These aspects of eagle-human interaction have been addressed primarily through two types of studies: those directly quantifying eagle "flush response distance" to different categories of human activity (e.g. Stalmaster and Newman 1978, McGarigal et al. 1991), and those indirectly linking eagle distribution to secondary measures of human activity such as housing density and development set-back distance (e.g., Buehler et al. 1991).

The purpose of our study was to test the null

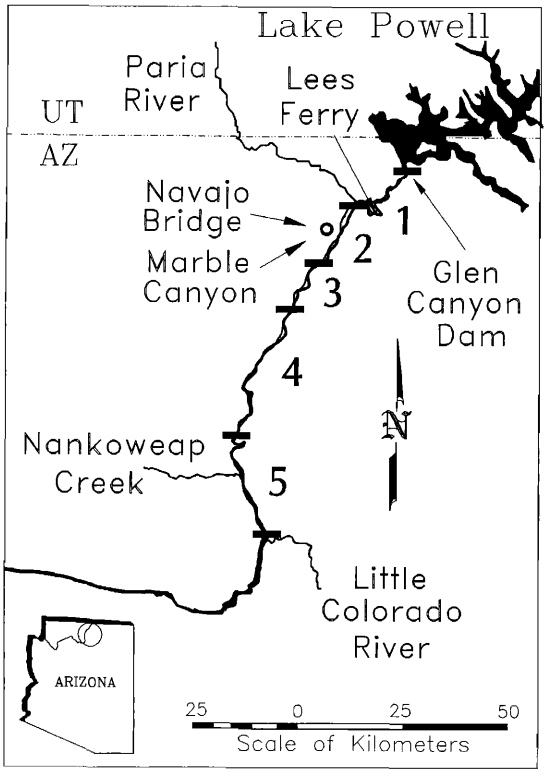

Figure 1. Map of the Colorado River study area in Glen Canyon National Recreation Area and Grand Canyon National Park, Arizona, showing River Reaches One through Five.

hypothesis that winter distribution of Bald Eagles along the Colorado River in Arizona was not correlated with indirect measures of human activity obtained from National Park Service (NPS) recreational use reports. We also considered physical variables and prey differences that may influence eagle distribution.

STUDY AREA AND METHODS

Our study was conducted along the Colorado River through Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP) in northern Arizona, from 2 km downstream of Glen Canyon Dam to the confluence of the Little Colorado River (120.2 km; Fig. 1). The completion of Glen Canyon Dam in 1963 altered the river's physical and biological characteristics, and a subsequent introduction of rainbow trout (*Oncorhynchus mykiss*) benefited wintering Bald Eagles (Brown et al. 1989, Brown and Stevens 1992, Brown 1993). A concentration of wintering eagles began to occur during the 1980s at Nankoweap Creek, 105 km downstream from the dam, when large numbers of spawning trout were present (Brown et al. 1989).

The study area was divided into five river reaches based on bedrock geology (modified after Schmidt and Graf 1990: Table 1). Reaches varied in geomorphic width, but all were in deep canyons bounded by cliffs typically >300 m high. Reach One, from Glen Canyon Dam to the Paria River, supported a productive rainbow trout fishery and was heavily used in winter by bank and boat fishermen from Lees Ferry. Boating activity upstream of Lees Ferry consisted of motorboats used by fishermen; downstream of Lees Ferry, motorized and nonmotorized rafts were on multi-day trips through GCNP. Reach Two, from the Paria River to Soap Creek Rapid, was moderately used by bank fishermen and hikers that accessed it from Lees Ferry or by several trails. The number of raft trips departing downstream to pass through GCNP was limited

Table 1. Habitat features, relative human activity levels, and prey parameters potentially influencing winter Bald Eagle distribution along the Colorado River in Glen and Grand canyons, Arizona.

PARAMETER	RIVER REACH				
	1	2	3	4	5
Length (km)	22.6	16.7	18.5	28.2	34.2
Surface[a] (ha/km)	12.6	9.3	5.3	5.7	9.2
% riffle/rapid[a]	5.7	4.3	13.9	15.8	11.4
Boats/mo[b]	671	30	19	19	19
Fishermen/mo[c]	570	350	10	10	10
Activity level	High	Moderate	Low	Low	Low
Fish[d] (kg/ha)	190	53	69	79	82
Waterfowl[e]	6344	157	101	35	21

[a] Unpubl. data, U.S. Bureau of Reclamation.
[b] Data provided by NPS; Reach 2 estimated.
[c] Data provided by NPS; Reaches 2–5 estimated.
[d] Unpubl. biomass data, 1990–1994, from R.A. Valdez and R.J. Ryel, BIO/WEST, Inc., Salt Lake City, UT, U.S.A.
[e] Number winter waterfowl detected/km^2/hr of observation (Unpubl. data).

Table 2. Numbers of Bald Eagles detected and expected by river reach in winter 1990–1991 along the Colorado River in Glen and Grand canyons, Arizona. Numbers/reach are presented two ways: the entire study period and that time when no spawning trout were in Nankoweap Creek in Reach Five.

	River Reach				
Parameter	1	2	3	4	5
Entire study period					
No. detected	3	3	36	58	43
No. expected	28.5	19.0	22.6	30.3	42.6
Detections/km	0.13	0.18	1.95	2.06	1.26
No spawning trout					
No. detected	3	2	20	41	31
No. expected	19.3	12.9	15.3	20.6	28.9
Detections/km	0.13	0.12	1.08	1.45	0.91

by NPS regulations. The community of Marble Canyon was immediately adjacent to the river where Navajo Bridge on U.S. Highway 89 crossed Reach Two. Reaches Three, Four, and Five extended from Soap Creek Rapid to the Little Colorado River and were remote, far from roads, and accessed only by a few foot-trails, with the number of bank fishermen and hikers limited by NPS regulations. Nankoweap Creek was located in Reach Five.

Fifteen helicopter surveys of the study area were conducted, 1/wk from November 1990–March 1991, to determine eagle abundance and distribution. A special research permit was obtained from NPS for helicopter use because of the potential for helicopters to disturb park resources and visitors. Most surveys occurred before 1200 H. Air speed was approximately 90 km/hr at a height of 100 m above river level on a flight path directly over the river. Surveys were initiated from both ends of the study area. The pilot and front-seat observer detected eagles; a rear-seat assistant recorded observations and localities. Numbers of eagles detected were summarized by reach and compared to expected numbers of eagles/reach using a Chi-square goodness-of-fit test, with statistical significance accepted at $P < 0.05$. Expected numbers of eagles/reach were derived by multiplying the total number of eagles detected by the proportion of total river-km/reach.

Winter boat launches/mo and bank fishermen/mo for Reach One from November 1990–March 1991 were obtained from recreational records maintained by NPS at GCNRA; monthly totals were averaged to obtain mean use. Winter raft launches/mo for Reach Two were obtained from records maintained by NPS at GCNP. Reaches Two through Five had almost identical levels of boating activity since all raft trips launching at Lees Ferry must pass through them; Reach Two received slightly more overall boating use because of motorboat activity by NPS maintenance and patrol trips. Mean numbers of bank fishermen/mo for Reaches Two through Five were estimated based on interviews with NPS personnel and our personal observations.

Results and Discussion

Twenty-two times more eagles were detected in Reaches Three through Five than in Reaches One and Two when total numbers of eagles detected were compared (Table 2; $\chi^2 = 44.0$, df = 4, $P < 0.001$); we found no difference in the number of eagles detected among Reaches Three through Five ($\chi^2 = 5.4$, df = 2, $P = 0.07$). Total numbers of eagles detected/km in Reaches Three through Five were more than 10 times greater than numbers of eagles detected in Reaches One and Two (Table 2).

Eagle distribution did not correspond to estimates of prey distribution. Fewer eagles were observed in Reaches One and Two despite biomass indices that indicated fish and winter waterfowl abundance to be greater in Reaches One and Two (Table 1). Reaches One and Two were wider with many pools with shallow margins all along the river. They also had a smaller percentage of riffle and rapid habitats making them more suitable for eagles as foraging areas (Hunt et al. 1992).

It appeared that negative effects due to moderate to high levels of human activity in these two reaches of the river may have reduced their suitability as eagle foraging areas or perhaps disturbed eagles from perching and roosting habitat. We did not find any eagles within 1 km of intensively used areas near Lees Ferry and Navajo Bridge at Marble Canyon. This negative correlation between human activity and Bald Eagle distribution was consistent with that reported in other studies (Buehler et al. 1991, McGarigal et al. 1991), although reasons why eagles avoid areas of higher human activity remain

unknown (Buehler et al. 1991). Repeated flushing by bank fishermen, hikers, or boats could have caused wintering eagles to avoid those reaches heavily used by anglers. McGarigal et al. (1991) reported a similar finding on the Columbia River where eagles avoided areas with heavy boat traffic. Although apparent habituation of Bald Eagles to human activity has been reported (Knight and Knight 1984), scarcity of eagles in Reaches One and Two of the Colorado River suggested that habituation did not occur in this area.

An alternative hypothesis was that more eagles occurred in Reaches Three through Five because they were attracted to easily accessible spawning trout in Nankoweap Creek (Reach Five). Abundant trout were spawning at Nankoweap from 15 February until the end of the study period (Brown and Stevens 1992). To test this hypothesis, we contrasted numbers of eagles detected/reach when spawning trout were and were not present at Nankoweap. Prior to 15 February, total numbers of eagles detected in Reaches Three through Five were 18 times greater than in Reaches One and Two (Table 2; $\chi^2 = 27.3$, df = 4, $P < 0.001$). Therefore, we rejected the alternative hypothesis.

Managed boating, hiking, and fishing activities are an established use of national parklands. However, we found an inverse correlation between wintering Bald Eagle distribution and human activity along the Colorado River within GCNRA and GCNP. Although correlation does not prove causation, we suggest human activity as the most likely cause. This would represent an apparent contradiction of NPS goals to preserve natural resources for future generations. A tradeoff of resources for recreation may be acceptable if the status quo can be maintained in Reaches Three through Five of our study area. However, the growing popularity of national parks such as GCNP increases economic and political pressures to provide more wilderness recreation opportunities (Frome 1992), and may result in long-term increases in human activity levels in Reaches Three through Five. Our findings reinforce the need to continue to manage some areas as refugia where species potentially sensitive to human disturbance, such as Bald Eagles, are not excluded or influenced by higher levels of human activity.

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