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INFLUENCES OF FLUCTUATING FLOWS FROM GLEN CANYON DAM AND EFFECTS OF HUMAN DISTURBANCE ON WINTERING BALD EAGLES ALONG THE COLORADO RIVER IN GRAND CANYON, ARIZONA

by

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EXECUTIVE SUMMARY

Surveys for wintering and migrating Bald Eagles were conducted along the Colorado River through a portion of Grand Canyon in northern Arizona during the winters of 1990 and 1991. In the Nankoweap study area, numbers of eagles/day varied from 2-26 in 1990 and 1-13 in 1991. Eagle abundance peaked in late February during both years, followed by a rapid decline. This pattern coincided with overall eagle abundance in the Colorado River corridor study area as determined through helicopter surveys, and indicated that the Nankoweap study area represented stopover feeding and resting habitat for spring migrant Bald Eagles.

Age structure varied within and between years, but immature and subadult eagles were significantly more abundant than adults at peak concentrations in both years. Immature and subadult eagles were present in the Nankoweap study area in significantly greater proportions than they were in the adjacent Colorado River corridor study area, demonstrating that younger age classes concentrate near abundant food resources.

Bald Eagles exhibited flow-dependent spatial foraging patterns at and near the confluence of Nankoweap Creek and the Colorado River during the 1990 study period. As river flows increased, the proportion of foraging attempts in the creek increased from ca. 50% to 100%. In contrast,

proportions of river, shore, and isolated pool foraging attempts declined. This pattern occurred because 1) prey on shore or in isolated pools were inundated by the river at higher flows, and 2) the difficulty of foraging in the river apparently increased at higher flow levels, causing eagles to shift their foraging activity to a less difficult foraging habitat.

Eagles foraging in the river corridor at localities other than Nankoweap may temporarily experience reduced opportunities to forage or a reduction in foraging success at the highest river flow levels. Proportionally more foraging attempts occurred > 50 m upstream in Nankoweap Creek during high river flows in 1990, but this flow-dependent shift in foraging patterns did not influence eagle foraging success. Flow-dependent spatial foraging patterns in 1991 were analogous to 1990 patterns, but there was no difference between the proportion of foraging attempts that occurred > 50 and < 50 m upcreek at different river flows. Trout stranded in isolated pools left by fluctuating flows represented a moderate, beneficial contribution to the eagle concentration.

Winter foraging strategies of Bald Eagles exhibited a pattern of dynamic optimization under changing conditions. Eagles acquired food by hunting live prey (86%), scavenging (8%), and interspecific piracy (6%). Most foraging attempts (99%) were for rainbow trout. Hunting methods, success, and

spatial and temporal patterns of foraging differed between years, apparently as a result of changing prey abundance. Eagle foraging strategies were independent of age.

Bald Eagles modified their foraging strategies to maximize foraging success in most instances where risk of injury was minimal. When faced with prey exploitation decisions, eagles should forage in Nankoweap Creek whenever possible using either ground or aerial attacks when prey is abundant. When prey is scarce, eagles should forage in the creek but use aerial attacks. Any forages in the river should use ground attacks, regardless of prey abundance.

Human disturbance strongly influenced the behavior and distribution of wintering and migrating Bald Eagles at the confluence of Nankoweap Creek and the Colorado River from January to March 1991. Forty-six disturbance events occurred in the 1991 study period, preventing eagles from foraging at or near the creek mouth for 13% of all daylight hours. Time required by eagles to return to the creek mouth area after a disturbance event ended differed between disturbance types (mean, SD in minutes; helicopter = 1, 1.3; hiker = 79, 57.5; boat = 42, 56.0). Return times after disturbance increased with increasing duration of disturbance. Low-level helicopter activity within 700 m of the confluence caused > 50% of all eagles to elicit a flushing response. Hiking or boating activities caused > 50% of all adult and immature eagles to flush at distances of 600 m and 300 m,

respectively, but flushing distance decreased with increasing height of eagles above the disturbance. Immature eagles were more tolerant of boating and hiking activities than adults.

If future monitoring indicates the eagle concentration to be of consistent, annual occurrence and of sizeable or increasing abundance, we recommend that park management consider adopting guidelines to control or eliminate human disturbance from the Nankoweap area during the peak eagle concentration.

Paired observation trials to detect Bald and Golden Eagles in the Nankoweap study area were conducted from both rim and river in 1990. Rim observations of Bald Eagles underestimated actual eagle abundance in most cases. The numbers of adult and subadult Bald Eagles were more likely to be accurately represented by rim observations, apparently due to the misidentification of Golden Eagles as immature Bald Eagles from the rim. These findings suggest that: 1) observers should receive more intensive training in identifying Bald versus Golden Eagles prior to annual monitoring; and 2) higher-powered spotting scopes with greater optical quality should be employed during rim monitoring. We recommend that additional rim versus river observation trials to determine eagle numbers be conducted during the first monitoring effort to occur after submission of this report for evaluation of the accuracy of the final protocol.

We recommend that rim (and river, for 1 year) monitoring of the eagle concentration at Nankoweap take place from 22 February to 3 March each year. The management and scientific goals of the monitoring program would be to: 1) determine if a Bald Eagle concentration occurred during the monitoring period; 2) determine the size and age class distribution of the eagle concentration, and the timing of the peak concentration; and 3) document the relative abundance of trout in Nankoweap Creek and the relative abundance of other fish-eating predators that may become habituated to the trout spawn. We propose a draft monitoring protocol employing three salaried observers and several volunteers annually. Contingency plans are proposed to adjust to future changes in the status of the eagle concentration.

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INTRODUCTION

The recent development of a winter concentration of Bald Eagles (Haliaeetus leucocephalus) at the confluence of Nankoweap Creek and the Colorado River in Grand Canyon was as unexpected as it was sudden (Brown et al. 1989). The eagle concentration increased from a few individuals in the early 1980s to 18 in 1988, primarily as a result of abundant prey in the form of spawning rainbow trout (Oncorhynchus mykiss) in the creek. Trout were not native to the Grand Canyon section of the Colorado River, but had been introduced and then flourished in the cold, clear water released by Glen Canyon Dam. The combination of abundant prey at this relatively remote location suggested that the eagle concentration could continue to increase in size, similar to the increase exhibited by the Bald Eagle concentration in Glacier National Park (McClelland 1973).

But the development of the Bald Eagle concentration posed a dilemma to both the managers of Glen Canyon Dam and Grand Canyon National Park. Was the eagle concentration increasing in size each year, and how was it limited by trout abundance? How long did the concentration last, and when was its peak? What, if any, were the influences of fluctuating flows from Glen Canyon Dam on the eagles? Did the abundance of prey in the creek have an effect on eagle foraging success and food

consumption, particularly of immature eagles which are food-limited in winter and experience a higher mortality rate? Was there a conflict between the eagle concentration and recreational use of the area? And if the concentration was important to the recovery of this endangered species, what was the best technique for future monitoring?

In response to these and other questions, this study was designed in the winter of 1989-1990 as part of an Environmental Impact Statement on the operations of Glen Canyon Dam. The U.S. Bureau of Reclamation, as the lead agency, provided funding for a 2-year study of the eagle concentration to be administered by the National Park Service.

The objectives of this study were as follows:

1. Provide baseline information on the abundance, timing, and age composition of the concentration.
2. Determine the influences of fluctuating flows from Glen Canyon Dam on eagle foraging patterns and prey capture.
3. Examine eagle foraging ecology to determine if eagle foraging success was influenced by age, foraging location, attack method, or changing prey abundance.
4. Determine the effects of human disturbance on the eagle concentration from both the existing literature and field research at Nankoweap.

5. Develop a draft protocol for future monitoring of the eagle concentration.

6. Make recommendations to dam and park management that would identify strategies to maintain or enhance the eagle concentration.

CHAPTER 1

WINTER ABUNDANCE, AGE STRUCTURE, AND DISTRIBUTION OF BALD EAGLES ALONG THE COLORADO RIVER IN GRAND CANYON, ARIZONA

ABSTRACT

Surveys for wintering and migrating Bald Eagles were conducted along the Colorado River through a portion of Grand Canyon in northern Arizona during the winters of 1990 and 1991. In the Nankoweap study area, numbers of eagles/day varied from 2-26 in 1990 and 1-13 in 1991. Eagle abundance peaked in late February during both years, followed by a rapid decline. This pattern coincided with overall eagle abundance in the Colorado River corridor study area as determined through helicopter surveys, and indicated that the Nankoweap study area represented stopover feeding and resting habitat for spring migrant Bald Eagles.

Age structure varied within and among years, but immature and subadult eagles were significantly more abundant than adults at peak concentrations in both years. Immature and subadult eagles were present in the Nankoweap study area in significantly greater proportions than they were in the adjacent Colorado River corridor study area, demonstrating that younger age classes concentrate near abundant food resources.

INTRODUCTION

Several hundred transient Bald Eagles are present in Arizona each winter (Grubb and Kennedy 1982), where they tend to congregate at lakes, reservoirs, and along rivers when prey is abundant (Grubb et al. 1989, Brown et al. 1989). Feeding concentrations of wintering or migrating Bald Eagles have been reported from the Pacific Northwest (e. g. McClelland 1973, Stalmaster 1987), but are rare in the desert Southwest where riverine ecosystems are more limited in extent. A feeding concentration of wintering and migrating Bald Eagles occurring along the Colorado River in Grand Canyon National Park, Arizona (Brown et al. 1989) is of special interest because of its location in a protected natural area. The concentration has developed and has continued to increase since 1980 due to a winter spawn of introduced rainbow trout made possible by the operation of Glen Canyon Dam.

We examined the occurrence of wintering and migrating Bald Eagles along the Colorado River through a portion of Grand Canyon over a 2-year study period. Our purposes were to: 1) contrast eagle abundance patterns relative to prey abundance between years, 2) examine age structure of the concentration within and among years, and 3) test the hypothesis that younger eagles were more abundant near concentrated food resources. Counts of migrant and wintering Bald Eagles at annual, regularly-used feeding concentrations provide a useful index of long-term population trends (Ward and Berry

1972), and assist in defining priorities for local and regional raptor management (Titus and Fuller 1990).

METHODS

Study Area

The river corridor study area included 119 of the 122 km of the Colorado River from Glen Canyon Dam to the confluence of the Little Colorado River in north-central Arizona (Fig. 1-1). This portion of the Colorado River has undergone substantial changes due to the 1963 construction of Glen Canyon Dam and its subsequent operation (Turner and Karpiscak 1980). Reduction of sediment concentrations, range of average annual temperatures, and frequency of flooding has transformed the river from a turbid, warm-water fishery into a clear, cold-water fishery dominated by non-native species (Johnson and Carothers 1987). Rainbow trout were introduced into the river as early as 1930, and quickly became one of the dominant fishes after impoundment (Brown et al. 1989).

The river between Glen Canyon Dam and the Little Colorado River confluence exhibits lower turbidity, higher productivity, and higher densities of trout than the river below the Little Colorado River confluence (Carothers and Brown 1991). Therefore, we made the assumption that the river upstream of the Little Colorado River confluence would attract more Bald Eagles in designating it as the river corridor study area.

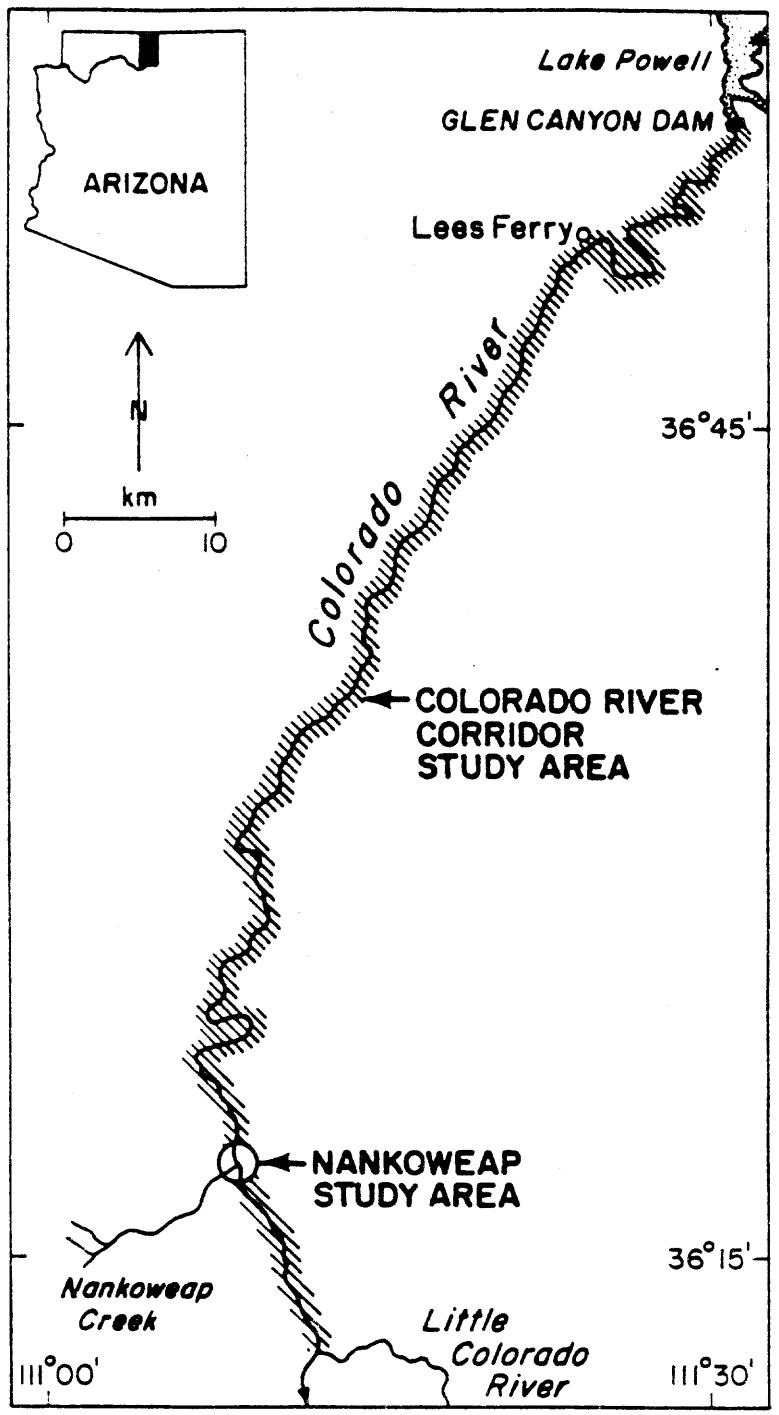


Figure 1-1. The Colorado River through a portion of Grand Canyon, Arizona, showing the 2 study areas.

The Nankoweap study area was a ca. 3 km^2 area at and near the confluence of the Colorado River and Nankoweap Creek, a small tributary 108 km downstream from the dam (Fig. 1-1). Spawning rainbow trout first began to appear in Nankoweap Creek in the mid-1970s. By the mid-1980s as many as 1500 spawning trout were present in the downstream-most 1.5 km of the creek during peak spawning, which may last from November through April (Brown et al. 1989). The creek averages 1.5-2 m wide, 30 cm maximum depth, and winter flows average ca. 0.05-0.20 m^3/sec. The Nankoweap study area extended 1.6 km up- and downriver of the confluence of Nankoweap Creek and included Colorado River Miles 51 to 53 (Stevens 1983).

Survey methodology

Daily eagle numbers by age class were recorded at Nankoweap from 7 February to 20 March, 1990, and from 24 January to 13 March, 1991. Continuous observations beginning 30 minutes before sunrise and ending 30 minutes after sunset were made by up to 5 concurrent observers with 10-45x spotting scopes from an uncamouflaged observation post located 800 m west and 100 m above the confluence. Trout abundance in the downstream-most 600 m of the creek was visually estimated from the observation post each day, and was supplemented by occasional nocturnal counts.

The minimum number of eagles/day at Nankoweap was determined by combining the largest number of concurrently detected individuals of each age class. We did not mark or

band eagles during the study. Individuals with unique plumage characteristics were added to the daily total if they were not observed concurrently with the largest daily group. If there was no reason, based on timing, plumage, or individual markings, that separate observations of eagles were of different individuals, then those observations were assumed to be the same individual. This conservative technique may have underestimated daily eagle abundance.

A fixed-wing aircraft was used to survey Bald Eagles in the Colorado River corridor study area in February 1990. Three repetitions of the survey were made on each of two survey days, beginning at approximately 08:00 hrs and ending at approximately 12:00 hrs. Aircraft speed during the surveys was approximately 110 km/hr at an altitude of approximately 350 m above the river (just above the Redwall; the lowest altitude at which the pilot felt it was safe to fly). Two to 3 observers were present during each survey in addition to the pilot. Concurrent observations were made during the overflight of the Nankoweap study area by both the fixed-wing observers and the ground observers to compare the accuracy of the two survey techniques.

Fifteen helicopter surveys for Bald Eagles were conducted in the Colorado River corridor study area from November 1990 to March 1991 to determine abundance, distribution, and age composition. One repetition of the survey took place each survey day, usually before 12:00 hrs. Aircraft speed was 90

km/hr on a flight path directly over the river from downriver to upriver. Aircraft speed was reduced to 75 km/hr over the Nankoweap study area to account for the greater number of eagles expected there. Flight elevation was 100 m above river level. Concurrent observations were made during the helicopter overflight of the Nankoweap study area by both the helicopter observers and the ground observers to compare the accuracy of the two survey techniques. The advantages and disadvantages of fixed-wing versus helicopter surveys for raptors are discussed by White and Sherrod (1973).

Bald Eagles exhibiting a primarily white head and tail were classified as adults (Basic III, IV, and V plumage of McCollough [1989]); those with largely brown plumage mottled with white were classified as subadults (old immature and subadult plumage of Bortolotti [1984], Basic I and II plumage of McCollough [1989]); those with primarily dark plumage and a completely dark head and beak were classified as immatures (young immature plumage of Bortolotti [1984]; juvenal plumage of McCollough [1989]). Because observations were made in February and March, when individual Bald Eagles classified as immatures would have been in their second year and approximately 8-11 months of age, some immatures had flecks of white on the belly and back and were approaching the Basic I plumage of McCollough (1989). These individuals were classified as immatures after the methods of Hansen (1986) because theirs was a distinctly recognizable age class during

the study. Subadults and immatures were collectively referred to as younger age classes. Percent age composition was calculated by adding the number of eagles/day by age class over the number of days and then dividing this by the total number of eagles/day over the same time.

RESULTS

Eagle Abundance and Chronology

Bald Eagle ranged from 2-26/day at Nankoweap in 1990 (Fig. 1-2). Eagle abundance rose from a low of 5 in mid-February to a high of 26 in late February, then rapidly declined to 2 in mid-March. The peak concentration occurred from 26 February to 4 March, when > 20 eagles/day were present on 5 days. Increasing eagle abundance at Nankoweap paralleled increasing trout abundance in Nankoweap Creek through late February (Fig. 1-3). Eagle abundance declined sharply in early March although trout abundance remained high.

Bald Eagle numbers ranged from 1-13/day at Nankoweap in 1991 (Fig. 1-2). The pattern of eagle abundance in 1991 was similar to 1990, but approximately half as many eagles/day were present in 1991. The peak concentration occurred from 22 February to 2 March, when at least 9 eagles/day were present on 8 days. There were few (1-5) eagles in late January and early February when no trout were present in the creek (Fig. 1-3). Numbers of eagles increased through late February as trout abundance increased, but declined rapidly

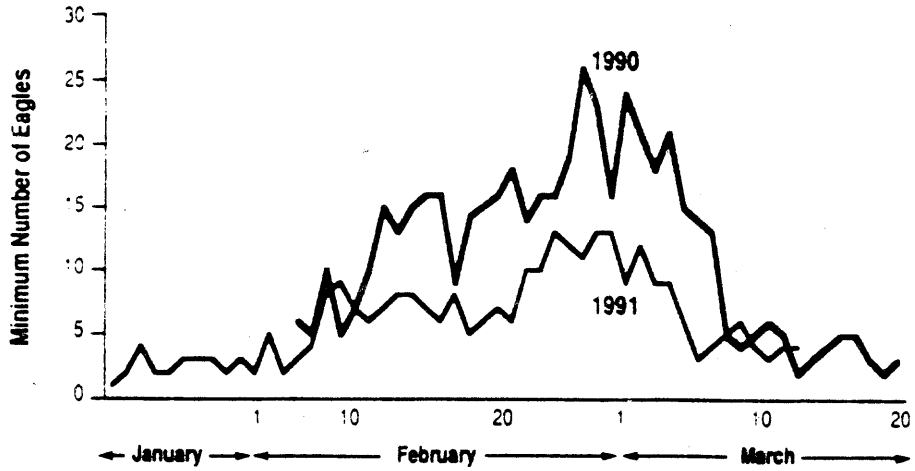


Figure 1-2. The abundance of wintering and migrating Bald Eagles in 1990 and 1991 at the Nankoweap study area, Grand Canyon, Arizona.

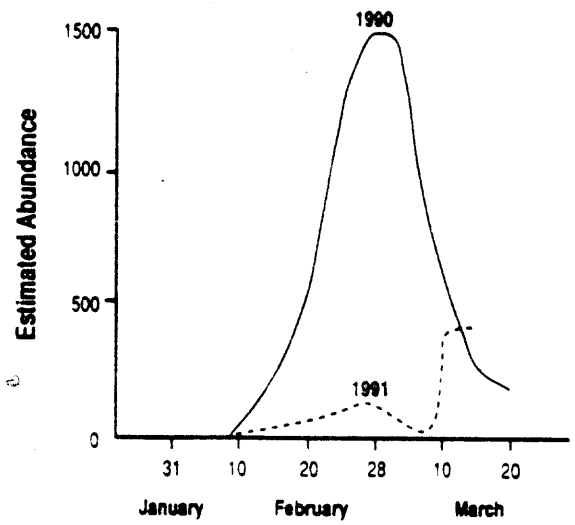


Figure 1-3. Estimated abundance of spawning rainbow trout during the 1990 and 1991 study periods in the lowermost 600 m of Nankoweap Creek, Grand Canyon, Arizona.

in early March even though trout abundance continued to increase.

Few eagles (0-1) were detected by fixed-wing aircraft surveys in the Colorado River corridor study area in February 1990 (Table 1-1). Concurrent ground surveys of the Nankoweap study area indicated that accuracy of aircraft surveys was low, never exceeding 20% of the number of eagles detected by ground observers. For this reason, additional fixed-wing aircraft surveys for eagles that had been scheduled for late February and March 1990 were cancelled.

Two to 23 eagles/flight were detected during helicopter surveys of the Colorado River corridor study area, November 1990 to March 1991 (Fig. 1-4). Eagle density in the river corridor ranged from a low of 0.026/River Mile in November and March 1991 to a high of 0.303/River Mile at peak eagle abundance in late February. Eagle numbers in the Colorado River corridor study area exhibited a pattern of increasing abundance from November through late February, followed by a rapid decline. This pattern was similar to that observed in the Nankoweap study area from the river-level observation post in 1990 and 1991.

Comparison of eagle numbers detected in the Nankoweap study area by helicopter surveys versus eagle numbers detected by ground observers indicated an average of 61% of the actual eagle numbers present were detected from the helicopter (Table 1-2). There was no difference in probability that

Table 1-1. Numbers of Bald Eagles (all age classes combined) detected during fixed-wing aircraft surveys of the Colorado River corridor study area (from Glen Canyon Dam to the Little Colorado River). Included is a comparison of the number of eagles seen in the Nankoweap study area from the aircraft versus a river-level observation post (OP), February 1990.

		Number of Bald Eagles Detected		
Date	Survey Number	By Aircraft, Colorado River Study Area	From River Level OP in Nankoweap Study Area	From Aircraft Over Nankoweap Study Area
2-10-90	1	0	5	0
	2	0	5	1*
	3	1	3	0
2-24-90	1	0	11	0
	2	0	11	0
	3	0	10	0

* This individual was soaring high above the Redwall over the Nankoweap study area and was not at river level.

Table 1-2. Comparison of the number of Bald Eagles in the Nankoweap study area detected from the river-level observation post (OP) versus the number detected from low-level helicopter flights, January and February 1991.

Detections By Flight Date	Number Detected From Nankoweap OP	Number Detected From Low-Level Helicopter	Percent Detected From Low-Level Helicopter
28 January	2	0	0
8 February	4	3	75
21 February	3	3	100
25 February	9	5	56
Total (all ages)	18	11	61
Total (adults)	8	5	63
Total (immatures and subadults)	10	6	60

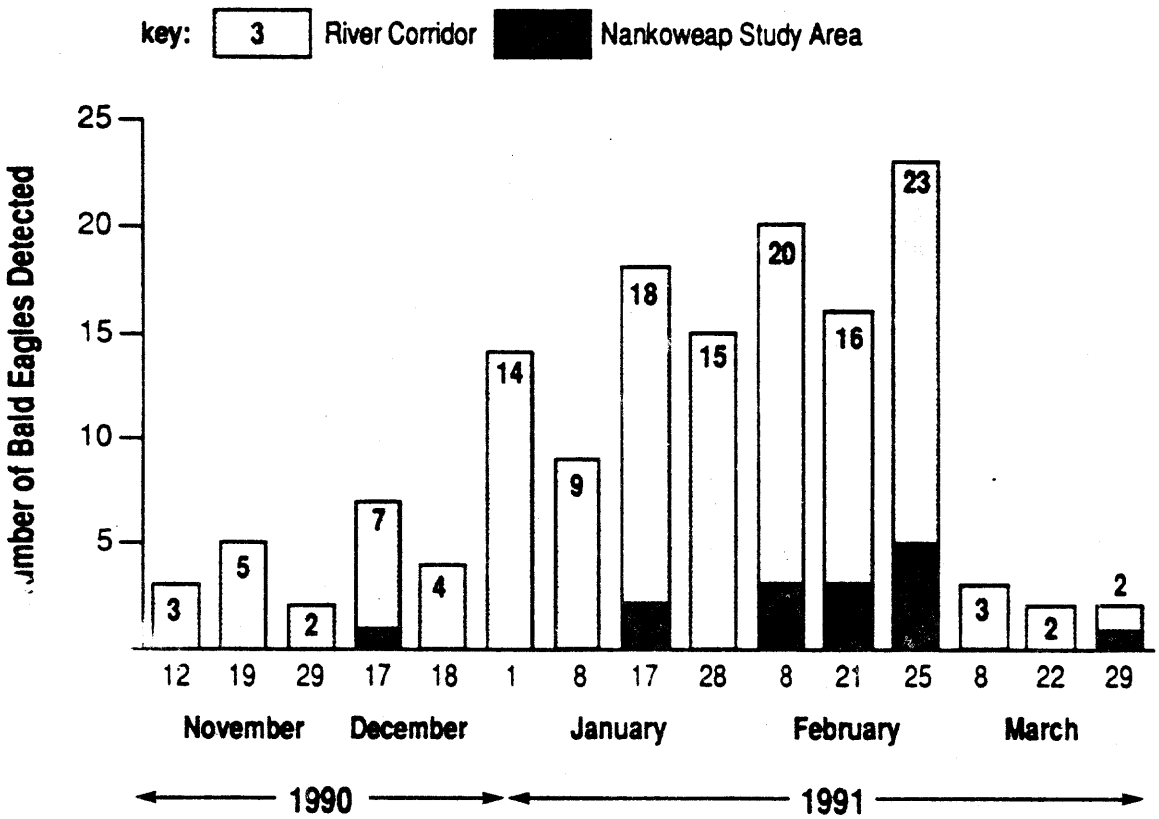


Figure 1-4. Numbers of wintering and migrating Bald Eagles detected during helicopter surveys of the Colorado River corridor and Nankoweap study areas in the winter of 1990-91, Grand Canyon, Arizona.

either adults or immatures and subadults would be detected during helicopter surveys ($\underline{x}^2$ = 0.01, df = 1, $\underline{P}$ = 0.960).

The majority of eagles detected in the Nankoweap study area during helicopter surveys were in February (Fig. 1-4), when spawning trout were present in the creek (Fig. 1-3). Eagle numbers detected during helicopter surveys peaked on 25 February, when 5 eagles observed in the Nankoweap study area (out of 9 actually present; Table 1-2) comprised 22% of the 23 eagles detected along the Colorado River from Glen Canyon Dam to the Little Colorado River (both study areas combined). Therefore, the Nankoweap study area attracted less than one-fourth of the known number of eagles present in the river corridor study area at the peak concentration in a year of low prey abundance.

Prey Abundance

Trout abundance in the downstream-most 600 m of Nankoweap Creek peaked in late February in 1990 and in mid-March in 1991 (Fig. 1-3). No trout were present in the creek when the study period began in 1990, and no trout were present during the first two weeks of the study period in 1991. Although trout were staging at the creek mouth both years when the study period began, there was no evidence (fish skeletons) that any sizeable spawning activity in the creek had occurred either winter prior to the study period.

Age Structure

Age composition at Nankoweap differed from week to week during 1990 and 1991 (Fig. 1-5). Immatures and subadults combined were significantly more abundant in 1990 from early February through early March than they were after early March ($\underline{x}^2$ = 11.93, df = 1, $\underline{P}$ = 0.001). Adults were predominant in 1991, except during the peak concentration. Immatures and subadults combined were significantly more abundant in 1991 from 8 February through 7 March than they were before and after that time ($\underline{x}^2$ = 19.97, df = 1, $\underline{P}$ < 0.001). Younger age classes comprised the majority at the peak concentration in both years, although the proportion of immatures and subadults combined from 8 February through 7 March, 1990, was significantly greater than 1991 ($\underline{x}^2$ = 10.70, df = 1, $\underline{P}$ = 0.001).

Age composition of eagles in the Colorado River corridor study area in 1991, as determined by helicopter surveys, also differed between months (Fig. 1-6). Adults were the predominant age class throughout the majority of the study period, except in March when the combined proportion of immatures and subadults equalled that of adults. The proportion of younger age classes gradually increased from November through March. This difference was not significant when age composition prior to January 1 was compared to that on and after January 1 ($\underline{x}^2$ = 3.52, df = 1, $\underline{P}$ = 0.060).

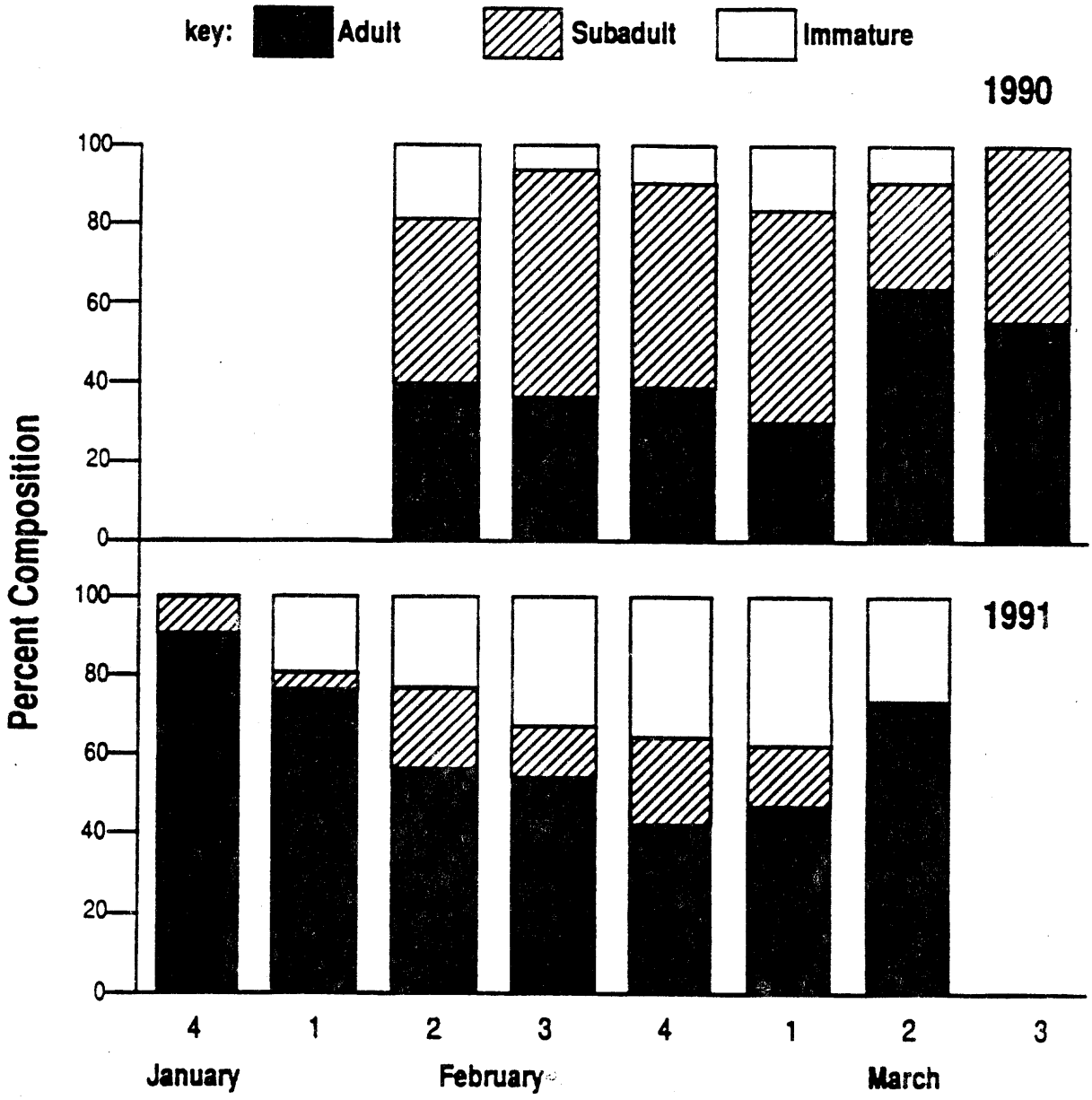


Figure 1-5. Percent age composition of wintering and migrating Bald Eagles in the Nankoweap study area during 1990 and 1991, Grand Canyon, Arizona.

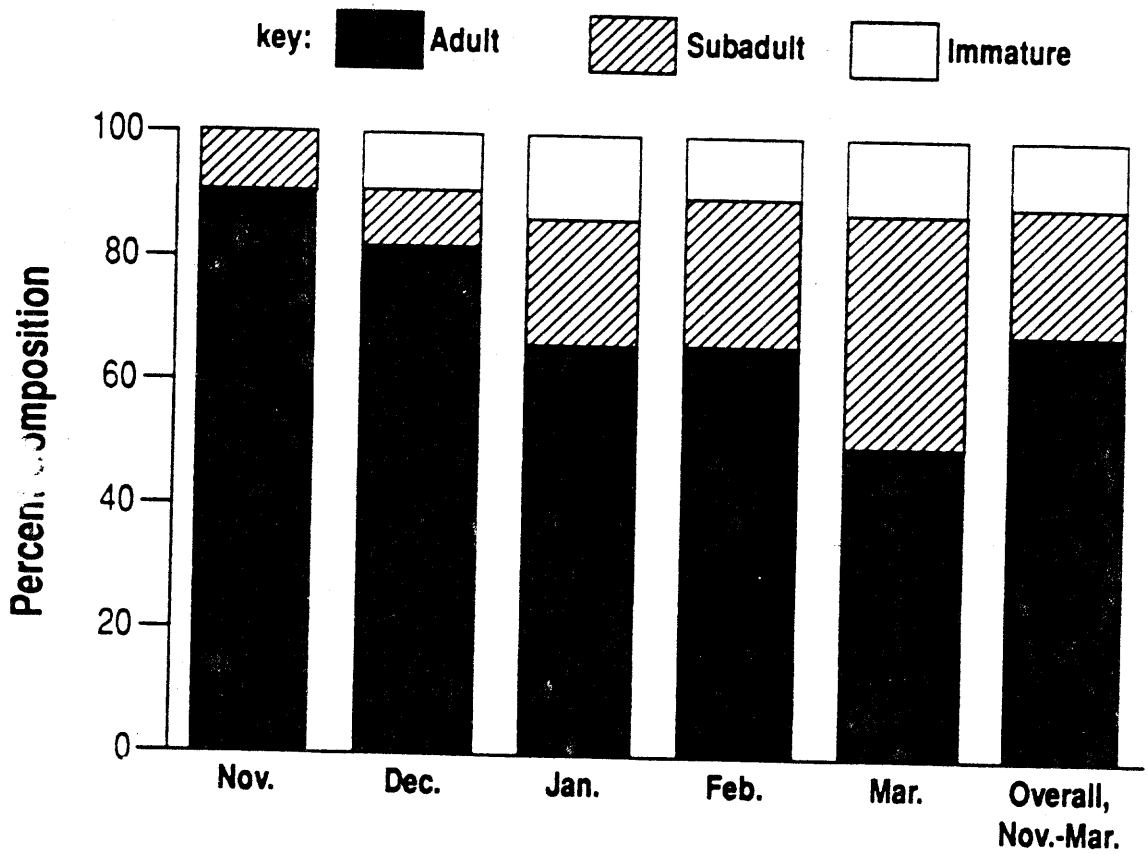


Figure 1-6. Percent age composition of wintering and migrating Bald Eagles in the Colorado River corridor study area during the winter of 1990-91, Grand Canyon, Arizona.

Distribution of Younger Age Classes

Immature and subadult Bald Eagles were present in greater proportions in the Nankoweap study area (Fig. 1-5) than they were in the Colorado River corridor study area (Fig. 1-6) from late January to mid-March 1991. Adult to younger age class ratios at Nankoweap versus the river corridor during this time were 165:134 and 46:20, respectively. This difference was significant when tested using expected values derived from the combined proportions of each age group from both study areas ($\underline{x}^2 = 4.74$, df = 1, $\underline{P} = 0.029$). The difference was significant during the peak concentration from 8 February to 7 March 1991, using expected values derived by the same criteria (Table 1-3; $\underline{x}^2 = 7.47$, df = 1, $\underline{P} = 0.006$).

Table 1-3. Frequency of occurrence of adult versus subadult and immature Bald Eagles in the Nankoweap study area (River Miles 51-53) versus that in the Colorado River corridor study area, 8 February to 7 March, 1991. Expected values, based on the combined proportions of each age group from both study areas, are in parenthesis.

Area Surveyed	Adult		Immature and Subadult		Total	
	n	%	n	%	n	%
Nankoweap Study Area	112 (121)	48	120 (111)	52	232	100
Glen Canyon Dam to Little Colorado River	36 (27)	69	16 (25)	31	52	100
Total	148	52	136	48	284	100

Proportionally more immatures and subadults combined were present in the Colorado River corridor study area than were present at Lake Powell. Eagle numbers observed during 11 low-level, fixed-wing aircraft surveys of Lake Powell from November 1990 through March 1991 (Daw 1991) were compared to helicopter-derived eagle numbers observed from the Colorado River corridor study area. This comparison tested the hypothesis that no significant difference existed in the age structure of the two populations. A significantly greater proportion of younger age classes was present in the Colorado River corridor study area than was present on Lake Powell ($\underline{x}^2 = 18.42$, df = 1, $\underline{P} < 0.001$).

DISCUSSION

Bald Eagles were approximately twice as abundant in the Nankoweap study area in 1990 as 1991 (Fig. 1-2), apparently due in part to the scarcity of spawning trout in 1991. However, other factors could partially explain the smaller eagle concentration at Nankoweap in 1991. The winter of 1990-1991, prior to March, was one of the driest on record, and February 1991 was one of the warmest (National Climatic Data Center 1951-1991). The warm weather may have created more widespread thermal updrafts, affecting the migration paths of northward-moving eagles. Such updrafts would reduce the eagles' reliance on prominent north-south trending escarpments (Kerlinger 1989) traditionally used as raptor

migration corridors, such as the East Kaibab Monocline that traverses the eastern Grand Canyon from south to north.

The Bald Eagles at Nankoweap Creek represented the largest sustained (ca. 30 days) feeding concentration of eagles in the Southwest during the 1990 study period. No comparable eagle concentration occurred in Arizona (pers. comm., T. Tibbitts, Arizona Game and Fish Dept.) or New Mexico (pers. comm., J. Hubbard, New Mexico Game and Fish Dept.) in 1990. However, temporary (ca. < 5 days) feeding concentrations of up to 40 eagles did occur elsewhere in Arizona (pers. comm., J. Grubb, U.S. Forest Service). Arizona is near the periphery of Bald Eagle winter range in the Southwest, and much larger concentrations occur in the Pacific Northwest (McClelland 1973, Millsap 1986).

The eagle concentration at Nankoweap Creek in 1990 and 1991 comprised at least ca. 13% and 6%, respectively, of the approximately 200 transient eagles present in Arizona each winter (Grubb et al. 1989). The number of eagles present at the peak concentration probably underestimated the actual number of individuals occurring at Nankoweap throughout the winter. The 26 eagles present at Nankoweap at the peak concentration in 1990 represented an increase over the peak of 18 eagles reported for 1988 (Brown et al. 1989), and the Nankoweap eagle concentration could continue to increase in numbers if prey availability is maintained and human disturbance is managed. McClelland et al. (1982) reported

that nearly 30 years elapsed between the establishment of the kokanee salmon (Oncorhynchus nerka) run in Glacier National Park, Montana, and a major increase of migratory eagles there, even though salmon were abundant throughout that time.

Reasons for the sharp decline in eagle abundance in early March of 1990 and 1991 could be due to a combination of factors. First, eagles may simply have departed on their northward migration. The eagles' innate migratory urge may have caused them to leave Nankoweap, even though abundant food resources were still available. Results of the 1990-1991 helicopter survey of the Colorado River corridor study area and the 1990-1991 aircraft survey of Lake Powell (Daw 1991) support this hypothesis, as most eagles had left Grand Canyon and Lake Powell by early March. Published information on the spring chronology of eagle migration in the Southwest is sparse (Palmer 1988). However, 8 years of unpublished information on the rate of passage by spring migrant Bald Eagles in the Sandia Mountains, New Mexico (the same latitude as Grand Canyon), indicate that northward migration peaks in late February and sharply drops off by early March (pers. comm., S. Hoffman).

Second, increasing levels of human disturbance in the Nankoweap study area may have caused some eagles to prematurely leave. Human disturbance by hikers and rafters in 1990 increased from once every 2.9 days before 6 March to once every 1.5 days after 6 March (see Chapter 4 for more

details). Recreational boating, fishing, and hiking activities have been shown to adversely affect eagle behavior, distribution, and food intake (Stalmaster and Newman 1978, Knight and Knight 1984, Knight et al. 1991, McGarigal et al. 1991). Human disturbance to eagles has been studied largely under conditions of dispersed food resources; the effects of human disturbance on eagles at a concentrated food resource, such as the trout spawn at Nankoweap Creek, could potentially be more severe (Knight et al. 1991).

The findings of this study suggest that Bald Eagles use the Nankoweap study area as a migratory stopover for feeding and resting immediately prior to their northward spring migration. The following scenario describes in general terms the probable schedule of wintering and migrating Bald Eagles in northern Arizona with respect to the development of the feeding concentration at Nankoweap and the abundance of eagles in the Colorado River corridor study area. Although several aspects of this probable scenario have not been scientifically documented, the scenario is useful in identifying the probable role of both study areas within the broader context of eagle migration across the Southwest.

Migrant Bald Eagles from the Pacific Northwest and Rocky Mountains apparently begin to move into and through the Grand Canyon region in late October and early November (Palmer 1988). Some individuals wintering south of Utah may continue on to central and southern Arizona (Grubb et al. 1989) and

northwest Mexico (Brown and Warren 1985). Since the trout spawn at Nankoweap in early winter is highly variable and food resources along the river are dispersed, the Grand Canyon prey base is apparently insufficient to concentrate eagles throughout the entire winter. Eagle abundance in the Colorado River corridor and Nankoweap study areas continues to increase through January, but does not reach peak abundance until February.

Trout abundance in Nankoweap Creek begins to increase in most years in mid-February, coincidental with the initiation of northward migration by Bald Eagles located to the south of Grand Canyon. At this time, eagles that have previously become accustomed to exploiting the trout spawn at Nankoweap return to the area, and are joined by ever-increasing numbers of eagles that may have discovered the site by chance or by following other eagles to it (see McClelland et al. [1982] for a review of these behavior patterns). Nankoweap Creek is located astride a regularly-used raptor migration corridor across the eastern Grand Canyon, and this geographic coincidence probably facilitates the eagles' discovery of the trout spawn at Nankoweap.

Eagle abundance in the Nankoweap and river corridor study areas increases from early February through late February and early March. However, the exact timing of the concentration may vary from year to year depending on the status of the trout spawn, regional weather patterns, and possibly the

levels of human disturbance in the study area. At some point, the number of eagles departing from the study area on their northward migration exceeds the number of eagles arriving from the south, and the concentration rapidly diminishes. Few eagles remain by mid-March, and even these leave the study area by April.

The reasons for the eagle concentration at Nankoweap are analogous to those that caused the Bald Eagle concentration along McDonald Creek in Glacier National Park, Montana (McClelland 1973). There, the autumn run of introduced kokanee salmon was responsible for the largest concentration of migrating Bald Eagles in the contiguous 48 states. The timing of the salmon spawning run at Glacier National Park, like Nankoweap, coincided exactly with eagle migration and allowed eagles to use the creek as a staging area for stopover resting and feeding prior to continuing their migration.

In contrast, the temporal occurrence of Bald Eagles in Glen Canyon National Recreation Area (Kline 1990, Daw 1991) indicates that the Lake Powell eagle population is dominated by wintering individuals and not migrants. Peak abundance of wintering eagles in Glen Canyon National Recreation Area occurs each year in January (Kline 1990, Daw 1991), with fewer eagles in February during or immediately prior to migration. This is similar to the January population peak exhibited by Bald Eagles across the Southwest (Grubb 1984).

At peak eagle abundance on Lake Powell on 28 January 1991, eagle density (0.031 eagles/km of survey route) was less than along the Colorado River from Glen Canyon Dam to the Little Colorado River confluence on the same day (0.123 eagles/km of survey route). The 19 Bald Eagles detected that day in 609 km of survey route in Glen Canyon National Recreation Area (Daw 1991), combined with the 15 eagles detected along the river from the dam to the Little Colorado River confluence, indicated that at least 34 Bald Eagles were present in the Glen Canyon/Grand Canyon ecosystem on that day. The high probability that many eagles went undetected by the survey technique suggests that substantially more Bald Eagles may have been present.

Younger age classes of wintering Bald Eagles have been suggested to occur more frequently in areas where prey is especially abundant (Southern 1963, Stalmaster 1976, McClelland et al. 1982, Grubb 1984, Bennetts and McClelland Press). This distribution pattern for younger eagles may occur because they are less experienced, and therefore less efficient at obtaining food (McClelland et al. 1982, Fischer 1985). Once younger eagles encounter an area of abundant prey, the attraction of remaining there may outweigh the uncertainty of moving on to an area with an unknown food supply (McClelland et al. 1982). Although younger eagles may encounter increased aggression and competition from adults in areas of concentrated food resources (McClelland et al.

1982), younger eagles may be dependent upon group-facilitated food finding (Knight and Knight 1983, Griffin and Baskett 1985). Since younger age classes in winter appear to be food-limited and often cannot consume enough to meet their daily energy requirements (Stalmaster 1983), there should be strong selection pressure for younger age classes to locate concentrated food resources and forage with groups of eagles even if more competition from adult eagles is experienced (McClelland et al. 1982). The potential for enhanced competition from adults at Nankoweap in 1991, when prey abundance was low, may have resulted in the exclusion of some younger eagles and their significantly lower proportions at the concentration that year compared to 1990.

This study has demonstrated that younger age classes occurred in significantly greater proportions in an area of concentrated food resources (Nankoweap) than an area of dispersed food resources (Colorado River corridor). Moreover, the greater abundance of eagles and the higher proportion of younger age classes along the Colorado River corridor compared to Lake Powell suggests that food resources were more abundant in the river corridor.

Immatures and subadults comprised 66% of the Nankoweap concentration at its peak in 1990 when food resources were abundant, but only 56% at the same time in 1991 when food resources were much less abundant. The percent composition of younger age classes in both years was greater than the

percentage of younger age classes in the North American population of wintering Bald Eagles, which ranged from 32.7% to 41.2% in 1979 to 1982 (Millsap 1986). Immatures and subadults occurred in the Nankoweap study area in greater proportions than expected, apparently as a result of food abundance and availability. If food is the most important limiting factor determining survivorship, particularly of younger eagles (Sherrod et al. 1976, Stalmaster and Gessaman 1984, Griffin and Basket 1985), then management strategies along the Colorado River through Grand Canyon that would help to maximize food intake of younger age classes in winter would increase survivorship and aid in the recovery of this endangered species (Stalmaster and Gessaman 1984).

CHAPTER 2:

INFLUENCES OF FLUCTUATING FLOWS FROM GLEN CANYON DAM ON THE BALD EAGLE CONCENTRATION AT NANKOWEAP CREEK

ABSTRACT

Bald Eagles exhibited flow-dependent spatial foraging patterns at and near the confluence of Nankoweap Creek and the Colorado River during the 1990 study period. As river flows increased, the proportion of foraging attempts in the ek increased from ca. 50% to 100%. In contrast, proportions of river, shore, and isolated pool foraging attempts declined. This pattern occurred because 1) prey on shore or in isolated pools were inundated by the river at higher flows, and 2) the difficulty of foraging in the river apparently increased at higher flow levels, causing eagles to shift their foraging activity to a less difficult foraging habitat. Eagles foraging in the river corridor at localities other than Nankoweap may temporarily experience reduced opportunities to forage or a reduction in foraging success at the highest river flow levels. Proportionally more foraging attempts occurred > 50 m upstream in Nankoweap Creek during high river flows in 1990, but this flow-dependent shift in foraging patterns did not influence eagle foraging success. Flow-dependent spatial foraging patterns in 1991 were

analogous to 1990 patterns, but there was no difference between the proportion of foraging attempts that occurred > 50 and < 50 m upcreek at different river flows. Trout stranded in isolated pools left by fluctuating flows represented a moderate, beneficial contribution to the eagle concentration.

INTRODUCTION

Changes in environmental conditions affect foraging strategies and success of wintering Bald Eagles (Knight and Skagen 1988). Rates of foraging and foraging strategies of Bald Eagles along the coast of Oregon and Washington are strongly influenced by tidal cycles, with low tide being the major determinant of eagle daily activity cycles (Watson et al. 1991). Daily patterns of dam-controlled riverflow mimic natural tidal cycles and may have similar influences on eagle foraging ecology. However, published information regarding the influence of dam-controlled fluctuating riverflows on Bald Eagle foraging ecology is largely anecdotal (Stalmaster 1987) or nonexistent.

The purpose of this study was to examine the influence of fluctuating flows from Glen Canyon Dam on the foraging ecology and prey capture of wintering Bald Eagles along the Colorado River near the confluence of Nankoweap Creek. Our objectives were to: 1) determine if fluctuating flows influenced spatial foraging patterns, 2) examine the effect

of this influence on foraging success, and 3) calculate the contribution made by fluctuating flows to eagle prey capture.

METHODS

Influences of Fluctuating Flows on Spatial Foraging Patterns

A description of the Nankoweap study area, the general survey methodology, and the 1990 and 1991 study period were included in Chapter 1.

The time of each eagle foraging attempt in the study area was recorded to the nearest minute and correlated with river discharge (flow level). Colorado River flow levels corresponding to each foraging attempt were calculated by first adding 2 hours to the time of each foraging attempt. Then, this adjusted time was paired to the corresponding measured discharge for that time at the U.S. Geological Survey gaging station (No. 09383100) above the mouth of the Little Colorado River near Desert View (15 km, or 9 miles, downstream of Nankoweap Creek). As the Little Colorado River gage was ca. 2 hours downstream of Nankoweap, adding 2 hours to the time of each foraging attempt at Nankoweap Creek indicated the flow level at which the foraging attempt had taken place. For example, the river flow level corresponding to an eagle foraging attempt at 12:30 hours was derived from the Little Colorado River gage readings for 14:30 hours, since that was when the 12:30 flow level passing Nankoweap

reached the gage. The Little Colorado River gage was the closest gaging station to the study area, and thus provided the best possible measure of the magnitude of flows moving past Nankoweap Creek.

All flow levels were recorded in cubic feet per second (cfs). Calculations of the range and extent of daylight river flows were made by summarizing flow data at 15-minute intervals beginning 30 minutes before sunrise and ending 30 minutes after sunset. Local sunrise and sunset times varied throughout the study period (U.S. Naval Observatory 1959). Flow levels < 10,000 cfs were referred to as low; flow levels from 10-20,000 cfs were intermediate; and flows > 20,000 cfs were high.

A logistic regression model (Hosner and Lemeshow 1989) was used to predict the location of foraging attempts for live trout in the creek each year. Computations were made using the NONLIN module of SYSTAT (Version 4; Wilkinson 1989). Foraging attempts within 50 m of the creek mouth were treated as a discrete event, as were foraging attempts > 50 m upcreek. Only one group of upcreek data was desirable to counterbalance the large proportion of data < 50 m from the creek mouth. The null hypothesis that the logistic regression coefficient for the riverflow variable was zero corresponded to the null hypothesis that increasing river flow levels would not affect spatial patterns of foraging attempts for live trout within the creek each year. The

daylight distribution of river flows was compared to the distribution of foraging attempts by river flows using the Kolmogorov-Smirnov test with SPSS software (Norusis 1986).

RESULTS

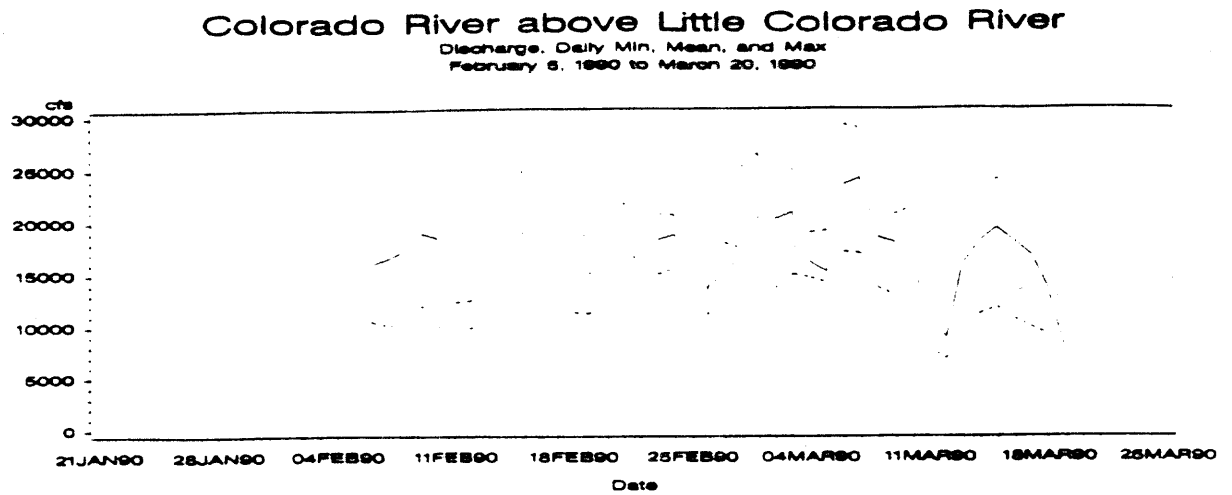
River Flows During the Study Period

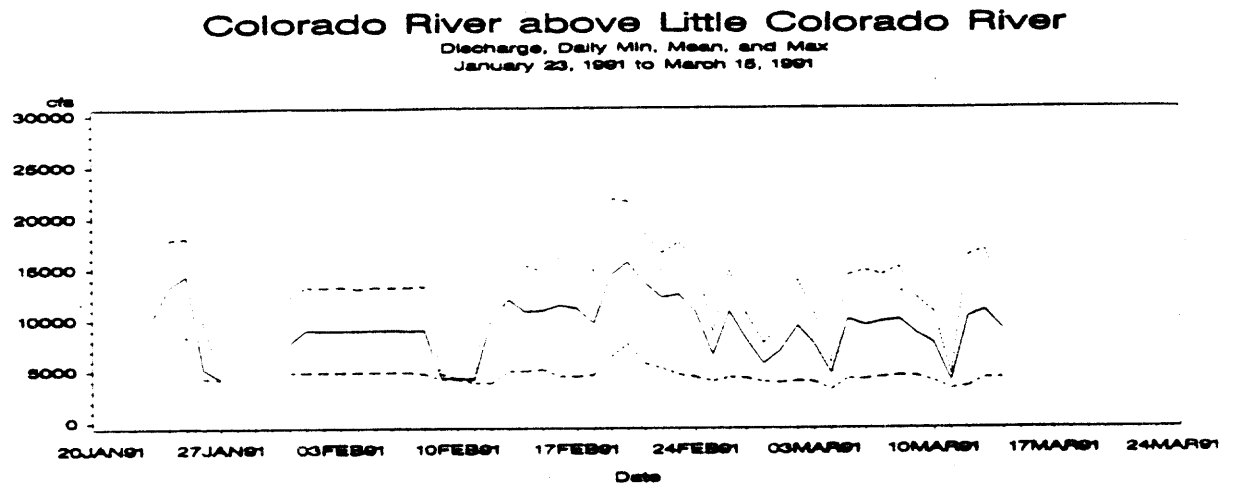
Colorado river flows recorded at the Little Colorado River gage ranged from 6,532 to 31,721 cfs in the 1990 study period (Fig 2-1) and 3,144 to 21,813 cfs in the 1991 study period (Fig. 2-1; U.S. Geological Survey, unpubl. data). Mean flows were 17,450 cfs in 1990 and 9,320 cfs in 1991.

We examined the distribution of river flows during daylight hours because the distribution of flows could influence the distribution of foraging attempts by flow and because eagles exhibit diurnal activity patterns. The majority (45%) of river flows occurring during daylight hours in 1990 were from 15-20,000 cfs (Fig. 2-2). The majority (43%) of river flows experienced during daylight hours in 1991 were from 5-10,000 cfs (Fig. 2-2).

Distribution of Foraging Attempts by River Flows

The majority (47%) of foraging attempts during the 1990 study period occurred when river flows were from 15-20,000 cfs (Fig. 2-3). The majority (50%) of foraging attempts recorded during the 1991 study period occurred when river flows were from 5-10,000 cfs (Fig. 2-3). There was no significant difference in the daylight distribution of river flows (Fig.





Source: US Geological Survey – Provisional Data

Figure 2-1. Daily mean and range of Colorado River flows passing the Little Colorado River gage during the 1990 and 1991 study periods.

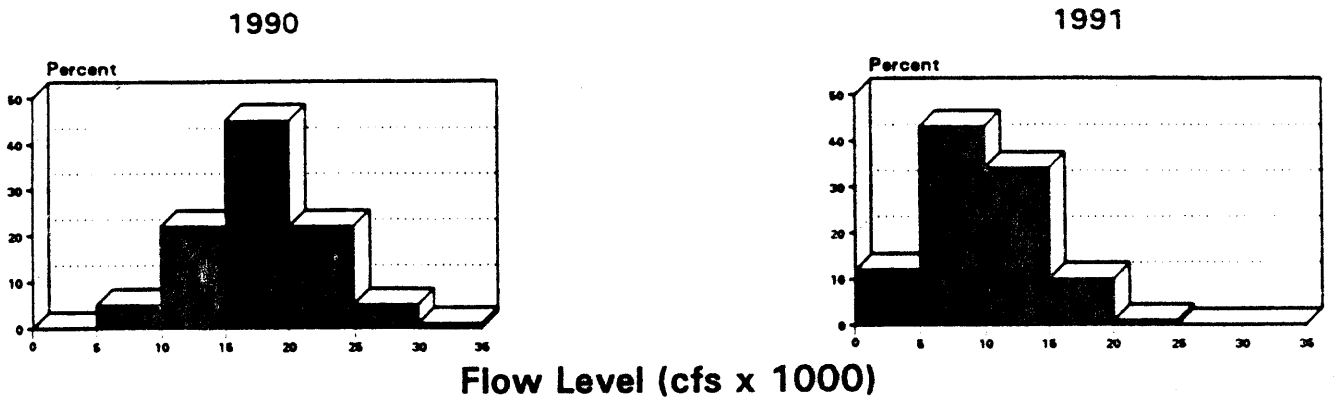


Figure 2-2. Percent of Colorado River flows passing the Little Colorado River gage during daylight hours by sequential flow categories during the 1990 and 1991 study periods.

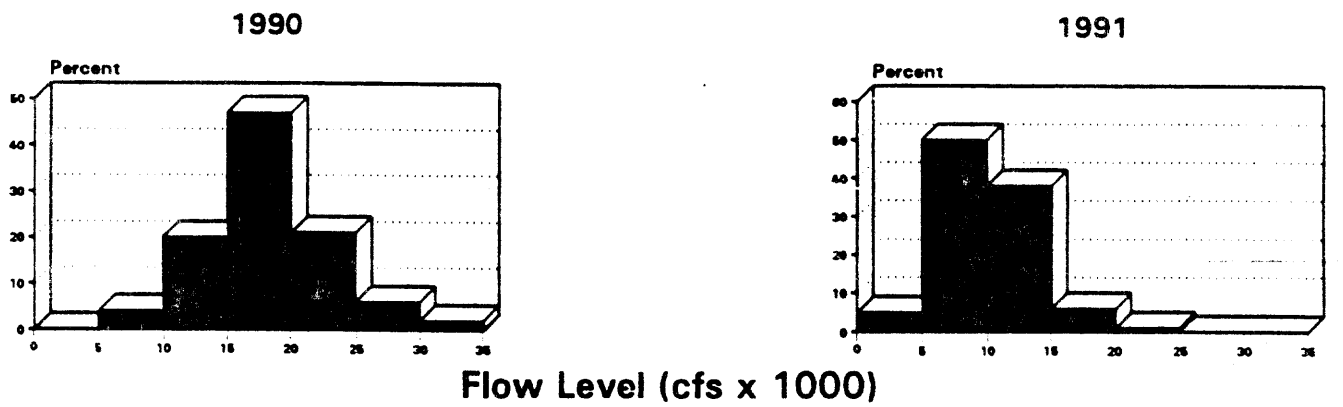


Figure 2-3. Percent of Bald Eagle foraging attempts by sequential flow categories during the 1990 and 1991 study periods at and near the confluence of Nankoweap Creek and the Colorado River.

2-2) compared to the distribution of foraging attempts by river flows (Fig. 2-3) in 1990 (Kolmogorov-Smirnov test, $\underline{D}$ = 0.05211, $\underline{P}$ = 0.078). In 1991, there was a significant difference between the distribution of daylight river flows versus the distribution of river flows by foraging attempts (Kolmogorov-Smirnov test, $\underline{D}$ = 0.07560, $\underline{P}$ = 0.032).

Patterns of Foraging Attempts by Location and Flow Level

The majority of eagle foraging attempts occurred in Nankoweap Creek at all river flow levels in 1990 (Fig. 2-4). Proportions of foraging attempts in the creek increased as river flow levels increased, so that 100% of all foraging attempts occurred in the creek at the highest river flow levels. As river flow levels increased, proportions of river, shore, and isolated pool foraging events declined, and no foraging events occurred at these three locations at the highest river flow levels.

The majority of eagle foraging attempts also occurred in Nankoweap Creek at all river flow levels in 1991 (Fig. 2-5), so that 100% of all eagle foraging attempts occurred in the creek at the highest flow levels. However, a smaller proportion of foraging attempts occurred in the creek at lower and intermediate flow levels in 1991 as compared to 1990. The overall pattern of increasing proportions of creek forages, and decreasing proportions of river, shore, and isolated pool forages as river flows increased was analogous to the pattern observed in 1990.

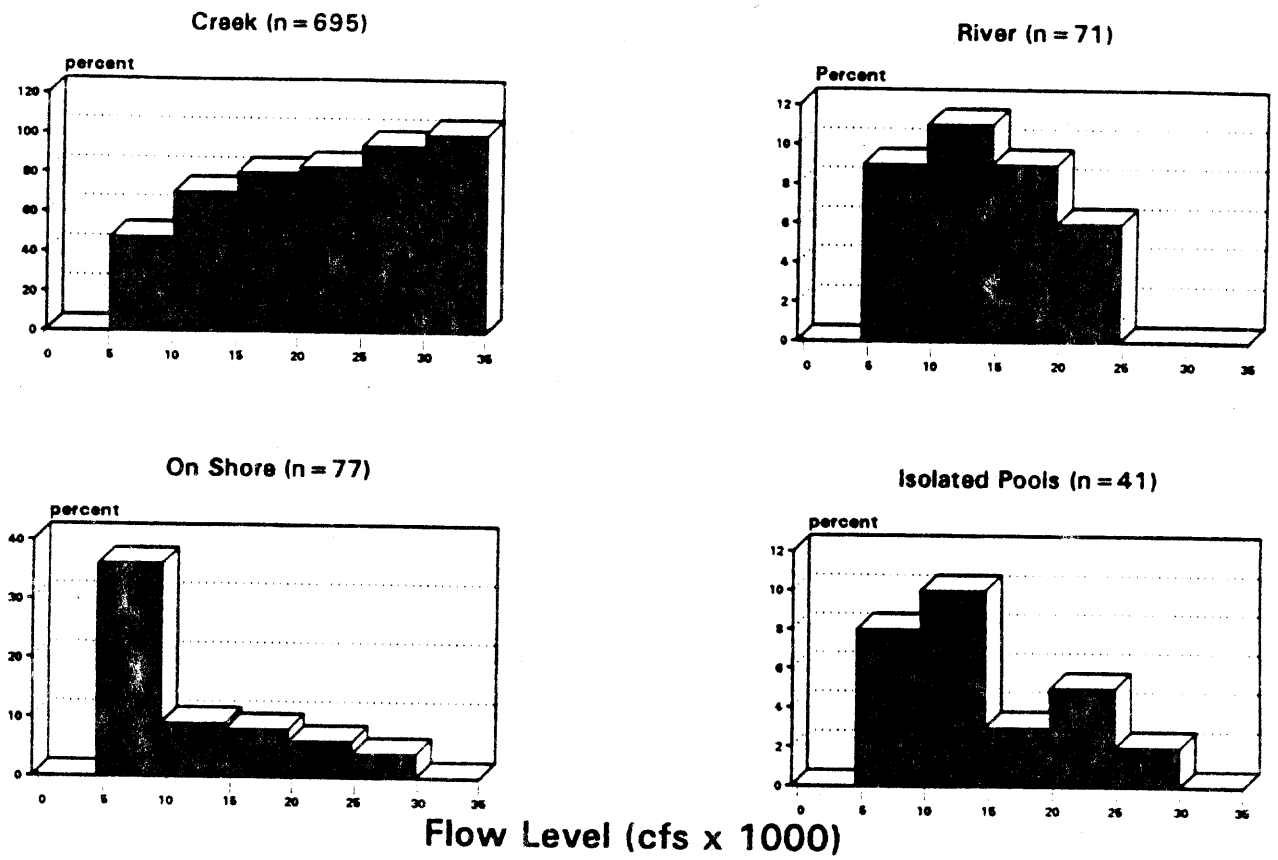


Figure 2-4. Percent of Bald Eagle foraging attempts by foraging location and river flow level, at and near the confluence of Nankoweap Creek and the Colorado River during the 1990 study period.

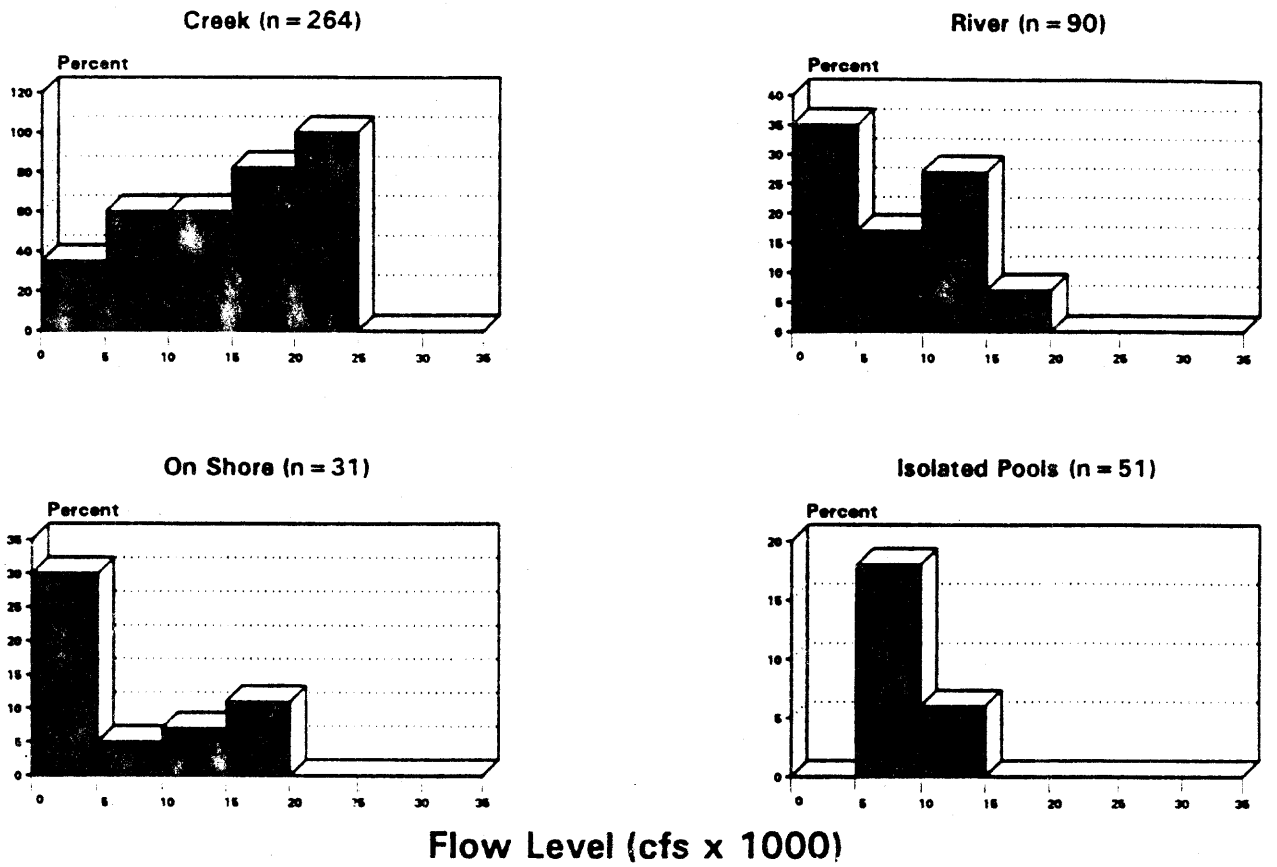
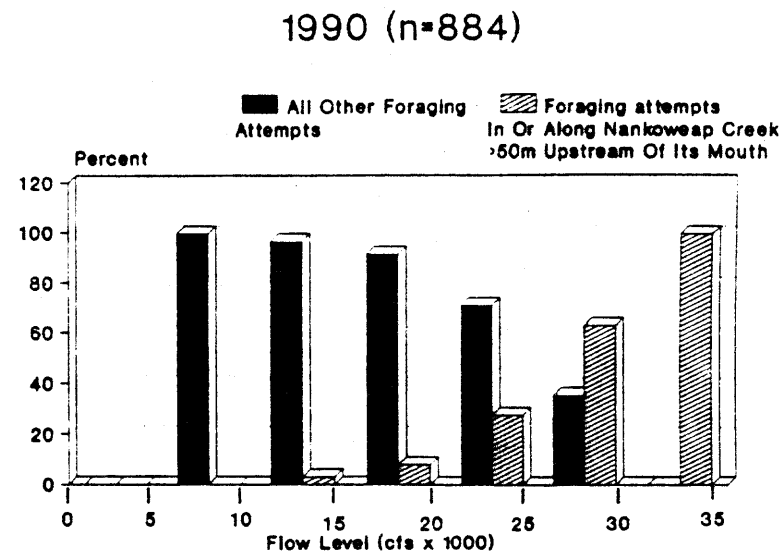


Figure 2-5. Percent of Bald Eagle foraging attempts by foraging location and river flow level, at and near the confluence of Nankoweap Creek and the Colorado River during the 1991 study period.

The distribution of foraging attempts in or along Nankoweap Creek > 50 m upcreek of its confluence with the Colorado River compared to all other foraging attempts revealed a flow-dependent spatial foraging pattern (Fig. 2-6). In 1990, increasing flows corresponded to an increasing proportion of foraging attempts > 50 m up the creek. All foraging attempts occurred > 50 m upcreek at the highest flows in 1990. The flow-dependent spatial foraging pattern observed in 1990 was analogous to the pattern observed in 1991 at river flows of < 20,000 cfs. River flows exceeding 20,000 cfs were rare in 1991 (Fig. 2-3), and that portion of Figure 2-6 above 20,000 cfs in 1991 was based on only four foraging events.

The flow-dependent nature of spatial foraging patterns was more pronounced when only foraging attempts for live trout in the creek during 1990 were considered. The probability that any given foraging attempt would be within 50 m of the creek mouth was 0.99 for low river flows in 1990 (Fig. 2-7). This probability declined to 0.06 for the highest river flows experienced in 1990. The difference in probabilities over the range of river flow levels was significant (logistic regression test for negative trend, $\underline{z} = 11.31$, $P < 0.001$). Probabilities that a given foraging attempt were within 50 m of the creek mouth ranged from 0.82 at the lowest river flows to 0.70 at the highest river flows in 1990 (Fig. 2-7). No significant difference existed between the number of creek foraging attempts for live trout < 50 m upcreek versus > 50 m



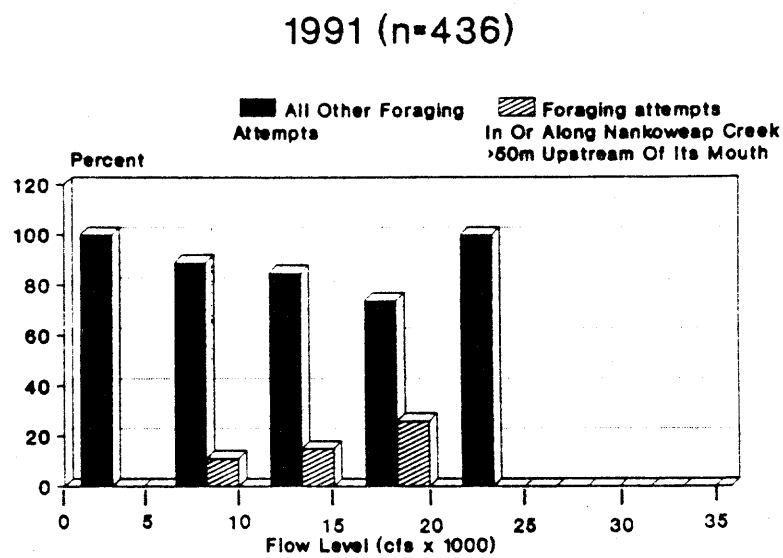


Figure 2-6. Bald Eagle foraging attempts > 50 m upstream in or along Nankoweap Creek versus all other forages by sequential river flow categories for the 1990 and 1991 study periods.

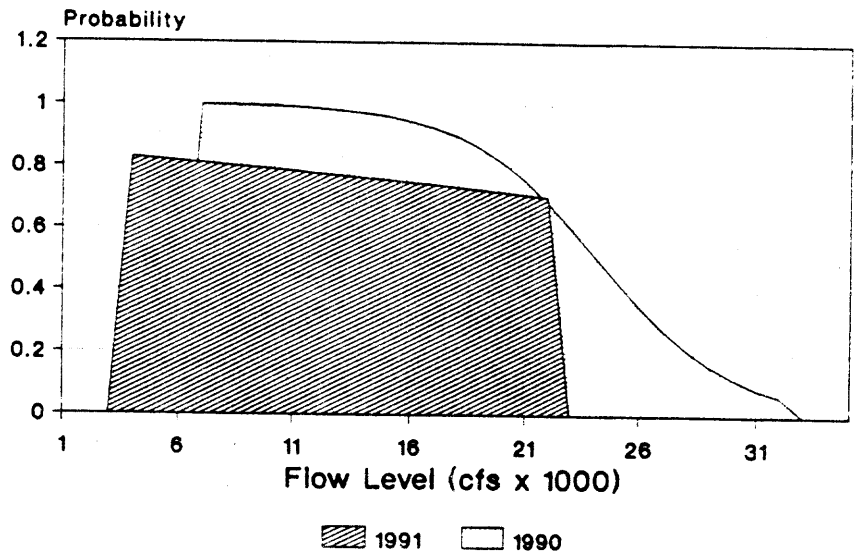


Figure 2-7. Probabilities, by river flow, that any given Bald Eagle foraging attempt for live trout in Nankoweap Creek was within 50 m of the confluence of the Colorado River, Grand Canyon, during the 1990 and 1991 study periods.

upcreek at high and low flows in 1991 (logistic regression test for negative trend, $z = 0.95$, $P = 0.338$). A comparison of 1990 foraging success rates for live trout in the creek indicated foraging success < 50 m upcreek (75%) was not significantly different than foraging success > 50 m upcreek (78%; $x^2 = 0.74$, df = 1, $P = 0.389$).

Contribution of Fluctuating Flows to Prey Capture

Of the 52 total foraging attempts (see Chapter 3) that occurred in isolated pools along the rivershore left by fluctuating flows from Glen Canyon Dam during the 1991 study period, 41 (all live trout) were successful. All of the 31 foraging attempts that took place on shore for carrion trout (see Chapter 3) were successful; 13 of these occurred immediately adjacent to the river and were left stranded on shore due to fluctuating flows from Glen Canyon Dam. Therefore, 54 trout (41 plus 13) captured by eagles were furnished by fluctuating flows, or 18.7% of all prey items captured by Bald Eagles at Nankoweap in 1991.

Of the 41 total foraging attempts that occurred in isolated pools in 1990 (Chapter 3), 37 (19 live trout, 18 carrion trout) were successful. All of the 78 foraging events that took place on shore for carrion trout were successful; 42 of these occurred immediately adjacent to the river. Therefore, 79 trout (37 plus 42; 19 live trout, 60 carrion trout) captured by eagles were furnished by fluctuating flows, or 11.5% of all prey items captured 1990.

DISCUSSION

Influence of Fluctuating Flows on Spatial Foraging Patterns

Fluctuating flows from Glen Canyon Dam exerted a strong influence on spatial foraging patterns of Bald Eagles at and near the confluence of Nankoweap Creek and the Colorado River. As river flows increased, the proportion of foraging attempts in the creek increased from ca. 50% to 100%, whereas proportions of river, shore, and isolated pool foraging attempts declined. This pattern was consistent over both years of the study.

This spatial foraging pattern resulted from the relative stability of Nankoweap Creek as foraging habitat and the relative instability of river, shore, and isolated pool foraging habitats. Foraging conditions in Nankoweap Creek were largely independent of Colorado River flow levels, except for the downstream-most 30 m of the creek in the river's zone of fluctuations. Creek discharge, depth, and turbidity rarely changed during the study period. In contrast, foraging conditions in river, shore, and isolated pool habitats were dependent on Colorado River flow levels.

River velocity and turbidity increased substantially with increasing river flows. Although no measurements were made of the extent of shallow, near-shore river foraging habitat more heavily used for foraging (see Chapter 3) at various flow levels, we estimated that proportionally more shallow, near-shore river foraging habitat existed at high flows than

at low flows. Why, then, did the proportion of river foraging attempts decrease with increasing river flows, and why were no river forages observed at the highest flows? We suggest that the difficulty of foraging in the river increased at the highest flow levels, causing eagles to shift their foraging activity to a less difficult and more productive foraging habitat (see Chapter 3). Knight and Skagen (1988) demonstrated that higher water levels in the Nooksack River, Washington, caused a decline in the relative availability of prey for Bald Eagles, presumably due to changes in foraging habitat, and caused a corresponding shift in eagle foraging strategies.

A conservative extrapolation of the change in spatial foraging patterns observed near Nankoweap Creek can be made to the entire river corridor. Eagles near Nankoweap Creek shifted their foraging activity entirely to the creek when river flows were at their highest levels, but eagles at other localities throughout the river corridor did not have a similar opportunity. If our suggestion is true that foraging in the river is more difficult at the highest flow levels, then eagles foraging in the river corridor at localities other than Nankoweap may experience a reduction in foraging success or reduced opportunities to forage at the highest flow levels. This potential temporary disadvantage for foraging eagles would diminish as flows decreased.

Foraging conditions on shore and in isolated pools were dependent on river flow levels, to the extent that these foraging habitats did not exist or were greatly reduced in extent at the highest flow levels. Foraging attempts taking place on shore were for carrion trout that were largely stranded at the river's shoreline or along the creek in the river's zone of fluctuations by decreasing flows. Higher flows would inundate the shoreline and creek mouth area, washing away any carrion trout. Likewise, ephemeral isolated pools created by decreasing flows would be inundated at higher river flows and become part of the river foraging habitat.

The flow-dependent spatial foraging patterns indicated that fluctuating flows can influence Bald Eagle foraging ecology. However, this flow-dependent shift in spatial foraging patterns did not influence eagle foraging success. Trout stranded in isolated pools left by fluctuating flows represented a moderate, beneficial contribution to the eagle energetic budget, a contribution that increased during a year of low prey abundance (see Chapter 3). However, the ultimate importance of this contribution can only be put into perspective by use of an energetics simulation model for Bald Eagles, such as that developed by Stalmaster (1983).

CHAPTER 3:

FORAGING ECOLOGY OF WINTERING BALD EAGLES

ABSTRACT

Winter foraging strategies of Bald Eagles exhibited a pattern of dynamic optimization under changing conditions. Eagles acquired food by hunting live prey (86%), scavenging (8%), and interspecific piracy (6%). Most foraging attempts (99%) were for rainbow trout. Hunting methods, success, and spatial and temporal patterns of foraging differed between years, apparently as a result of changing prey abundance. Eagle foraging strategies were independent of age.

Bald Eagles modified their foraging strategies to maximize foraging success in most instances where risk of injury was minimal. When faced with prey exploitation decisions, eagles should forage in Nankoweap Creek whenever possible using either ground or aerial attacks when prey is abundant. When prey is scarce, eagles should forage in the creek but use aerial attacks. Any forages in the river should use ground attacks, regardless of prey abundance.

INTRODUCTION

Optimal foraging theory predicts that prey exploitation is structured to maximize fitness, with foraging success often

used as an estimate of fitness (Charnov 1976, Dunbrack 1979, Fischer 1985, Stephens and Krebs 1986, Morse 1990). Birds making foraging decisions must be capable of evaluating energy content of the prey item, energetic cost of the attempt, probability of success in different habitats using different attack methods, and potential risk of injury involved in the attempt (Dunbrack 1979, Fischer 1985, Knight and Skagen 1988, Maurer 1990). Fluctuations in resource abundance may also influence prey exploitation choices and foraging strategies (Davies and Houston 1981, Ewald 1985, Knight and Skagen 1988).

Several hundred migratory Bald Eagles winter in Arizona each year, when they are continually moving over relatively large distances in search of prey (Grubb et al. 1989). The well-documented opportunistic nature of foraging by Bald Eagles (Haywood and Ohmart 1986, Watson et al. 1991) indicates they face constant choices regarding prey exploitation. If stronger selective pressures are brought to bear against migratory birds in winter, as some investigators argue (Lack 1966, Fretwell 1972), then winter is a key time to examine how choices in prey exploitation influence Bald Eagle foraging ecology. Here, we evaluate winter foraging ecology of a concentration of Bald Eagles exploiting an annually-occurring spawn of rainbow trout which has recently developed along the Colorado River in Arizona (Brown et al. 1989).

Our objectives were to: 1) describe foraging behavior, methods, prey use, and success of the eagle concentration, 2) test the hypothesis that eagle foraging strategy changed by age, and 3) determine if foraging success was influenced by foraging location, attack method, and changing prey abundance. This information has implications for the management of wintering Bald Eagles, and will aid in the development of guidelines for fisheries maintenance and the identification of key foraging habitat.

METHODS

The study was conducted in a 3 km^2 area at the confluence (elev. 850 m) of Nankoweap Creek and the Colorado River in Grand Canyon National Park, northern Arizona. The Colorado River through the study area is a large perennial stream up to ca. 10 m deep and ranging from 40-150 m in width (unpubl. data, Glen Canyon Environmental Studies, U.S. Bureau of Reclamation). Nankoweap Creek is a small tributary up to 2 m wide and averaging 30 cm maximum depth (Brown et al. 1989).

Observations were made from an uncamouflaged observation post located 800 m west and 100 m above the confluence. Up to 5 concurrent observers continuously monitored foraging attempts from 30 min before sunrise to 30 min after sunset, 6 February to 20 March 1990 and 23 January to 13 March 1991. The following information was recorded for each foraging attempt: date and time, age of foraging eagle, location,

foraging method, attack method, prey species and status, success of attempt, and distance to nearest shore.

Eagles with a primarily white head and tail were designated adults; those with dark plumage or largely brown plumage mottled with some white were designated immatures (Bortolotti 1984). Locations of foraging attempts were identified as creek, river, shore, or isolated pools. Isolated pools were shallow basins of water up to ca. 2 m in diameter and 30 cm deep left along the river bank due to daily fluctuating water releases from Glen Canyon Dam (110 km upstream). Prey status was alive, moribund or injured, and carrion (dead). Foraging methods included 1) hunting for live prey, 2) scavenging for moribund, injured, or carrion prey, and 3) interspecific piracy (kleptoparasitism) of prey.

Attack method was classified as a ground attack when eagles walked or jumped onto prey, or reached out with beak or talons to capture prey, from a ground perch; an aerial attack occurred when flapping flight was used to land on prey or to otherwise capture prey. A foraging attempt was successful when prey was secured, even though prey may have been pirated by conspecifics or other species before consumption began or was completed. Distance to shore for river foraging attempts was estimated to the nearest m. Water depths at foraging locations were estimated to the nearest m based on topographic river profiles (unpubl. data, Glen Canyon Environmental Studies, U.S. Bureau of Reclamation).

Differences between years compare the effects of changing prey abundance. Prey was abundant in 1990 and scarce in 1991 (see Chapter 1). We made the assumption that interyear differences in foraging strategies were due to differences in prey abundance.

Times of foraging attempts were transformed to minutes after or before local sunrise (U.S. Naval Observatory 1959) and tested for uniformity of distribution with Kolmogorov-Smirnov tests using SPSS software (Norusis 1986). Patterns of foraging success by age, attack method, location, and prey abundance (year) were analyzed with log-linear analysis using SPSS software (Norusis 1986). Chi-square goodness-of-fit tests were used to analyze success by foraging method and foraging locations in each year. All other analyses used Chi-square tests for association.

RESULTS

Foraging Methods, Prey Use, and Success

Eagles foraged primarily by hunting for live prey, although scavenging for carrion trout and interspecific piracy comprised 13.4% of foraging attempts from 1990-1991 (Table 3-1). The proportion of hunting for live prey increased from 1990-1991, scavenging decreased, and interspecific piracy increased (Table 3-1; $\chi^2 = 21.59$, df = 2, $P < 0.001$). An increase in the proportion of hunting for live prey from 1990-1991 corresponded to a decrease in hunting success (73%

Table 3-1. Foraging attempts (successful and unsuccessful) of wintering Bald Eagles by foraging method and year along the Colorado River in Grand Canyon, Arizona, 1990-1991. Percentages indicate percent of row totals.

	Foraging Method						
	Hunting Live Prey		Scavenging		Interspecific Piracy		
Year	N	%	N	%	N	%	Total
1990	757	85.7	86	9.8	40	4.5	883
1991	380	88.4	15	3.5	35	8.1	430
Total	1137	86.6	101	7.7	75	5.7	1313

to 62%, respectively; x^2 = 14.65, df = 1, $P < 0.001$). There was no difference in scavenging success from 1990-1991 (97% and 93%, respectively; $x^2 = 0.473$, df = 1, $P = 0.473$), nor was there a difference in piracy success between years (83% to 74%, respectively; $x^2 = 0.811$, df = 1, $P = 0.368$).

Interspecific piracy was directed at Common Ravens (*Corvus corax*; $n = 55$, 98% successful) and Golden Eagles (*Aquila chrysaetos*, $n = 20$, 25% successful). Most foraging attempts were for rainbow trout or unknown fish assumed to be rainbow trout ($n = 1303$, 99.2%), and only 10 attempts (0.8%; 1 in 1990 and 9 in 1991, all unsuccessful) were for waterfowl. More foraging attempts for waterfowl were made in 1991 compared to 1990 ($x = 14.049$, df = 1, $P < 0.001$).

Annual foraging success for all foraging methods combined declined from 76% in 1990 to 64% in 1991 ($x^2 = 20.25$, df = 1, $P < 0.001$). Foraging success from 1990-1991 was 72%. Scavenging was the most successful foraging method (97%) and was more successful ($x^2 = 37.23$, df = 2, $P < 0.001$) than attempts to pirate (79%) or to capture live prey (70%). The few unsuccessful scavenges occurred when aerial attacks failed to secure dead trout from the river.

Foraging Behavior

Time of day. Temporal foraging patterns on days without human disturbance had a different distribution in 1990 compared to 1991 ($D = 0.147$, $P = 0.001$). Foraging attempts in 1990 were not distributed evenly throughout the day (D =

0.128, $P < 0.001$), but exhibited morning and afternoon peaks (Fig. 3-1). Foraging attempts in 1991 (Fig. 3-1) were distributed evenly throughout the day ($D = 0.059$, $P = 0.37$).

Proximity to shore. In the river, 97 (71%) of 137 foraging attempts occurred < 5 m from shore. Since water depth was < 3 m within 5 m of shore where foraging occurred, eagles were hunting for trout in shallower water. Eagles experienced significantly greater foraging success in shallower water < 5 m from shore (47%) than in deeper water > 5 m from shore (18%; $x^2 = 10.90$, df = 1, $P = 0.001$). Significantly more foraging attempts < 5 m from shore occurred in 1990 (95%) than in 1991 (51%; $x^2 = 31.45$, df = 1, $P < 0.001$).

Location. Foraging attempts were not distributed evenly among the 4 foraging locations in either year (Table 3-2). Eagles foraged primarily in the creek in 1990 ($x^2 = 1358.7$, df = 3, $P < 0.001$) and 1991 ($x^2 = 304.5$, df = 3, $P < 0.001$) and foraged proportionally less in river, pool, and shore locations. Patterns of foraging attempts by location changed between years ($x^2 = 78.4$, df = 3, $P < 0.001$). More foraging attempts occurred in the creek in 1990 compared to 1991, and more foraging attempts occurred in the river and in isolated pools in 1991 as compared to 1990. Overall foraging success for all prey types from 1990-1991 was 75% in the creek, 41% in the river, 85% in isolated pools, and 100% on shore.

We examined river foraging success < 200 m from the creek mouth versus > 200 m from the mouth because trout may have

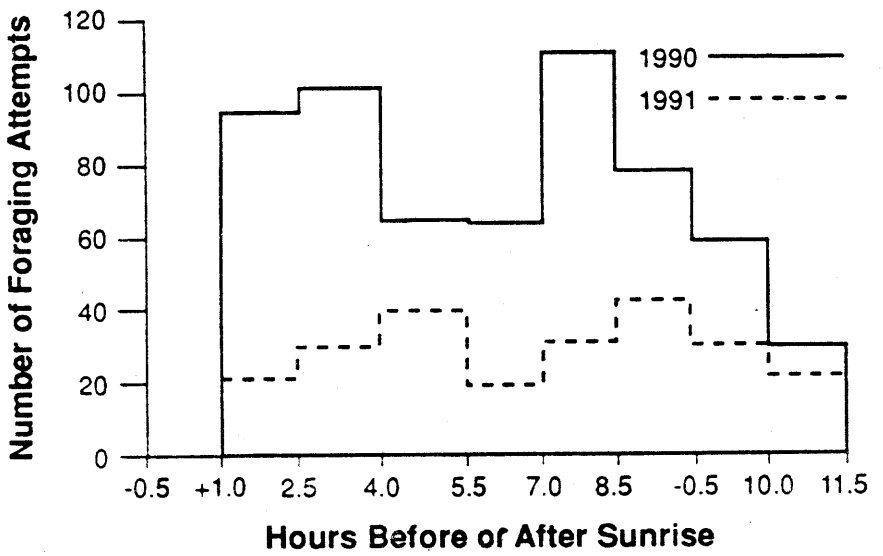


Figure 3-1. Temporal distribution of Bald Eagle foraging attempts in the winters of 1990 and 1991 along the Colorado River in Grand Canyon, Arizona. Only foraging attempts from days without human disturbance have been included (22 days in 1990, n = 603; 19 days in 1991, n = 236).

Table 3-2. Number and percent of foraging events by age, location, and year for wintering Bald Eagles at and near the confluence of Nankoweap Creek and the Colorado River, Grand Canyon National Park, Arizona, 1990-1991. Percentages for the four locations refer to the percent of total foraging events for that year only (n = 886 in 1990, 441 in 1991).

	Creek				River				Pool				Shore					
	1990		1991		1990		1991		1990		1991		1990		1991		Total	
Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Adult	143	16	102	23	26	3	44	10	22	3	24	6	32	4	16	4	409	31
Immature	553	62	162	37	45	5	50	11	19	2	28	6	46	5	15	3	918	69
Total	696	78	264	60	71	8	94	21	41	5	52	12	78	9	31	7	1327	100

congregated at the mouth prior to entering the creek to spawn, thereby increasing local prey abundance. In 1990, no river foraging attempts occurred > 200 m from the creek mouth. In 1991, foraging success < 200 m from the creek mouth was greater (45%) than success > 200 m from the creek mouth (19%; $\underline{x}^2 = 7.08$, df = 1, $\underline{P} = 0.008$). In addition, more ground attacks ($\underline{n} = 40$) than aerial attacks ($\underline{n} = 53$) occurred < 200 m from the creek mouth as compared to > 200 m from the creek mouth ($\underline{n} = 3$ and 49, respectively) for both years combined ($\underline{x}^2 = 22.35$, df = 1, $\underline{P} < 0.001$).

Foraging Success

Since 987 (74%) of the 1331 foraging attempts observed were for live trout in the creek or river, further analyses addressed the influences of age, location, attack method, and prey abundance (year) on foraging success in those two locations only.

More foraging attempts were initiated by immatures (73%) than by adults (27%; Table 3-3) as a result of the predominance of immatures throughout most of the study (see Chapter 1). Adults were more successful (74%) than immatures (66%) in capturing live prey. Adults were more likely to forage in the creek (80%) than the river (20%), whereas immatures foraged mainly in the creek (89%; 11% in the river). Age was not a significant factor above the level of a 2-way association with location, outcome, or prey abundance. Therefore, the greater foraging success of adults

Table 3-3. Loglinear model of associations between age, location, attack method, prey abundance (year), and outcome of Bald Eagle foraging attempts for live trout in Nankoweap Creek or the Colorado River, Grand Canyon National Park, Arizona, 1990-1991. Parameter estimates are listed only for effects resulting from the most parsimonious model.

Effect	Parameter Estimate	x^2	P
AGE	0.3757	214.86	0.0000
LOCATION	0.8053	587.24	0.0000
METHOD	0.0585	85.02	0.0000
PREY	0.1342	145.14	0.0000
OUTCOME	0.2495	135.72	0.0000
AGE x LOCATION	0.1696	7.45	0.0063
AGE x METHOD	------	2.32	0.1274
AGE x PREY	0.2366	32.00	0.0000
AGE x OUTCOME	-0.1658	14.76	0.0001
LOCATION x METHOD	0.3351	38.47	0.0000
LOCATION x PREY	0.1822	12.97	0.0003
LOCATION x OUTCOME	0.3274	53.64	0.0000
METHOD x PREY	0.2104	27.00	0.0000
METHOD x OUTCOME	------	0.23	0.6294
PREY x OUTCOME	0.0526	10.85	0.0010
AGE x LOCATION x METHOD	------	2.35	0.1247
AGE x LOCATION x PREY	------	0.15	0.6978
AGE x LOCATION x OUTCOME	------	2.93	0.0868
AGE x METHOD x PREY	------	0.20	0.6522
AGE x METHOD x OUTCOME	------	0.01	0.8892
AGE x PREY x OUTCOME	------	0.66	0.4133
LOCATION x METHOD x PREY	------	2.75	0.0967
LOCATION x METHOD x OUTCOME	-0.2784	18.79	0.0000
LOCATION x PREY x OUTCOME	------	0.03	0.8561
METHOD x PREY x OUTCOME	0.0128	6.03	0.0140
AGE x LOCATION x METHOD x PREY	------	0.04	0.8421
AGE x LOCATION x METHOD x OUTCOME	------	3.05	0.0804
AGE x LOCATION x PREY x OUTCOME	------	0.03	0.8558
AGE x METHOD x PREY x OUTCOME	------	0.03	0.8627
LOCATION x METHOD x PREY x OUTCOME	0.1416	7.32	0.0068

was consistent by any combination of location, method, and prey abundance.

More foraging attempts occurred in the creek (87%) than the river (13%), and foraging attempts in the creek were more successful (73%) than in the river (38%; Table 3-3). Ground attacks (65%) were more common than aerial attacks (35%), but did not differ by success. However, proportions of ground to aerial attacks differed by location. In the creek, 69% of foraging attempts were ground attacks and 31% aerial attacks; in the river, 34% were ground attacks and 66% aerial attacks. The ca. 2:1 difference in success exhibited in the creek versus the river varied by attack method. In the creek, ground attacks were 71% successful and aerial attacks 78% successful; in the river, ground attacks were 62% successful and aerial attacks 25% successful. Aerial attacks were more successful in the creek than the river, while ground attacks were more successful in the river.

Success rates were greater in a year of prey abundance, and more foraging attempts took place in the creek when prey was abundant (Tables 3-3, 3-4). In 1990, 92% of foraging attempts occurred in the creek and 8% in the river; in 1991, 75% occurred in the creek and 25% in the river. The proportion of ground and aerial attacks also differed by prey abundance. In 1990, 72% of foraging attempts were ground attacks and 28% aerial attacks; in 1991, 49% were ground attacks and 51% aerial attacks.

Table 3-4. Percent foraging success on live trout in Nankoweap Creek or the Colorado River by wintering Bald Eagles by location, prey abundance (year), age, and attack method, Grand Canyon National Park, Arizona, 1990-1991.

Attack Method by Age	Creek 1990 N	Creek 1990 %	Creek 1991 N	Creek 1991 %	River 1990 N	River 1990 %	River 1991 N	River 1991 %	Both Locations 1990 N	Both Locations 1990 %	Both Locations 1991 N	Both Locations 1991 %	Both Years N	Both Years %
Ground Attack														
Adult	82	85	45	60	11	64	11	73	93	83	56	63	149	75
Immature	378	73	86	55	17	53	6	67	395	72	92	55	487	69
Total	460	75	131	56	28	57	17	71	488	74	148	58	636	70
Aerial Attack														
Adult	41	80	45	82	8	63	23	39	49	78	68	68	117	72
Immature	123	72	54	82	22	18	35	11	145	64	89	54	234	60
Total	164	74	99	82	30	21	58	22	194	68	157	60	351	64
Total	624	75	230	67	58	43	75	33	682	72	305	59	987	68

Success rates of ground and aerial attacks differed by prey abundance because, relative to aerial attacks, ground attacks were more successful when prey was abundant (Tables 3-3, 3-4). Therefore, the relative abundance of prey has a greater effect on the success rate of ground attacks than aerial attacks.

The 4-way association between location, method, outcome, and prey indicated a difference in success rates by location, method, and prey abundance (Table 3-3). The success rates of ground and aerial attacks in the creek were high and equal during prey abundance, but the success rate of ground attacks exceeded that of aerial attacks in the river (Table 3-4). In contrast, aerial attacks were more successful than ground attacks in the creek when prey was scarce while the success rate of ground attacks in the river still exceeded that of aerial attacks in the river.

DISCUSSION

Foraging methods of Bald Eagles were dependent on prey abundance between years. Hunting for live prey was the predominant foraging method regardless of prey abundance, but hunting for live prey decreased when prey was abundant. Scavenging for dead trout was more frequent when prey was abundant due to the presence of greater amounts of carrion, but the rate of interspecific piracy was more frequent when prey was scarce. Eagles along the Colorado River hunted more

live prey but scavenged and pirated less compared to eagle foraging methods on the Columbia River estuary, Oregon (57%, 24%, and 19%, respectively; Watson et al. 1991).

A decline in prey abundance caused a shift in spatial foraging patterns in the river. During prey scarcity, more foraging attempts occurred farther from shore in deeper water where foraging success was lower, and more foraging attempts occurred > 200 m from the creek mouth where foraging success was lower. Prey scarcity also corresponded to a significant increase in foraging attempts for waterfowl on the river.

Foraging success was also dependent on prey abundance between years, with prey abundance resulting in higher foraging success. The success rate of hunting for live prey was higher during prey abundance, although success rates for scavenging and interspecific piracy were independent of prey abundance. Success rates of hunting and scavenging by eagles along the Colorado River (70% and 97%, respectively) were similar to success rates of eagles on the Columbia River estuary (66% and 98%, respectively). However, success rates for piracy differed substantially (79% and 46%, respectively; Watson et al. 1991). This difference was apparently due to the inclusion of intraspecific piracy in the Columbia River total, and the difference in target species. Most piracies in the Columbia River estuary were unsuccessfully directed against gulls (Larus spp.) which would drop prey into open water when eagles attempted piracy. In contrast, most

piracies along the Colorado River were successfully directed at Common Ravens, which could not fly away with intact prey.

Changes in temporal foraging patterns corresponded to changes in prey abundance. Daily foraging in 1990, when prey was abundant, exhibited morning and afternoon peaks that may have represented times when eagles preferred to forage. Morning peaks of foraging noted in other eagle studies are related to morning hunger (Harmata 1984, Watson et al. 1991). In contrast, times of daily foraging in 1991, when prey was scarce, were uniformly distributed throughout the day. We suggest that eagles may not have been able to forage at times of their choice as they may have done in 1990, and may have foraged as prey became available. This temporally uniform pattern of foraging for fish was documented in a population of nesting Bald Eagles in Arizona (Haywood and Ohmart 1986).

Wintering eagles attempting to forage in the Colorado River do so primarily in shallow water < 5 m from shore. Yearlong foraging patterns of eagles in the Columbia River estuary were similarly dependent on shallow water < 4 m deep (Watson et al. 1991). Foraging success was greater in shallow water along the Colorado River, but no difference existed in foraging success between deep and shallow water in the Columbia River estuary (Watson et al. 1991). The effects of water velocity were not examined in either study.

Bald Eagles in the Colorado River study area could choose to make foraging attempts from 4 different foraging locations

in close proximity, but chose the creek in which to initiate most foraging attempts. This pattern was consistent by age, attack method, and prey abundance. Foraging success was greater in the creek than the river, so eagles presumably increased their food intake by foraging in the creek whenever possible. Other studies have also demonstrated that foraging attempts should be initiated in locations with the highest rate of energy intake (Stephens and Krebs 1986). Although foraging attempts on shore and in isolated pools had higher success rates than the creek, these locations were used less frequently because they exhibited fewer prey items.

Eagle foraging strategies were independent of age. Adults were more successful than immatures, similar to the success rates of adults (84%) and immatures (64%) reported from Glacier National Park, Montana (Shea 1978). This reflects a lack of experience in immatures, as younger eagles are less efficient at foraging than adults (Stalmaster and Gessaman 1984). Although immatures made proportionally more foraging attempts in the creek than adults, the higher success rate of adults was consistent by location. Higher adult success was a stable advantage that persisted over the length of the study and was independent of any combination of foraging location, attack method, or prey abundance. Immature eagles did not come to parity with adults in a sequential manner by location, attack method, or prey abundance, but apparently gained generic experience across all foraging strategies.

What strategy should eagles adopt to increase foraging success when faced with the 16 foraging choices (4 foraging locations, 2 attack methods, 2 prey abundance levels) identified in the Colorado River study area? Assuming that strategies resulting in a higher success rate are preferable, then eagles (regardless of age) should always forage in the creek if possible. When prey is abundant, eagles should forage in the creek using either attack method. When prey is scarce, eagles should continue to forage in the creek but should use aerial attacks. Any foraging attempts in the river should use ground attacks near the creek mouth, regardless of prey abundance.

Eagle foraging strategies occasionally contradicted the assumption that strategies with the highest success rate were preferable. For example, aerial attacks in the creek when prey was scarce were more successful than ground attacks, yet ground attacks were more frequent. Ground attacks in the river during prey scarcity were more successful than aerial attacks, yet aerial attacks were more frequent. These apparent discrepancies may have been due to the risk of injury posed by certain foraging locations and attack methods. Knight and Knight (1988) demonstrated that Bald Eagle choice of foraging methods (pirating vs. scavenging) was partially influenced by risk of injury.

We suggest that risk of injury during aerial attacks was greater than risk during ground attacks because an airborne

collision with another object could potentially break a wing, resulting in death. Ground attacks were not without risk because of greater exposure to predators such as coyotes or humans (Hansen 1986). Likewise, we suggest that risk of injury during river foraging attempts was greater than during creek foraging attempts because a miscalculation in the river could result in submersion and drowning. Although no serious injuries or fatalities were observed during the study period, no potentially injurious situations were observed during creek foraging attempts. As also noted by Hansen (1986) on the Chilkat River in Alaska, we observed ca. 10 potentially fatal situations in which river foraging attempts resulted in submerged eagles being swept through rocky rapids and rough water. A dead immature found in the river in March 1988 showed no signs of injury and had apparently drowned (pers. obs., L.E. Stevens). If aerial attacks and river forages are riskier, then prey scarcity may result in greater probability of injury for foraging eagles.

Winter foraging strategies of Bald Eagles exhibited a consistent pattern of dynamic optimization under changing conditions. Eagles foraging strategies changed to maximize foraging success in most instances where risk of injury was minimal. These findings indicate that the winter foraging success of endangered Bald Eagles would benefit from management decisions to maintain or enhance the present status of the trout spawn in Nankoweap Creek.

CHAPTER 4:

INFLUENCES OF HUMAN DISTURBANCE ON THE BALD EAGLE CONCENTRATION AT NANKOWEAP CREEK

ABSTRACT

Human disturbance strongly influenced the behavior and distribution of wintering and migrating Bald Eagles at the confluence of Nankoweap Creek and the Colorado River from January to March 1991. Forty-six disturbance events occurred in the 1991 study period, preventing eagles from foraging at or near the creek mouth for 13% of all daylight hours. Time required by eagles to return to the creek mouth area after a disturbance event ended differed between disturbance types (mean, SD in minutes; helicopter = 1, 1.3; hiker = 79, 57.5; boat = 42, 56.0). Return times after disturbance increased with increasing duration of disturbance. Low-level helicopter activity within 700 m of the confluence caused > 50% of all eagles to elicit a flushing response. Hiking or boating activities caused > 50% of all adult and immature eagles to flush at distances of 600 m and 300 m, respectively, but flushing distance decreased with increasing height of eagles above the disturbance. Immature eagles were more tolerant of boating and hiking activities than adults.

If future monitoring indicates the eagle concentration to be of consistent, annual occurrence and of sizeable or increasing abundance, we recommend that park management consider adopting guidelines to control or eliminate human disturbance from the Nankoweap area during the peak eagle concentration.

INTRODUCTION

Human disturbance has been demonstrated to adversely affect the behavior, distribution, and energy budget of Bald Eagles (Stalmaster and Newman 1978, Stalmaster 1983). Disturbance causes displacement (flushing) of eagles to areas of lower human activity (Stalmaster and Newman 1978). Adult eagles flushed in response to human activity in the water or along an open shoreline at a mean distance of 230 m (range = 75 to 500 m) along the Nooksack River in Washington (Stalmaster and Newman 1978). Recreation-related disturbances increase eagle energy expenditures due to flight activity in avoidance of humans, or decreased food consumption due to an interruption of feeding or foraging (Stalmaster 1983). Recreational activities such as hiking, boating, and fishing cause disturbance to eagles as a function of time of year, eagle age, behavior, and location relative to the disturbance (Stalmaster and Newman 1978, Knight and Knight 1984, Buehler 1991, Grubb and King 1991). The primary management strategy to reduce or minimize these human disturbances to Bald Eagles

has been to create buffer zones, or activity restriction areas, of up to 250-800 m in width around important eagle use areas (Stalmaster and Newman 1978, McGarigal et al. 1991).

We examined the responses of a concentration of wintering and migrating Bald Eagles to human disturbance at the confluence of Nankoweap Creek and the Colorado River in Grand Canyon during the winter of 1991. The purpose of this study was to determine the overall influence of human activity on the eagle concentration. Study objectives were to: 1) document human activity levels in the study area, 2) determine the flushing response of eagles to different types of human activity, 3) determine what parameters influenced eagle flushing distance, 4) document the length of time required before eagles would return to the study area after disturbance,and 5) make recommendations to management concerning the potential need to control recreational activity at Nankoweap during the eagle concentration.

METHODS

The extent of human disturbance to the eagle concentration at the confluence of Nankoweap Creek and the Colorado River was observed from 7 February to 20 March 1990 and 23 January to 13 March 1991. The effects of human disturbance on the eagle concentration were only examined during the 1991 study period. Disturbance events were defined as those instances when humans were within 500 m of the confluence; events began

and ended when humans entered and left that area, respectively. All observations were made from an uncamouflaged observation post located 800 m west and 100 m above the confluence using binoculars and 10-45x spotting scopes. Up to five observers were concurrently present to record the events.

Return time was defined as the number of minutes elapsed from when a disturbance event ended to when the first eagle came back to the approximate locality near the creek mouth where eagles had been prior to disturbance. Since eagles were not marked or banded, we were not able to determine if returning eagles were the same as those that originally left the creek mouth due to disturbance or if they were individuals moving in from elsewhere. Return times could not be analyzed by age class due to the small sample size of returns involved.

Flushing response and distance were the criteria used to evaluate the influence of disturbance on perched or feeding eagles. The following information was recorded for each eagle exposed to disturbance: type of disturbance (helicopter, hiker, boat), response to disturbance (flush or not flush), behavior (perched or feeding), age (adult or immature), horizontal flushing distance, and vertical flushing distance. Horizontal flushing distance was defined as the horizontal distance in m from the eagle to the disturbance at the time when the eagle flushed. Vertical

flushing distance was the vertical distance in m that an eagle was above the disturbance. If an eagle did not flush in response to disturbance, the flushing distance became the closest distance from the eagle to the disturbance.

Horizontal flushing distances were estimated in 100 m intervals, and vertical flushing distances in 25 m intervals. A number of set distances between key landmarks near the creek mouth were measured to the nearest 25 m and plotted on maps of the study area prior to field work. Observers used copies of these field maps to estimate flushing distances within the appropriate distance intervals.

Analysis of return-time data was made using 1-way ANOVA and the Tukey Multiple Range Test for pairwise comparisons, both with SPSS software (Norusis 1986). Analyses to determine the probability of flushing based on horizontal and vertical flushing distances were performed for each disturbance type. The proportion of individual eagles that flushed was calculated for each combination of horizontal and vertical flushing distances. Using logistic regression techniques (Hosmer and Lemeshow 1989) with SPSS software (Norusis 1986), these proportions were incorporated into a model to predict the probability of flushing based on age, horizontal flushing distance, and vertical flushing distance. Age was not incorporated as a component of the model predicting flushing probability for helicopter disturbances because of the small sample size involved.

Locations of eagle perch sites were sampled at 15-minute intervals for each eagle present from 0630-1200 hours on 4 March 1991 to indicate those portions of the study area most heavily used by eagles. One eagle present for 70 minutes resulted in 5 perch-site locations.

The numbers of eagles/day were calculated after the methods for that parameter in Chapter 1; the numbers of successful prey captures/day were calculated after the methods for that parameter in Chapter 3. Mean numbers of prey captures per eagle/day for disturbance versus non-disturbance days were compared using Welch's Approximate t-Test with SPSS software (Norusis 1986)

RESULTS

Extent and Type of Human Disturbance

Human disturbance within 500 m of the creek mouth occurred on 20 days (48%) of the 42-day study period in 1990, comprising 23% (6364 of 27,926 minutes) of daylight during the study. Forty separate disturbance events were recorded, including 17 by boats (private, commercial, research, and park), 13 by fisheries technicians doing daylight research on trout in the creek, and 10 by hikers (including both permitted and unpermitted hiking parties).

Human disturbance within 500 m of the creek mouth occurred on 31 days (62%) of the 50-day study period in 1991, comprising 13% (4115 of 32,881 minutes) of daylight during

the study period. Forty-six disturbance events were recorded, including 23 by boats (private, commercial, research, and park), 13 by hikers (both permitted hikers and park patrols), 5 by low-flying helicopters (all research), and 5 by fisheries technicians doing daylight research on trout in the creek. More disturbance events occurred on more days in 1991, but the total elapsed time of disturbance was greater in 1990.

The number of private rivertrip launches from Lees Ferry during February and March has remained stable over the last decade (pers. comm., S. Cherry), but the number of research launches has recently increased and exceeded the number of private launches in 1991 (pers. comm., Susan Cherry; Table 4-1). February and March hiking permits for the Nankoweap Use Area (Grand Canyon National Park 1988a) have increased 800% since 1985 (Table 4-2).

Return Time After Disturbance

Mean return times (n = 24) exhibited by Bald Eagles (all ages combined) in returning to the confluence after disturbance differed by disturbance type (Table 4-3; F = 5.496, df = 2, P = 0.012). However, pairwise comparison of mean return times after helicopter, hiker, and boating disturbances indicated that the only substantive difference was between return times after helicopter and hiker disturbances (Tukey Multiple Range Test for Pairwise Comparisons, $P < 0.05$). If return time after disturbance was an indicator of the severity of

Table 4-1. Numbers of boating trips launched from Lees Ferry from November 1990 through March 1991, by administrative type. Information supplied by Grand Canyon National Park. Monthly totals differ from disturbance event totals in text because one trip may cause more than one disturbance event.

Time Period	Research	Recreational	Total
November 1990	11	7	18
December 1990	14	4	18
January 1991	16	0	16
February 1991	11	4	15
March 1991	11	17	28
	---	---	---
	63	32	95

Table 4-2. Hiking permits issued by the backcountry reservations office of Grand Canyon National Park for hikers wishing to enter the Nankoweap Use Area during February and March, 1985-1991. Information supplied by Grand Canyon National Park. User nights may not reflect actual user-night levels because some nights on the permit may have been spent outside of the Nankoweap Use Area.

Year	Number of Permits	User Nights
1985	2	7
1986	10	34
1987	13	69
1988	12	60
1989	14	62
1990	15	200
1991	16	64

disturbance, then helicopter disturbance was less severe than hiker or boating disturbances. Eagles did not return to the creek mouth area for the remainder of the day after 9 (of 33; 27%) disturbance events (hikers and boats only) occurring after 16:00 hours.

Time for eagles to return increased as the duration of the disturbance event increased when all 3 disturbance types were considered (Kendall's Tau, $\underline{B} = 0.511$, $\underline{P} < 0.001$). However, this relationship was influenced by the relatively short duration of helicopter disturbances (Table 4-3). Removing the helicopter disturbance events from further analysis, return time still increased as disturbance event duration increased when only hiker and boating disturbances were considered (Kendall's Tau, $\underline{B} = 0.423$, $\underline{P} = 0.005$).

Flushing Distance

The probability that an eagle would flush in response to a helicopter disturbance was > 0.5 for instances where the helicopter was at a horizontal distance of 600-700 m and a vertical distance of 0-100 m (Table 4-4). Probability of flushing declined rapidly with increasing vertical distance of the helicopter above the eagle, and declined gradually with increasing horizontal distance.

Immature eagles were more tolerant of hiker disturbance than adults. The probability that an adult eagle would flush in response to a hiker was > 0.5 when the hiker was at a horizontal distance of 700-800 m and a vertical distance of

Table 4-3. Times for Bald Eagles to return to the vicinity of the confluence of Nankoweap Creek and the Colorado River, Grand Canyon, after human disturbance events ended in January, February, and March 1991, by disturbance type. Disturbance events for which eagles did not return after disturbance ended (n = 9) were not included.

Disturbance Type	Return Time (minutes)		
	n	Mean	SD
Helicopters	4	1	1.3
Hikers	9	79	57.5
Boats	11	42	56.0
All types	24	49	57.4

Table 4-4. Probabilities that a Bald Eagle (all ages) will flush in response to the presence of a helicopter at certain horizontal and vertical distances, at and near the confluence of Nankoweap Creek and the Colorado River, January-March 1991. Probabilities range from 0 to 1; larger values indicate a greater probability of flushing. Vertical distance is the altitude of the helicopter above the eagle. n = 35.

Vertical Distance (m)	Horizontal Distance (m)							
	0	100	200	300	400	500	600	700
0-100	.95	.92	.88	.83	.75	.65	.54	.42
100-200	.86	.79	.70	.59	.48	.37	.27	.19
200-300	.65	.54	.42	.31	.22	.15	.10	.07
300-400	.36	.26	.18	.12	.08	.05	.03	.02
400-500	.15	.10	.07	.04	.03	.02	.01	.01
>500	.05	.03	.02	.01	.01	.01	.00	.00

0-25 m (Table 4-5). Probability of flushing for an adult declined evenly with increasing horizontal and vertical distance. Probability that an immature eagle would flush in response to a hiker was > 0.5 for a horizontal distance of 300-400 m and a vertical distance of 0-25 m (Table 4-5). Probability of flushing for an immature declined evenly with increasing horizontal and vertical distance.

Immature eagles were more tolerant of boating disturbance than adults. The probability that an adult eagle would flush in response to a boat was > 0.5 when the boat was at a horizontal distance of 600-700 m and a vertical distance of 0-25 m (Table 4-6). Probability of flushing for an adult declined evenly with increasing horizontal and vertical distance. Probability that an immature eagle would flush in response to a boat was > 0.5 for a horizontal distance of 300-400 m and a vertical distance of 0-25 m (Table 4-6). Probability of flushing for an immature declined evenly with increasing horizontal and vertical distance.

We examined the frequency of flushing by eagles in response to hiker disturbances along the main Nankoweap Trail connecting the North Rim to the river (at the lower river camp; see Fig. 4-1). Seven hiker disturbances in 1991 consisted of one or more hikers using this main Nankoweap Trail. Of 15 total eagles present < 700 m from the trail during these disturbances, 13 (87%) flushed immediately as hikers became visible where the trail crested the large

Table 4-5. Probabilities that an adult or immature Bald Eagle will flush in response to the presence of hikers at certain horizontal and vertical distance intervals, at and near the confluence of Nankoweap Creek and the Colorado River, January-March 1991. Probabilities range from 0 to 1; larger values indicate a greater probability of flushing. Vertical distance is the elevation of the eagle above the hiker. n = 44.

Vertical Distance (m)	Horizontal Distance (m)								
	0	100	200	300	400	500	600	700	800
Adults									
0-25	1.00	.99	.98	.96	.93	.86	.75	.59	.41
25-50	.99	.98	.96	.92	.84	.72	.55	.37	.22
50-75	.98	.95	.90	.82	.68	.51	.33	.19	.10
75-100	.94	.89	.79	.65	.47	.30	.17	.09	.04
100-125	.87	.76	.61	.43	.26	.15	.08	.04	.02
>125	.73	.57	.39	.23	.13	.06	.03	.02	.01
Immatures									
0-25	.95	.90	.81	.67	.49	.32	.18	.10	.05
25-50	.88	.78	.63	.45	.28	.16	.08	.04	.02
50-75	.75	.59	.41	.25	.14	.07	.04	.02	.01
75-100	.55	.37	.22	.12	.06	.03	.01	.01	.00
100-125	.34	.19	.10	.05	.03	.01	.01	.00	.00
>125	.17	.09	.04	.02	.01	.01	.00	.00	.00

Table 4-6. Probabilities that an adult or immature Bald Eagle will flush in response to the presence of boats at certain horizontal and vertical distance intervals, at and near the confluence of Nankoweap Creek and the Colorado River, January-March 1991. Probabilities range from 0 to 1; larger values indicate a greater probability of flushing. Vertical distance is the elevation of the eagle above the boat. n = 61.

Vertical Distance (m)	Horizontal Distance (m)							
	0	100	200	300	400	500	600	700
Adults								
0-25	.96	.93	.89	.83	.75	.64	.52	.39
25-50	.92	.88	.81	.72	.60	.48	.35	.25
50-75	.86	.78	.68	.56	.44	.32	.22	.14
75-100	.75	.65	.52	.40	.28	.19	.12	.08
100-125	.61	.48	.36	.25	.17	.11	.07	.04
>125	.44	.32	.22	.15	.09	.06	.04	.02
Immatures								
0-25	.84	.77	.66	.54	.41	.30	.20	.13
25-50	.73	.62	.50	.37	.26	.18	.11	.07
50-75	.58	.46	.34	.23	.15	.10	.06	.04
75-100	.42	.30	.21	.13	.09	.05	.03	.02
100-125	.27	.18	.12	.07	.05	.03	.02	.01
>125	.16	.10	.06	.04	.02	.01	.01	.01

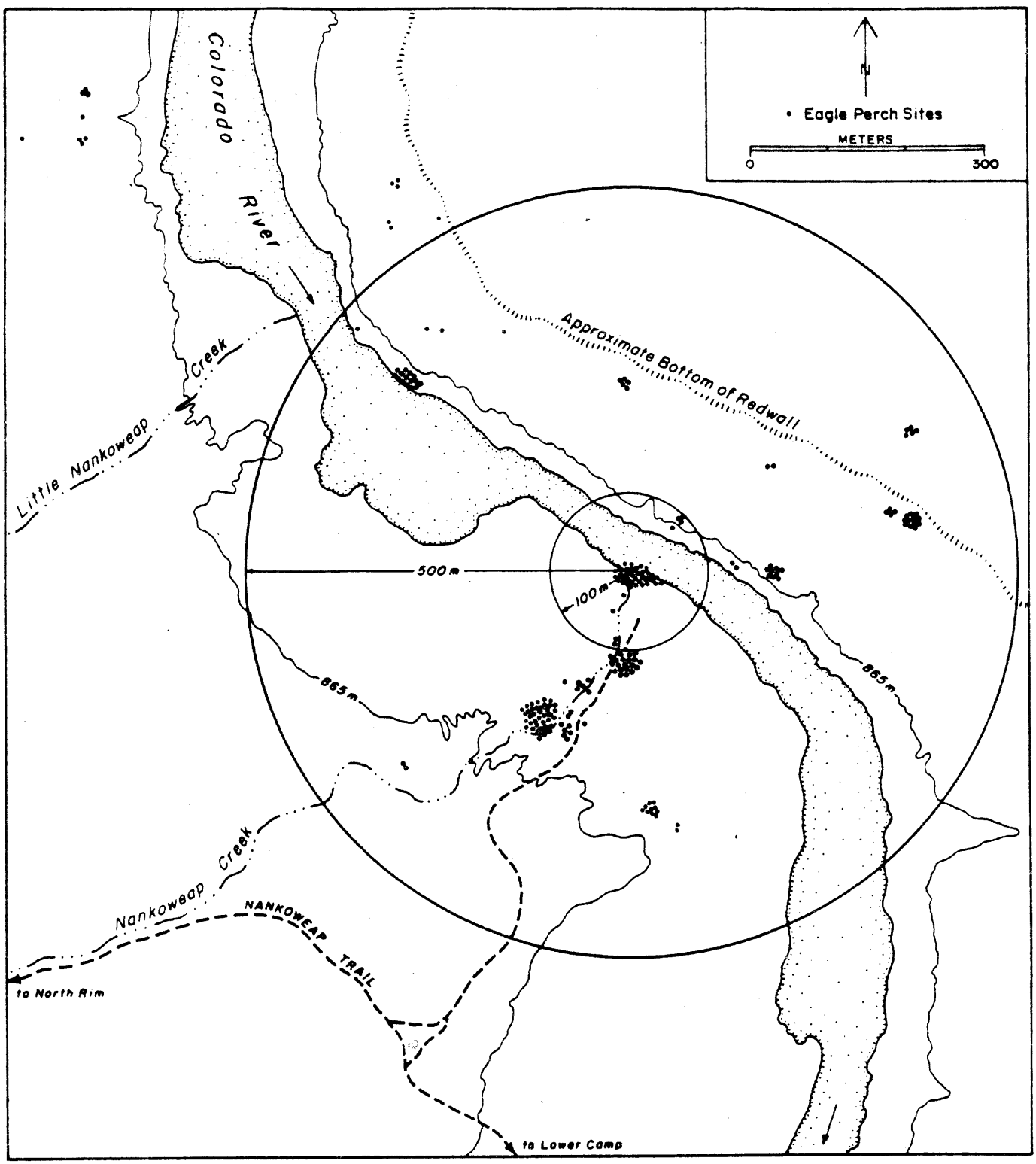


Figure 4-1. Map of the Nankoweap study area, showing the confluence of Nankoweap Creek and the Colorado River. Black dots represent Bald Eagle perch sites sampled from 0630-1200 hours on 4 March 1991; 9 eagles were present at that time.

alluvial ridge separating Nankoweap Creek and the lower camp. The trail itself was 600 m from the creek mouth. Eagles did not congregate only at the creek mouth, but also perched (Fig. 4-1) and foraged (Appendix A) several hundred m upstream along Nankoweap Creek. Eagles that perched or foraged several hundred m upcreek were < 300 m from the main Nankoweap Trail connecting the North Rim to the river (Fig. 4-1) and were more susceptible to hiker disturbance.

Sample size for feeding eagles was too small for analysis of the influence of behavior on flushing distance by age or disturbance type. Based on the small sample size of feeding eagles present when disturbance did occur within 700 m (n = 12), there was no difference in flushing response by feeding (5 flush, 7 do not) versus perching eagles (85 flush, 156 do not; $x^2 = 0.23$, df = 1, $P = 0.635$).

Energetic Costs of Disturbance

A total of 87 eagles flushed during 46 disturbance events in 1991. Stalmaster (1981) calculated that each eagle flushed by human disturbance expended an average of 0.953 Kcal of flight energy; therefore, the 87 eagle flushes represented 82.911 Kcal lost to human disturbance. There was no difference in the number of prey captures/eagle/day on disturbance days versus non-disturbance days (Table 4-7; t_w = 1.13, df = 32.64, $P = 0.266$).

Table 4-7. Number of prey captures/eagle/day made by Bald Eagles at and near the confluence of Nankoweap Creek and the Colorado River, Grand Canyon, February and March 1991. Captures of both live and carrion trout have been included.

Date	Number Eagles Present	Number Prey Captures	Captures/ Day/ Eagle
Days without human disturbance:			
2/07	4	4	1.00
2/08	8	12	1.50
2/16	6	19	3.17
2/18	5	5	1.00
2/19	6	9	1.50
2/21	6	0	0.00
2/22	10	9	0.90
2/23	10	11	1.10
2/26	11	13	1.18
2/27	13	14	1.08
2/28	13	15	1.15
3/01	9	9	1.00
3/02	12	6	0.50
3/06	3	2	0.66
3/07	4	6	1.50
3/10	4	4	1.00
Total	124	138	mean = 1.11
Days with human disturbance:			
2/09	9	2	0.22
2/10	7	0	0.00
2/11	6	1	0.16
2/12	7	10	1.43
2/13	8	9	1.13
2/14	8	9	1.13
2/15	7	7	1.00
2/17	8	8	1.00
2/20	7	7	1.00
2/24	13	15	1.15
2/25	12	16	1.33
3/03	9	2	0.22
3/04	9	2	0.22
3/05	6	2	0.33
3/08	5	5	1.00
3/09	6	8	1.33
3/11	3	3	1.00
3/12	4	12	3.00
3/13	4	0	0.00
Total	138	118	mean = 0.86

Potential Disturbances Caused by Eagle Researchers

Research personnel participating in the study did not approach within 800 m of the creek mouth during daylight hours, as morning and afternoon observers travelled to and from the observation post before first light or after twilight, respectively. However, observation crews changed at noon, at which time observers passed within 700 m of the creek mouth. To determine the influence of this daylight activity on the eagle concentration, each observation crew change was treated as a disturbance event and the appropriate data was gathered. During noon crew changes (n = 32), 113 eagles were present within 800 m of the observation post. Only 3 (2.6%) of these eagles flushed, at vertical distances of 400 m (immature), 600 m (adult), and 600 m (adult).

DISCUSSION

Return Time After Disturbance

Eagles returned to perch in the creek mouth area more quickly after low-flying helicopter disturbances than hiking or boating disturbances. From a management perspective, hiking and boating disturbances were similar with respect to their effect on the length of time taken by eagles to return to the creek mouth area. The finding that increasing duration of disturbance increased eagle return-time after disturbance has useful implications for management. If management decides to permit some level of recreational use in the Nankoweap area

during the eagle concentration, then recreational events of short duration (i.e. < 30 minutes) would cause less disturbance to the eagle concentration.

Flushing Distance

The vertical height of helicopters flying over the Nankoweap area influenced eagle flushing distance more than the horizontal distance of the helicopter. The probability of an eagle flushing was minimal (0.05) when the altitude of the helicopter was > 500 m (at or above the Supai formation), and probability of flushing dropped to 0.01 when the helicopter also maintained an approximate horizontal distance of 300-400 m from the eagle concentration at the creek mouth. Although helicopter use below the rim is unusual and requires park authorization, management guidelines should be considered that would restrict helicopter use to altitudes of at least 500 m above the creek mouth during the eagle concentration.

The horizontal distance at which the probability of eagles flushing in response to hiking and boating disturbances was > 0.5 documented in this study generally exceeded that of other studies. Stalmaster and Newman (1978) found that the mean flushing distance of adults and immatures disturbed by hikers was approximately 225 m and 100 m, respectively, along the Nooksack River in Washington. Eagles perched in riverside trees in Washington flushed in response to an approaching boat at mean distances of 150 and 168 m on 2 different rivers (Knight and Knight 1984). Their mean flushing distance

parameter (Stalmaster and Newman 1978, Knight and Knight 1984) was generally comparable to our $\underline{P} > 0.5$ values because of the symmetric nature of their data sets and because of our assumption that their mean values approximated median values. Eagle flushing distances in Washington may have been less than flushing distances documented at Nankoweap because the terrain was heavily forested in Washington, restricting an eagle's visibility of an approaching hiker. Second, flushing distances may have differed because eagles in Washington were habituated to high levels of human disturbance and were therefore more tolerant of human intrusion. Third, eagles in Washington may have been energy-limited (Stalmaster and Gessaman 1984) and therefore less prone to expend energy for relatively distant disturbances.

Adult eagles were more sensitive to human disturbance than younger eagles, a consistent pattern of reaction to disturbance also noted in other studies (Stalmaster and Newman 1978, Knight and Knight 1984). Adults exhibited a high probability of flushing in response to disturbances > 600 m away. Stalmaster and Newman (1978) did not record disturbances > 500 m from eagles along the Nooksack River in Washington because of the chance that the eagles would flush because of an unknown factor.

The proximity of that portion of the main Nankoweap Trail closest to the eagle concentration was such that hikers using the trail during daylight hours caused most eagles along the

creek or near the creek mouth to flush. Eagles would benefit from management action to control or eliminate daylight hiking activity on this portion of the Nankoweap Trail during the peak of the eagle concentration. One option would be to require all hikers using that portion of the Nankoweap Trail within 1 km of the confluence do so only before first light or after twilight during the peak of the eagle concentration. Second, management could limit or reduce the number of hiking permits for the Nankoweap Trail during the eagle concentration, and require all Nankoweap hikers to stay on the main trail and pass quickly through the area within 1 km of the confluence. This would minimize the effects of disturbance by reducing the amount of time after disturbance required by eagles to return to the creek mouth to forage. And third, no hikers could be allowed to enter the area within 1 km of the confluence during the eagle concentration, eliminating any possibility of human disturbance to the eagles. Temporary trail signs erected prior to the time of the eagle concentration could increase hiker cooperation.

Boating activity near the confluence had the same effect on the eagle concentration as hiking activity: eagles would flush in response to the disturbance, returning later as a function of disturbance duration. Management action to control, reduce, or eliminate boating activity during the peak of the eagle concentration would benefit the eagles. To minimize the influence of boating disturbance, management

could require the following: 1) boating trips passing the confluence during the eagle concentration should do so only after 16:00 hours, when most eagles have already fed for the day; 2) boating trips should not stop or pull ashore within 500 m of the confluence; and 3) all boats on the trip should pass the confluence as a group, not scattered out over a km or more, to minimize disturbance time. A reduction or limit on the number of boating permits issued for the peak of the eagle concentration would probably have much the same effect as all of the above restrictions. Management would eliminate potential boating disturbances to the eagles by not issuing any boating permits for the peak of the eagle concentration.

Energetic Costs of Disturbance

The 82.911 Kcal in expended flight energy lost to the Nankoweap eagle concentration due to human disturbance was negligible, considering that the mean energy requirement for one eagle for one day is approximately 500 Kcal (Stalmaster and Gessaman 1984). The real energetic cost of human disturbance to the eagle concentration may have been a reduction in foraging time, and therefore food consumption, a parameter that could not be quantified during the study. Belanger and Bedard (1990) demonstrated that the greatest energetic cost of human disturbance to migrating Snow Geese (*Chen caerulescens*) was a reduction in foraging time, not the cost of expended flight energy to escape disturbance. Furthermore, they demonstrated that geese did not compensate

for loss of foraging time by increasing foraging time to maximize food consumption during undisturbed periods. Similarly, there was no difference in the number of prey captures/eagle/day made at Nankoweap on disturbance versus non-disturbance days in 1991. However, this finding should be interpreted with caution because of the lack of banded or marked individuals during the study and because compensatory mechanisms may have existed that were undetected.

Potential Disturbances Caused by Eagle Researchers

Activities of the eagle research team had minimal or negligible influence on the eagle concentration. The probability of an eagle near the confluence flushing in response to the noon change of observation crews was very low. The eagles may have become habituated to the routine of daily noon change of crews, as suggested by Stalmaster and Newman (1978).

Daytime fisheries research activities at or near the creek mouth that were conducted during our study period had the same negative influence on eagle behavior and distribution as hiking or boating activity. We recommend that future fisheries research activities at and near the creek mouth during the peak of the eagle concentration take place at night to minimize disturbance to the eagles. The least intrusive method of monitoring trout abundance in the future would be to use powerful spotting scopes from the rim (see Chapter 5).

A Case Study: Management of the Bald Eagle Concentration in Glacier National Park, Montana

The development of the Bald Eagle concentration at Nankoweap is analogous to the development of what was the largest concentration of migrant eagles in the United States south of Canada. Kokanee salmon were introduced into McDonald Creek in Glacier National Park, Montana, in 1916, an area where Bald Eagles were historically uncommon. An increase in salmon abundance eventually attracted increasing numbers of migrant Bald Eagles (639 on the peak day in 1981) to the largest concentration in the lower 48 states (McClelland 1973).

An approximately 6 km section of McDonald Creek supported the annual salmon spawn, in an area of the park that was accessible to park visitors. As the concentration increased in size and knowledge of its existence became more widely known, visitor disturbances to the eagles (often well-meaning individuals who merely wanted to see the eagles) reached unacceptably high levels. In 1970, Glacier National Park began to initiate a series of management actions designed to reduce and eventually eliminate human disturbance to the eagle concentration (McClelland 1981). Eventually, the entire area of McDonald Creek where the eagle concentration occurred was closed to public access during the peak of eagle migration. A no-entry buffer zone averaging 1.5 km wide along each side of the creek was designed to minimize human-

eagle conflicts (Glacier National Park 1983). Two locations were made available for visitor viewing: a public bridge across McDonald Creek and a camouflaged observation blind along the creek from which eagles could be photographed by visitors escorted by park interpreters. These restrictions on human access were in effect for 20 years until 1989, when the salmon spawn collapsed and the eagle concentration no longer occurred (Spencer et al. 1991).

Conflicts with National Park Service Policy

The responsibilities of the National Park Service concerning management of lands used by Bald Eagles are clearly defined by the Migratory Bird Treaty Act of 1918, the Bald Eagle Protection Act of 1940, and the Endangered Species Act of 1973 and its subsequent amendments (Bean 1977). Bald Eagles must be given the highest priority when managing for conflicting uses on federal lands. Juxtaposed against this is the mandate of Grand Canyon National Park to manage the Colorado River corridor "to preserve the natural environmental processes and resources of the river environment" (Grand Canyon National Park 1988b). A potential conflict exists over the appropriate management response to an "unnatural" Bald Eagle concentration supported by the non-native spawn of rainbow trout in Nankoweap Creek.

The challenges faced by management when dealing with a similar conflict concerning the Bald Eagle concentration in Glacier National Park were discussed by McClelland et al.

(1984) and apply equally well to Grand Canyon National Park. The eagle concentration at Nankoweap, which is supported by a non-native trout spawn, is in direct conflict with a literal interpretation of National Park Service policy. Suggestions have been made that the eagle concentration be denied special management protection within the park, because of its "artificial, man-made" status. A lack of management protection, under a scenario of status quo or increased recreational use of Nankoweap Creek, could negatively influence the eagle concentration and lead to its reduction or elimination.

A potential justification for denial of management protection might be the concern that a concentration of eagles could increase the risk of increased mortality through disease, extreme weather, or other potential natural disasters (McClelland et al. 1984). Density-dependent threats do put large congregations of animals at greater risk, but the congregation of eagles at concentrated food sources is typical eagle behavior (Stalmaster 1987). The eagle concentration at Nankoweap is "unnatural" only in location, as a similar situation did not exist there prior to the construction of Glen Canyon Dam and the introduction of trout (Brown et al. 1989).

Concerns over the inappropriate presence of non-native species in Grand Canyon National Park, such as rainbow trout, should be met with similar concerns for positive

relationships that have developed with other native species, such as the endangered Bald Eagle (McClelland et al. 1984). The existence of non-native rainbow trout may be in conflict with park management goals, but this food source is of substantial benefit to the Arizona population of wintering and migrating eagles. The availability of abundant prey at Nankoweap may increase the survivorship of immature eagles during their first (and presumably most vulnerable) winter. Assuming that the eagle concentration at Nankoweap maintains itself at approximately 1990 levels or even increases and that the trout spawn persists, the lack of some form of management protection to the Nankoweap area would be detrimental to Bald Eagles and a potential violation of existing federal law.

MANAGEMENT RECOMMENDATIONS

Three basic options are available to Grand Canyon National Park concerning management actions to address human disturbance of the eagle concentration at Nankoweap:

1. No Action. Continue winter recreational use of Nankoweap as allowed under current park guidelines. Assume that the eagle concentration is "unnatural", due to the spawning of non-native rainbow trout, and does not warrant special protection by the National Park Service. Under a worst-case scenario of increased

recreational use of the area, the value of Nankoweap Creek to Bald Eagles would be greatly reduced or virtually eliminated. This option would be appropriate if the eagle concentration consistently failed to occur because of a collapse of the trout spawn or other natural occurrence.

2. Reduce Human Disturbance to Eagles. Adopt regulatory guidelines designed to reduce, but not completely eliminate, recreational use of Nankoweap at the peak eagle concentration (20 February to 5 March). The area within 500 m of the confluence would be closed to all land-based activities, including hiking, fishing, and camping. The number of rivertrip launches from Lees Ferry would be controlled, limited or reduced during this period, with no rivertrip camping within 1000 m of the confluence. Rivertrips passing Nankoweap would be asked to not float below River Mile 50 until after 16:00 hours, the time when most eagles have already foraged for the day, and to streamline the duration of their passage past the creek mouth area. Hikers wishing to use the Nankoweap Trail within 1000 m of the confluence would be regulated, limited or reduced during this period. This action would benefit the eagle concentration by limiting or reducing the effects of human disturbances, and would probably result in greater food consumption by eagles. Park visitors would still

be able to view eagles from outside the 500 m closure zone.

3. Eliminate Human Disturbance to Eagles. Prohibit all recreational activities within 1000 m of the confluence from 20 February to 5 March each year, and for longer if necessary. No river launch permits or hiking permits would be issued during this period.

   This intensive management action should compensate for the loss of visitor ability to view the eagle concentration by creating and promoting a public eagle viewing area from the rim above Nankoweap. This could be accomplished in conjunction with long-term monitoring of the concentration from the rim, and should be coordinated by the National Park Service, Bureau of Reclamation, and the Navajo Nation.

We recommend that option number three be adopted by the park by 1995, if the eagle concentration continues to be both of consistent, annual occurrence and of sizeable or increasing abundance.

Management actions to minimize disturbances to the eagle concentration caused by recreational use of the Nankoweap area should only be considered if the size of the concentration at its peak is sufficient to warrant such action. This is an important consideration, because future changes in the status of the trout spawn in Nankoweap Creek (or other natural causes) could reduce or even eliminate the

eagle concentration. On the other hand, the concentration could increase in numbers in the near future to a size (ca. 30 eagles/day for 10 days) that would more than justify immediate management action. We recommend that management action to control recreational use in the Nankoweap area be considered only if future monitoring indicates that at least 10-15 eagles/day occur at the creek for a period of at least 2 weeks each year, such as was observed in 1990. Years in which the concentration will be smaller, such as 1991, are to be expected occasionally.

For this reason, we recommend that the managers of Grand Canyon National Park adopt interim guidelines for the temporary regulation of recreational use at Nankoweap until future monitoring confirms that the eagle concentration is both consistent and sizeable. If prey abundance during February and March 1992 is sufficient to support an eagle concentration meeting the minimum criteria outlined above, then interim guidelines similar to option number two above should be developed for implementation in 1993. Interim guidelines should be designed to control, but not eliminate human disturbance at Nankoweap. Boating or hiking parties without park permits, such as were observed at Nankoweap in both 1990 and 1991, will doubtless cause more human disturbance than these interim guidelines allow. The occurrence of these unpermitted activities should be taken into account if interim guidelines are developed.

If monitoring from 1992-1994 indicates that the size of the concentration does not meet minimum guidelines identified above, we recommend no management action be taken to control human disturbance at Nankoweap. If monitoring in 1992 and subsequent years indicates that the eagle concentration continues to be of consistent, annual occurrence and of sizeable or increasing abundance, then we recommend that park management adopt longer-term, more intensive guidelines in 1995 to eliminate human disturbance from the Nankoweap area. These intensive guidelines would be similar in scope to option number three above.

In this instance, we recommend that the park consider regulations designed to eliminate all forms of human disturbance within 1000 m of the confluence during the peak eagle concentration each year (20 February to 5 March or longer, depending upon the changing size and duration of the concentration in the future). Management should consider the need for periodic review of these regulatory guidelines, which may need modification as dictated by changing conditions and the findings of annual monitoring activities.

Implementation of these proposed regulations will be controversial, even if the park determines such action to be warranted. The existence of a regulatory precedent for eagle protection in Glacier National Park notwithstanding, special interest groups could take offense at any attempt to control their particular recreational use of the Nankoweap area. For

this reason, we suggest that the following organizations be asked for their input during the development of any interim regulations: Grand Canyon River Guides, Sierra Club, Trout Unlimited, and representatives of the private boating community.

CHAPTER 5:

RECOMMENDATIONS FOR THE DEVELOPMENT OF A MONITORING PROTOCOL FOR THE BALD EAGLE CONCENTRATION AT NANKOWEAP CREEK

ABSTRACT

Paired observation trials to detect Bald and Golden Eagles in the Nankoweap study area were conducted from both rim and river in 1990. Rim observations of Bald Eagles underestimated actual eagle abundance in most cases. The numbers of adult and subadult Bald Eagles were more likely to be accurately represented by rim observations, apparently due to the misidentification of Golden Eagles as immature Bald Eagles from the rim. These findings suggest that: 1) observers should receive more intensive training in identifying Bald versus Golden Eagles prior to annual monitoring; and 2) higher-powered spotting scopes with greater optical quality should be employed during rim monitoring. We recommend that additional rim versus river observation trials to determine eagle numbers be conducted during the first monitoring effort to occur after submission of this report for evaluation of the accuracy of the final protocol.

We recommend that rim (and river, for 1 year) monitoring of the eagle concentration at Nankoweap take place from 22 February to 3 March each year. The management and scientific goals of the monitoring program would be to: 1) determine if a Bald Eagle concentration occurred during the monitoring period; 2) determine the size and age class distribution of the eagle concentration, and the timing of the peak concentration; and 3) document the relative abundance of trout in Nankoweap Creek and the relative abundance of other fish-eating predators that may become habituated to the trout spawn. We propose a draft monitoring protocol employing three salaried observers and several volunteers annually. Contingency plans are proposed to adjust to future changes in the status of the eagle concentration.

INTRODUCTION

The unexpected development of the Bald Eagle concentration at Nankoweap Creek in the 1980s (Brown et al. 1989) has been of interest to both resource managers and research scientists. The annual occurrence of the concentration had substantial implications for the operation of Glen Canyon Dam (see Chapter 2) and for recreational use of the Nankoweap area (see Chapter 4), and represented the largest sustained concentration of Bald Eagles in the Southwest (see Chapter 1). For these reasons, the National Park Service and the Glen Canyon Environmental Studies (U.S. Bureau of

Reclamation) requested that a long-term monitoring program be developed to assess the size, rate of growth, and regularity of the eagle concentration at Nankoweap.

The purpose of this study was to design a draft monitoring protocol that would be subject to one season of field testing before completion of the final monitoring protocol. Study objectives were as follows: 1) identify the goals of future monitoring; 2) conduct field trials to compare the accuracy and precision of rim versus river observations; and 3) develop a draft monitoring protocol that would fulfill the criteria of being efficient, inexpensive, and logistically uncomplicated while allowing for the most precise comparison possible between monitoring years.

METHODS

Two feasible localities existed from which to observe the Bald Eagle concentration at Nankoweap Creek: a river observation post located on a ridge 800 m west of and 100 m above the confluence of Nankoweap Creek and the Colorado River in Grand Canyon National Park, and a rim observation post located 1000 m southeast of and 1000 m above the confluence on the Navajo Indian Reservation.

A comparison of eagle numbers derived from rim observations versus river observations was made by conducting paired observation trials during the 1990 study period. Trials were made on 9-11 February, 23-25 February, and 10-18 March.

Observation trials consisted of 2-hour intervals in which the rim and river observation teams made concurrent observations of eagle abundance in the Nankoweap study area (see Chapter 1 for study area boundaries). Observation teams were composed of up to five observers using up to 10x binoculars and 10-45x spotting scopes.

The following information was recorded during each observation trial: date, time of trial, numbers and names of observers, weather conditions, numbers of Bald Eagles by age class (immature, subadult, and adult; see Chapter 1 for detailed descriptions of age classes), and numbers of Golden Eagles (by age class if possible). The number of eagles/trial was determined by combining the largest number of concurrently detected individuals of each age class and/or species. We did not mark or band eagles during the study. Individuals with unique plumage characteristics or other distinctive markings were added to the trial totals even if they were not observed concurrently with the largest trial group. If there was no reason, based on timing, plumage, or individual markings, that separate observations of eagles were of different individuals, then those observations were assumed to be the same individual. This conservative technique may have underestimated actual eagle abundance. Eagle age classes were determined as defined in Chapter 1.

Three important assumptions were made in the comparison of rim versus river observations. First, the river observation

post was much closer to the eagle concentration and therefore we assumed that the number of eagles observed from the river represented the actual number of eagles present. Second, we assumed no inter-observer variability in observation skills so differences in total eagle numbers/trial were not due to observer differences. And third, we assumed numbers of eagles present during each trial were independent.

Rim versus river eagle numbers were evaluated by computing the difference between rim and river abundance (adjusted to rate/hour) and comparing that statistic between age class and species categories. Differential observation rates in rim versus river trials by age class and species were tested using the Friedman test (Conover 1980). Other statistical computations were made using ANOVA techniques with SYSTAT software (Version 4; Wilkinson 1989).

RESULTS

A total of 36 paired observation trials were completed during the 1990 study period. Numbers of eagles reported in rim observations were significantly different than eagle numbers reported in river observations ($\underline{x}^2 = 29.61$, $\underline{P} < 0.001$, $v = 3$; Table 5-1). Rim observations reported total eagle abundances equal to that reported by river observations in only 11 of 36 (30.6%) 2-hour observation trials. Difference between rates of observation by either age class/hour or species/hour varied between age class and species categories. By

Table 5-1. Differential rates of observations/hour of Bald Eagles (adult = Ad BE, subadult = Sub BE, immature = Imm BE, and all = All BE), Golden Eagles (all ages = GE), and total eagles (Total) between rim and river observation trials at Nankoweap Creek, Grand Canyon, Arizona, 1990. Integer data are the number of trials (n = 36) in which rim and river observation totals were identical.

Ad BE	Sub BE	Imm BE	All BE	GE	Total
24	20	15	11	21	11
(66.7%)	(55.6%)	(41.7%)	(30.6%)	(58.3%)	(30.6%)

Table 5-2. Univariate simple linear regression equations for pairwise comparisons of eagle observations/hour for Bald Eagles (adult = Ad, subadult = Sub, immature = Imm, all = All), Golden Eagles (all ages = GE), and total eagles (Tot) between rim (Rim) and river (Riv) observation trials at Nankoweap Creek, Grand Canyon, Arizona, 1990. The r^2 values are adjusted squared multiple r.

Equation	F	P	df	r^2
Ad Rim = -0.052 + 0.957(Ad Riv)	225.621	0.000	1,34	0.865
Sub Rim = 0.129 + 0.708(Sub Riv)	234.259	0.000	1,34	0.870
Imm Rim = 0.297 + 1.088(Imm Riv)	28.316	0.000	1,34	0.438
All Rim = 0.216 + 0.918(All Riv)	415.245	0.000	1,34	0.922
GE Rim = 0.160 + 0.094(GE Riv)	0.686	0.413	1,34	0.000
Tot Rim = 0.189 + 0.879(Tot Riv)	272.131	0.000	1,34	0.886

subtracting the rim abundance rate from the river abundance rate, we found that differential observation rates (Fig. 5-1) were statistically equivalent for all eagle age classes and species, except for immature Bald Eagles (Friedman test statistic 15.91, $\underline{P}$ = 0.007, df = 5; critical Friedman $\underline{t}$ = 24.74, a = 0.05, $\underline{P}_{imm}$ < 0.005, df = 175).

Covariate temporal effects by Julian day were not statistically significant for these differential abundance rate patterns among the age class and species categories (Wilk's lambda = 0.94, approximate $\underline{F}$ = 0.45, $\underline{P}$ = 0.772, df = 4, 31). Therefore, rim observations consistently reported fewer eagles than were reported in river observations for age and species classes except for immature Bald Eagles, and these differences were independent of time.

Despite differences in observation rates, univariate pairwise comparisons of simultaneous rim versus river observation trials (Table 5-2) revealed strong positive correlations for most eagle age class and species categories. Regression equations of simultaneous abundance rate data from rim and river trials were all strongly statistically significant ($\underline{F}$ > 28.0, $\underline{P}$ < 0.001, df = 1, 34) except for Golden Eagle observations ($\underline{F}$ = 0.68, $\underline{P}$ = 0.413, df = 1, 34). Although strongly significant, rim observation rates of immature Bald Eagles were poorly correlated with river observation rates (r^2 = 0.438).

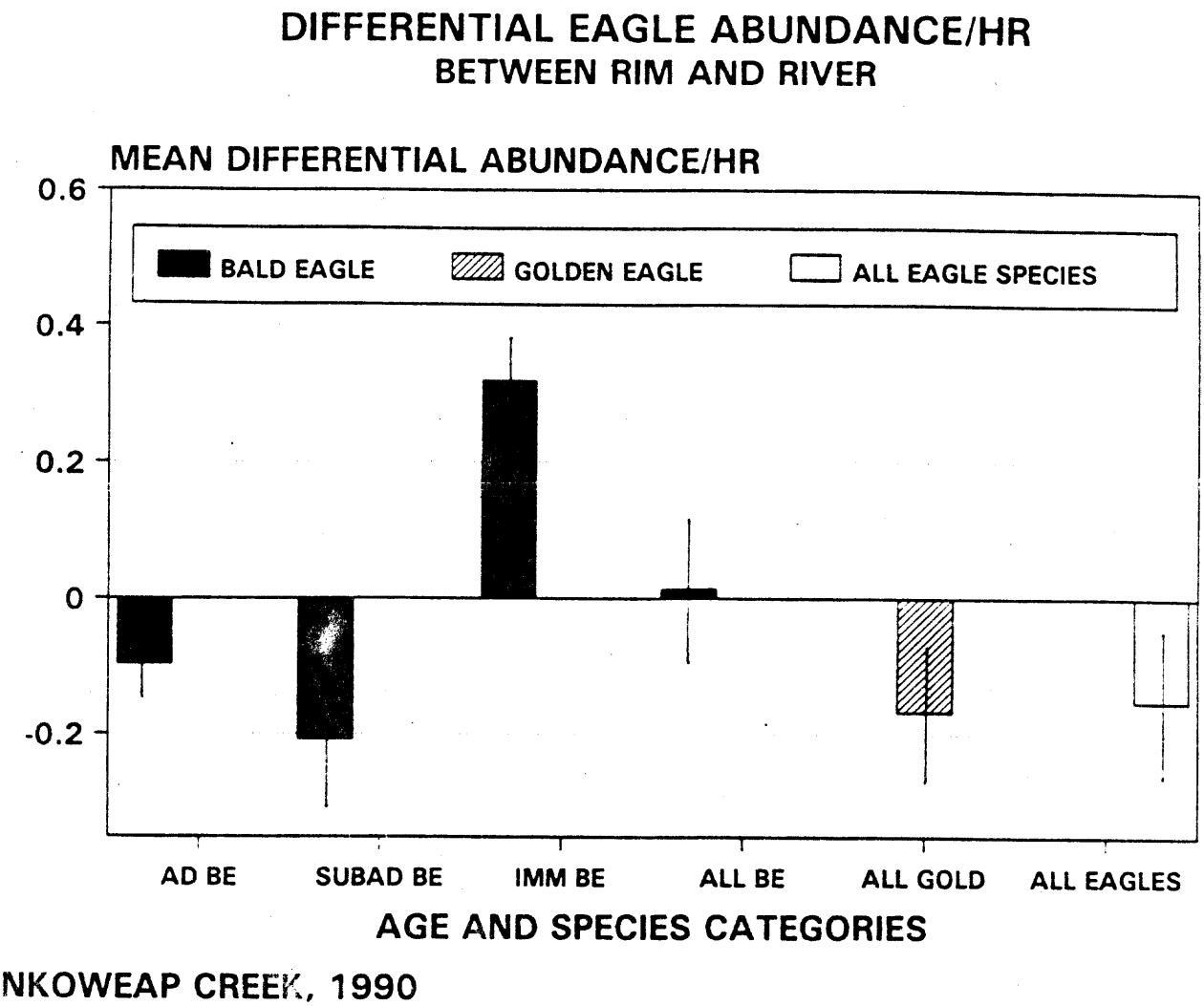


Figure 5-1. Mean difference between rim and river observation trial totals for Bald Eagles (adult = AD BE, subadult = SUB BE, immature = IMM BE, all = ALL), Golden Eagles (ALL GOLD), and all eagles (ALL EAGLE) in observations/hour at Nankoweap Creek, Grand Canyon, Arizona, 1990. Immature Bald Eagles were reported in significantly greater abundance from the rim than from the river ($P_{imm} <$ 0.005, df = 175), apparently because they were misidentified as Golden Eagles. In all cases n = 36. Error bars are plus or minus one standard error.

DISCUSSION

The numbers of adult and subadult Bald Eagles were more likely to be accurately represented by rim observations, although adult and subadult abundance was generally underestimated by rim observations. The tendency for rim observations to report fewer eagles than were reported in river observations except for immature Bald Eagles was probably due to their misidentification as Golden Eagles. Rim observations were made from a height of 1000 m above the study area using only 10-45x spotting scopes, and difficulties in distinguishing between immature Bald Eagles and any age class of Golden Eagles were to be expected under these circumstances. This finding suggested two points for future monitoring of the eagle concentration at Nankoweap. First, observers needed more training in differentiating between the two species. Second, spotting scopes with higher power and greater optical quality were required.

Rim observations of Bald Eagles in the Nankoweap study area underestimated actual eagle abundance in most cases. River observations were a more precise method to determine eagle abundance, although rim observations promise to be a valuable future monitoring technique. Future rim observations may not be able to accurately estimate total eagle abundance, but are nevertheless desirable because they are efficient, inexpensive, and logistically uncomplicated. We suggest that completely accurate estimates of eagle abundance should not

be the primary goal of future monitoring efforts. The primary goal of future monitoring should instead be to determine if the concentration occurred that year, the timing of the peak concentration, and the relative abundance of eagles between years. We suggest that the importance of knowing if 5 or 50 eagles were present far outweighs the importance of knowing if exactly 45 or 48 were present.

We propose that full implementation of the final monitoring protocol be preceded by another monitoring season in which simultaneous river observation trials would be made. The justification for and purpose of one additional season of simultaneous rim and river observations would be to more accurately determine the differences between rim and river observations. Future rim versus river differences may not have been accurately represented by observation trials conducted in 1990, especially considering that future rim monitoring should employ a modified design of more intensively trained observers and more powerful optics.

We propose that the first eagle rim monitoring effort occurring after the submission of this report be combined with simultaneous river observation trials. In addition to the rim and river observation teams completing all the tasks required in the draft monitoring protocol, both teams should complete at least 30 paired observation trials exactly as performed in 1990. The results of the observation trials should be evaluated exactly as the 1990 trials were evaluated

in this chapter, with the purpose of 1) determining rim versus river differences (if any) and 2) determining if regression equations could be developed to more accurately estimate eagle abundance during rim monitoring. Results of the paired observation trials would be described in the monitoring report for that year and, if necessary, incorporated into the final monitoring protocol.

The river observation team for the paired observation trials should be small. Three experienced, salaried observers could be assisted by one or two volunteers. The river observation team should use the same equipment, survey protocol, and techniques used during the 1990 trials. A separate river trip may not be required to support the river observers if they could be dropped off before and picked up after the monitoring period by other scheduled trips.

DRAFT INTERIM MONITORING PROTOCOL

The first rim monitoring effort should be combined with simultaneous river observation trials. The justification for and purpose of these paired trials is explained above. Both rim and river observation teams should follow the draft protocol described below, except that the river observation team should census trout in Nankoweap Creek each night rather than through spotting scopes late in the afternoon as the rim observation team will. Observation teams will conduct four 2-hour trials instead of continuous observations.

DRAFT LONG-TERM MONITORING PROTOCOL

This protocol has been designed to monitor the abundance of Bald Eagles at Nankoweap Creek at the peak of the annual winter concentration. Even if the concentration fails to materialize during one monitoring season, the event should be fully documented. However, environmental changes could occur that would cause the eagle concentration to permanently fail to materialize, or cause it to undergo a spatial or temporal shift. Such possibilities are discussed at the end of this protocol and contingency plans for such occurrences are outlined.

Goals of Monitoring

Goals of the monitoring protocol have been designed to answer questions of interest to both managers and scientists, as follows:

1. Determine if a Bald Eagle concentration occurred during the monitoring period.
2. Determine the size, age class distribution, and timing of the peak concentration.
3. Document the relative abundance of trout in Nankoweap Creek, and the relative abundance of other fish-eating predators that may become habituated to the spawn.

Overview of Monitoring Procedure

Seven basic steps need to be followed for the successful completion of the annual Bald Eagle monitoring program:

1. The monitoring agency needs to identify the key person (project leader) that will be responsible for implementation and completion of that year's monitoring effort. The project leader will need to begin making logistical preparations for monitoring as early as November preceding the monitoring activities.
2. The project leader needs to obtain the necessary field equipment, permits, and arrange for personnel to be available for the monitoring effort.
3. Pre-monitoring training of all field personnel, regardless of experience, will ensure that observers are proficient in eagle detection and identification techniques, are familiar with field forms, and are proficient with field equipment.
4. The monitoring team will spend 10 consecutive days (22 February to 3 March) at the rim observation post overlooking the confluence of Nankoweap Creek and the Colorado River.
5. The monitoring team will complete one field form/day describing eagle numbers present, and field forms on human disturbance will be completed as needed.
6. After field work, data reduction and summary should begin, based on the completed field forms.

7. An annual monitoring report should be prepared by the project leader and distributed to cooperating agencies. All field forms completed during monitoring should be compiled and filed away in a secure location.

Pre-Monitoring Preparation

The monitoring agency should identify the key person (project leader) who will conduct and complete that year's monitoring effort. The project leader should be appointed by at least early November, so preparations for monitoring (gathering equipment, obtaining personnel, making necessary agency inquiries, etc.) can be made.

A permit will be required from the Navajo Nation to conduct research from a location on Navajo tribal lands. Written application for a research permit should be submitted to the Navajo Nation by November 1 of the year preceding the monitoring effort. For an application, contact the Navajo Nation, Navajo Fish and Wildlife Branch, P.O. Box 1480, Window Rock, AZ 86515.

Obtaining Field Equipment and Personnel

All field personnel should be equipped with at least 10x binoculars (Leitz Trinovid 10x40 are recommended). Two Celestron C90 spotting scopes (with both 55x and 80x eyepieces) equipped with durable tripods are essential for use by rim observers. Field forms (at least 20 of each),

pencils, and clipboards complete the list of monitoring equipment needed. All field personnel should have their own equipment and supplies suitable for camping 10 nights under conditions that may include snow, extreme wind, and temperatures down to 10°F. Small folding chairs are recommended to reduce neck and muscle strain while using spotting scopes. At least two trucks with high clearance (4-wheel-drive is recommended) will be required to transport the monitoring team to the rim at Nankoweap. Trucks and equipment should be placed some distance from the rim in a pattern providing protection from the wind.

Three salaried personnel (including the project leader) are required for rim monitoring. Several volunteer assistants (including agency personnel) should be solicited for part or all of the monitoring period. All field personnel should be comfortable with winter camping techniques. If possible, salaried personnel should have experience in detecting, identifying, and aging Bald and Golden Eagles. Representatives from the Navajo Nation, the Arizona Game and Fish Department, the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, and Grand Canyon National Park should be solicited.

Pre-Monitoring Training of Personnel

The project leader should have sufficient experience in detecting, identifying, and aging Bald and Golden Eagles to

train all field personnel. If not, pre-monitoring training may be obtained by contacting State or Federal agencies with the appropriate expertise in this area and requesting assistance. Contact Mr. Richard L. Glinski of the Arizona Game and Fish Department (telephone 602/942-3000) or Mr. Timothy Tibbitts of the U.S. Fish and Wildlife Service in Phoenix (telephone 602/379-4720).

The 2 days preceding the initiation of monitoring activities should be training days. The first day should cover eagle identification techniques (a slide show is recommended), a general overview of the monitoring effort, familiarization with field forms, and an understanding of the monitoring techniques. Identification of other raptors that may be observed in the monitoring area should be stressed (see Clark 1987, Dunne et al. 1988). The second day should be a field trip to a nearby locality (such as upper Lake Mary near Flagstaff) where eagles can readily be observed.

Annual Timing and Length of Monitoring

Monitoring of the Nankoweap Bald Eagle concentration should take place each year from 22 February to 3 March. This monitoring period has been designed to coincide with the peak concentration (26 February in 1990, 24-28 February in 1991). The monitoring team should be in place by the evening of 21 February and could leave after monitoring is completed on 3 March.

Field Procedures

Rim observations of eagle numbers in the Nankoweap study area should take place continuously from 08:00 to 17:00 hours each day. Only two observers, each with a Celestron spotting scope, should locate and count eagle numbers. Other personnel should be rotated into the observation team on a rest-rotation basis. The least experienced personnel can also look and listen to the observer team for learning purposes, but should not participate in locating or counting activities.

The number of eagles/day can be determined by combining the largest number of concurrently detected individuals of each age class. Individuals with unique plumage characteristics or other distinctive markings should be added to the daily totals even if they were not observed concurrently with the largest group. If there was no reason, based on timing, plumage, or individual markings, that separate observations of eagles were of different individuals, then those observations should be assumed to be the same individual. This technique may underestimate actual eagle numbers. Written notes on eagle numbers by age class should be made on the back of the daily summary form at ca. 20 minute intervals.

Bald Eagles exhibiting a completely white head and tail should be classified as full adults (Basic III, IV, and V plumage of McCollough [1989]); individuals with a mostly

white head and tail, but exhibiting small brown patches on the head or tail should be classified as near-adults. Those with largely brown plumage mottled with white should be classified as subadults (old immature and subadult plumage of Bortolotti [1984], Basic I and II plumage of McCollough [1989]); osprey-plumaged subadults are those in which the white triangle on the back is continuous with the white on top of the head and a distinct dark stripe is evident over the eye; white-belly subadults are those exhibiting a distinct light triangle on the back and a distinctly light or white "belly". Eagles with primarily dark plumage and a completely dark head and beak should be classified as immatures (young immature plumage of Bortolotti [1984]; juvenal plumage of McCollough [1989]). Because observations will be made in February and March, when individual Bald Eagles classified as immatures will be in their second year and approximately 8-11 months of age, some immatures may have flecks of white on the belly and back and be approaching the Basic I plumage of McCollough (1989). These individuals can be classified as immatures after the methods of Hansen (1986) because theirs will be a distinctly recognizable age class during monitoring.

Two field forms will be used to record observations: the daily summary form (Fig. 5-2) and the human disturbance form (Fig. 5-3). One daily summary form is to be completed each day, summarizing eagle numbers present and the conditions

Figure 5-2. A daily summary form to be completed by the rim observation team (front side only).

Daily Summary Form

Date (mo/da/yr):

Observation times: start_____ end_____
0700: ___°F, wind ___mph, precip Y N, clouds_____%
1200: ___°F, wind ___mph, precip Y N, clouds_____%
Recorder:_____ Observers:_____

Number of Bald Eagles observed:

Adult	_____	
Near-adult	_____	
Subadult		
Osprey	_____	
Whitebelly	_____	
Immature	_____	
Unknown	_____	(do not add to total unless # exceeds above; if so, # unk = total)
TOTAL	_____	

Number of Golden Eagles observed:

Adult	_____	
Subadult	_____	
Immature	_____	
Unknown	_____	(do not add to total unless # unless # exceeds above; if so, # unk = total)
TOTAL	_____	

Estimated no. Common Ravens present: _____
Were coyotes present along creek? Y N #? _____
Estimated no. trout in creek: _____
Did human disturbance occur within 600 m of the creek mouth today? Yes No
If so, number of disturbance events? _____
Creek turbidity: clear opaque muddy
River turbidity: clear opaque muddy
Were any other fish-eating animals present (such as gulls, bobcats, osprey, etc.)? _____

Notes:

Figure 5-2. Continued; back side of the daily summary form.

Date (mo/da/yr):

Age Class				Times			
Ad							
Nr-ad							
Ospr							
Wh-Be							
Imm							
TOTAL							
Times							
Ad							
Nr-ad							
Ospr							
Wh-Be							
Imm							
TOTAL							
Times							
Ad							
Nr-ad							
Ospr							
Wh-Be							
Imm							
TOTAL							
Times							
Ad							
Nr-ad							
Ospr							
Wh-Be							
Imm							
TOTAL							
Times							
Ad							
Nr-ad							
Ospr							
Wh-Be							
Imm							
TOTAL							

GOLDEN EAGLES: make notes on numbers and times observed below, at same time as BE summaries.

Figure 5-3. A human disturbance form to be completed for each disturbance event occurring within 600 m of the confluence.

Human Disturbance Form

Date (mo/da/yr):

Recorder: _____ Observers: _____

_____

Disturbance no. ___ of ___ total today.

Time disturbance begins: _____ ends: _____

Disturbance type: boat hiker helicopter fishermen

Number Bald Eagles present in area when disturbance began? _____

Number Bald Eagles present within 100 m of creek mouth when disturbance began? _____

Did eagles near creek mouth leave their area? Y N

Describe the nature of the disturbance (numbers of hikers, boats, type of boats, how close to creek mouth did they come, etc.):

Did more another disturbance event/type overlap this event? Yes No If so, describe:

If hikers, did they camp overnight within 600 m of the creek mouth? Yes No

If boaters, did they camp overnight at any of the Nankoweap camps? Yes No Which one? _____

_____

Notes:

under which monitoring took place. One human disturbance form is to be completed for each instance when human disturbance (hikers, rafters, fishermen, helicopters, etc.) occurs within approximately 600 m of the confluence and has the potential to cause eagles to leave the study area. A disturbance event ends when human activity within 600 m of the confluence is terminated.

Relative trout abundance can be easily monitored on a daily basis using a Celestron spotting scope with its highest-power eyepiece. Trout abundance in the creek should be determined from its confluence with the river to ca. 500 m upcreek to where the creek is even with the distinct outcrop of Bright Angel Shale. We estimate that relative trout abundance can be determined to within approximately 10% of the actual total, but the accuracy of this estimate will be determined during the first monitoring period with concurrent rim and river observations (the river observation team will count trout in the creek at night, with the rim team counting trout in the creek late each day using a Celestron scope). Long-term monitoring of trout abundance in the creek from the rim with spotting scopes is preferable to on-site trout monitoring in the creek because of low cost, ease of implementation, and because daytime human disturbance at the creek that would influence eagle abundance is avoided.

Monitoring activities will not be possible when winds are excessive (ca. > 30 mph), rain or snow is falling, or when

the confluence is obscured by clouds. These deviations from the monitoring schedule should be noted on the daily summary form.

Data Analysis and Summary

The 10 daily summary forms should be summarized into a single table outlining the season's monitoring results. The number of disturbance events should be summarized by type and duration, then compared to previous years. Eagle numbers/day may need to be converted to probable actual numbers present with regression equations, but only if the rim versus river observation trials made during the first season of monitoring indicate this is feasible. A Wilcoxon signed rank test (Conover 1980) can be used to test for differences in eagle abundance between years, if the distribution of the numbers of eagles/day is a binomial distribution (which it will usually be). If the distribution of eagle numbers/day approximates a normal distribution, then make the comparison using Student's t-test.

Preparation of the Annual Monitoring Report

Preparation of an annual monitoring report will complete the year's monitoring activities. The format of the report is somewhat flexible, but should largely conform to the first monitoring report, and should contain certain specific information categories. These sections include:

1. A methods section outlining all procedures, personnel, and observation periods. Identify any deviation from the pre-established monitoring protocol.
2. A results section summarizing the year's monitoring results with tables of eagles/day, human disturbance levels, and weather conditions.
3. A discussion section giving an overview of results and explaining their implications. Comparisons with previous years should be included here. Suggest changes that would benefit the following year's monitoring effort. If the duration or timing of the peak concentration has changed, recommend strategies for adjusting the monitoring protocol to these changes without invalidating comparisons to previous monitoring results.

Contingency Plans

The eagle concentration at Nankoweap is of recent occurrence, and may change in abundance, duration, location, and timing in the future. The concentration is also ecologically precarious in that its occurrence depends on the extent and timing of the trout spawn in Nankoweap Creek, which in turn is dependent on aquatic ecology and productivity of the Colorado River. Changes in the riverine ecosystem could potentially eliminate the trout spawn or change its timing,

terminating the eagle concentration. This scenario caused the recent collapse of the huge Bald Eagle concentration in Glacier National Park (Spencer et al. 1991).

We suggest that the length of the monitoring period be reduced if the eagle concentration fails to occur (< ca. 10 eagles/day at the peak) for 2 consecutive years due to inadequate numbers of trout (< ca. 50) in the creek or other reasons. This alternative would monitor the mouth of Nankoweap Creek, using the same technique described in this protocol, but for only 1 full day each season. This monitoring day should be timed to occur on the day of the peak eagle concentration in previous years. This day should be free of human disturbance, or nearly so, and weather conditions should not be extreme. If extreme human disturbance or weather conditions prevailed on that day, the monitoring team should remain an additional day(s) and attempt to determine eagle abundance. This scaled-down monitoring should continue for as many years as the likelihood persists that the trout spawn will re-establish itself.

A likely scenario is the peak of the eagle concentration will shift over time. If this is evident after several years, then the monitoring protocol should also shift so that the 10 days of observation overlap the expected "new" peak.

In another scenario, the eagle concentration could shift to another location. Tapeats Creek or even Bright Angel

Creek could theoretically support an eagle concentration (> ca. 10 eagles/day), but are unlikely to do so because of either unfavorable levels of human disturbance or unfavorable geographic location or both. Nevertheless, future resource managers can use this protocol as a guideline to developing an appropriate monitoring program for that potential scenario. We do not recommend using helicopters in any way during future monitoring of Bald Eagles along the Colorado River in Grand Canyon.

CHAPTER 6:

RECOMMENDATIONS TO MANAGEMENT

The abundance of prey in Nankoweap Creek during February and March was found to be of substantial importance to wintering and migrating Bald Eagles in Arizona. The implications of this finding extend far beyond the boundaries of Grand Canyon National Park. The presence of prey in the creek resulted in increased foraging success, and presumably food consumption, for those eagles making use of Nankoweap. This was particularly beneficial to immature eagles in their first winter that tend to congregate near abundant food resources. Immature eagles encountering Nankoweap and remaining there may experience greater survivorship, potentially resulting in higher rates of recruitment to the breeding population of Bald Eagles in western North America.

The Bald Eagle concentration at Nankoweap was the largest sustained feeding concentration of eagles in Arizona in 1990. The numbers of eagles decreased substantially in 1991 and failed to meet the minimum criteria defining an eagle concentration of management concern as identified in this report. This raised questions about the long-term regularity and abundance of the concentration.

Eagles at Nankoweap exhibited flow-dependent spatial foraging patterns as a result of regulated discharge from Glen Canyon Dam, but the overall influence of these effects on eagle foraging success was neutral. Prey obtained from isolated riverside pools left by fluctuating flows in 1991 represented a modest positive contribution to eagle prey capture in a year of low prey abundance. The overall effects of fluctuating flows were relatively minor compared to the effects of human disturbance, which had a strong influence on eagle abundance, behavior, and distribution at Nankoweap during the concentration.

Based on these most important findings of the study, we propose the following recommendations to management for their consideration:

1. The trout spawn in Nankoweap Creek should be maintained, or even enhanced if necessary, for the benefit of wintering and migrating Bald Eagles in the Southwest.
2. Rim monitoring of the eagle concentration at Nankoweap should take place from 22 February to 3 March each year. The management and scientific goals of the monitoring program would be to: 1) determine if a Bald Eagle concentration occurred during the monitoring period; 2) determine the size and age class distribution of the eagle concentration, and the timing of the peak concentration; and 3) document the relative abundance of

trout in Nankoweap Creek and the relative abundance of other fish-eating predators that may become habituated to the trout spawn.

3. Additional rim versus river observation trials to determine eagle abundance should be conducted during the first monitoring effort to evaluate the accuracy of the final monitoring protocol.

4. The length of the monitoring period should be reduced if the eagle concentration fails to occur (< ca. 10 eagles/day at the peak) for 2 consecutive years due to inadequate numbers of trout (< ca. 50) in the creek or other reasons. This alternative would monitor the mouth of Nankoweap Creek, using the same technique described in this protocol, but for only 1 full day each season.

5. If future monitoring indicates the eagle concentration to be both of consistent, annual occurrence and of sizeable or increasing abundance, we recommend that the park initiate management action to reduce human disturbance at Nankoweap by 1993 and eliminate human disturbance by 1995. If monitoring indicates the eagle concentration is not of annual occurrence or does not meet minimum criteria defining an eagle concentration of management concern as defined in this report, we recommend no management action to control human disturbance.

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APPENDIX A:

LOCATIONS OF BALD EAGLE FORAGING ATTEMPTS IN THE NANKOWEAP STUDY AREA

METHODS

Bald Eagle foraging attempts in the Nankoweap study area were recorded continuously each day during the 1990 and 1991 study periods (see Chapter 3 for details). Foraging habitats were designated as 1) the creek, 2) the river, 3) on shore, and 4) isolated pools. Locations of foraging attempts in each foraging habitat were estimated to the nearest 10 m upstream or downstream of the creek mouth.

RESULTS

In 1990, 78% of all eagle foraging events took place within 50 m of the confluence of the creek and the river. Eighty percent of all creek forages took place within 50 m of the creek mouth, as did 83% of river forages, 64% of forages on shore, and 56% of forages in isolated pools (Figs. A-1, A-2, A-3).

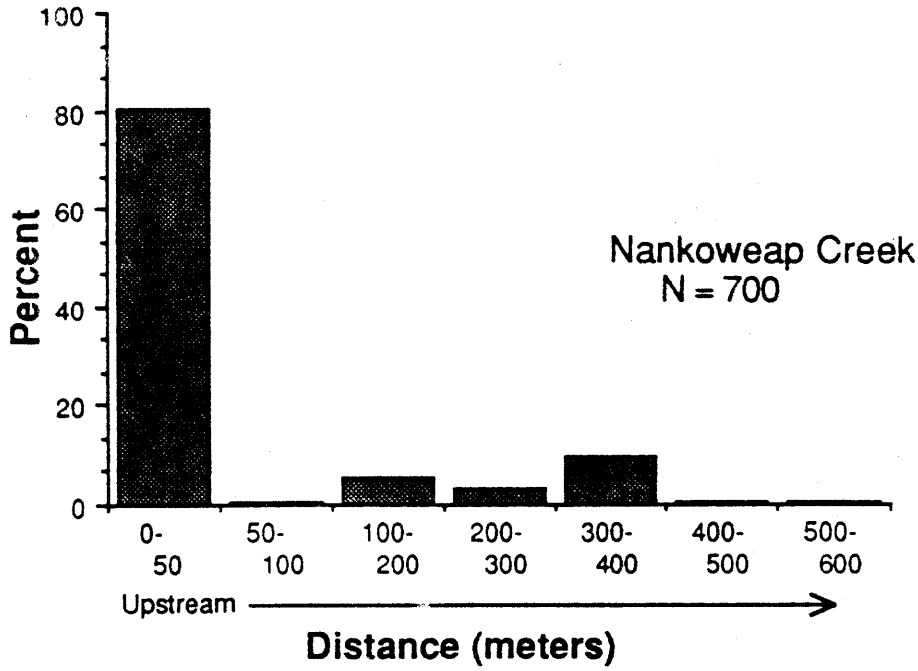
In 1991, 67% of all eagle foraging events took place within 50 m of the creek mouth. Seventy-eight percent of all creek forages took place within 50 m of the creek mouth, as did 38%

of all river forages, 45% of forages on shore, and 75% of forages in isolated pools (Figs. A-4, A-5, A-6).

DISCUSSION

The confluence of Nankoweap Creek and the Colorado River was the focal point of most eagle foraging activity during 2 years exhibiting different prey abundance.

A smaller proportion of foraging events took place within 50 m of the creek mouth in 1991, a year of relatively low prey abundance (see Chapter 1). The proportions of creek forages occurring within 50 m of the creek mouth were similar between years, but the proportions of river and shore forages close to the creek mouth declined substantially in 1991.



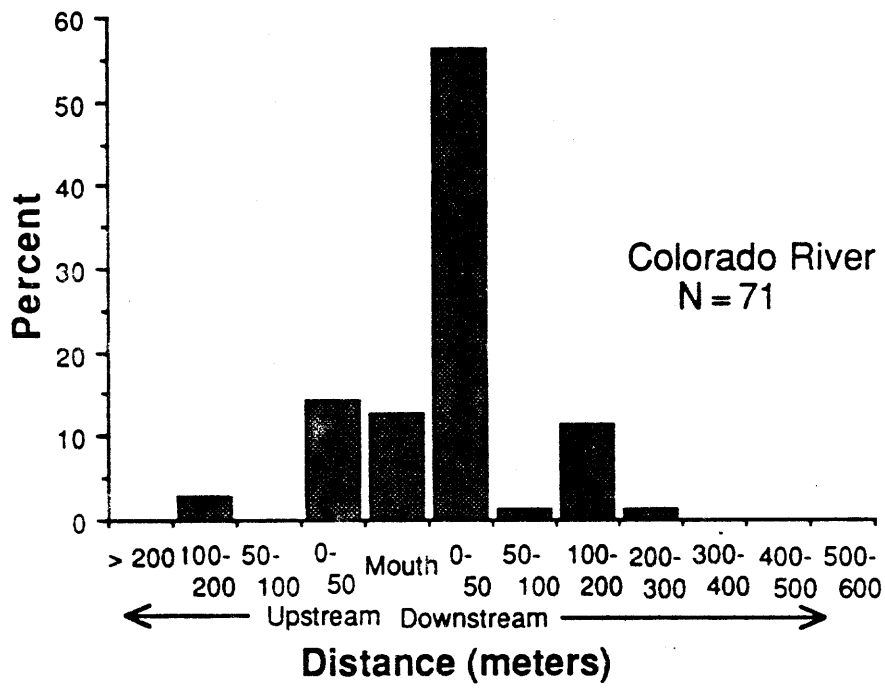


Figure A-1. Locations of Bald Eagle foraging attempts in Nankoweap Creek (top) and in the Colorado River within 600 m of the creek mouth (bottom), Grand Canyon, February and March 1990.

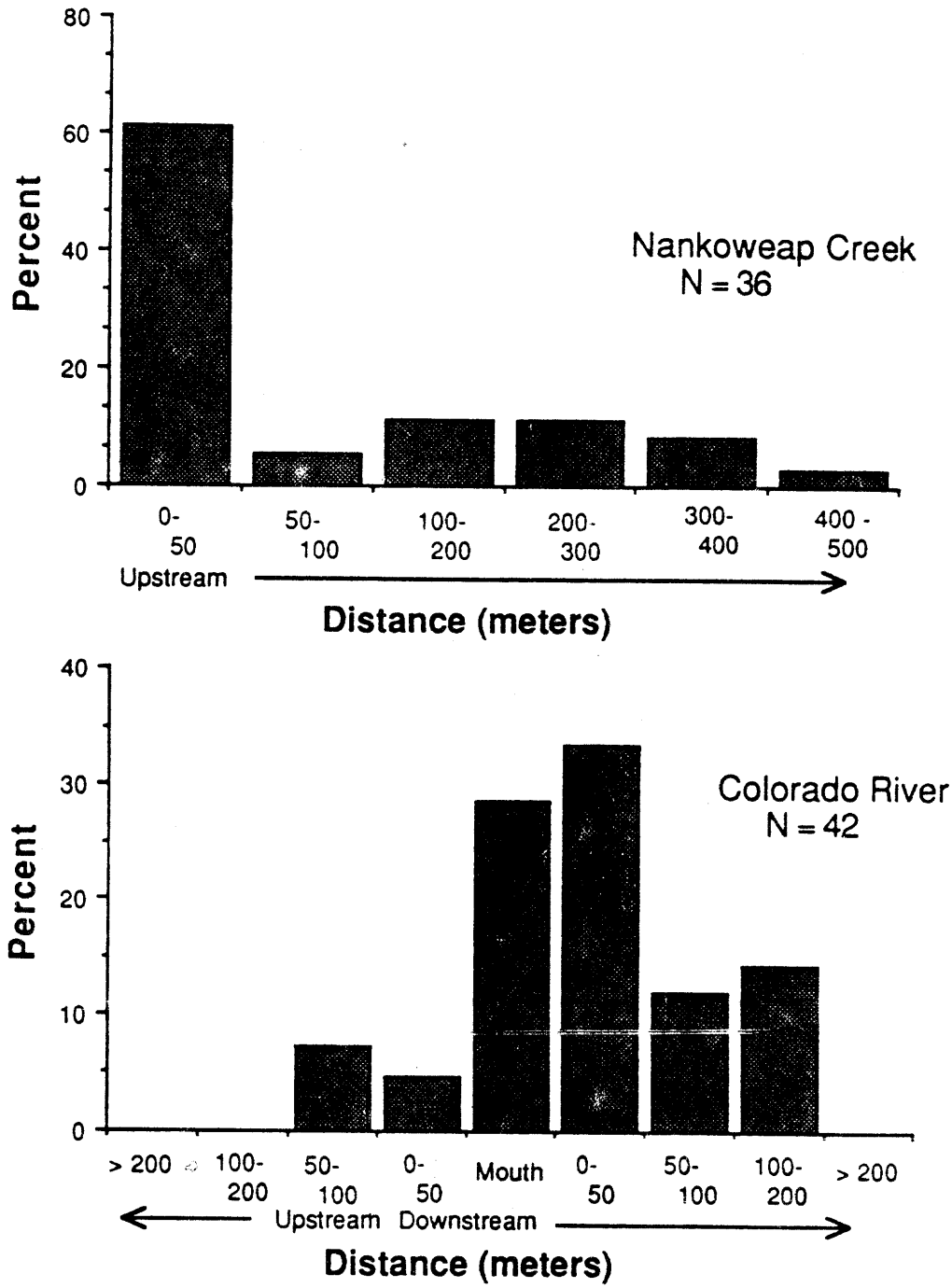


Figure A-2. Locations of Bald Eagle foraging attempts on shore along Nankoweap Creek (top) and on shore along the Colorado River within 600 m of the creek mouth (bottom), Grand Canyon, February and March 1990.

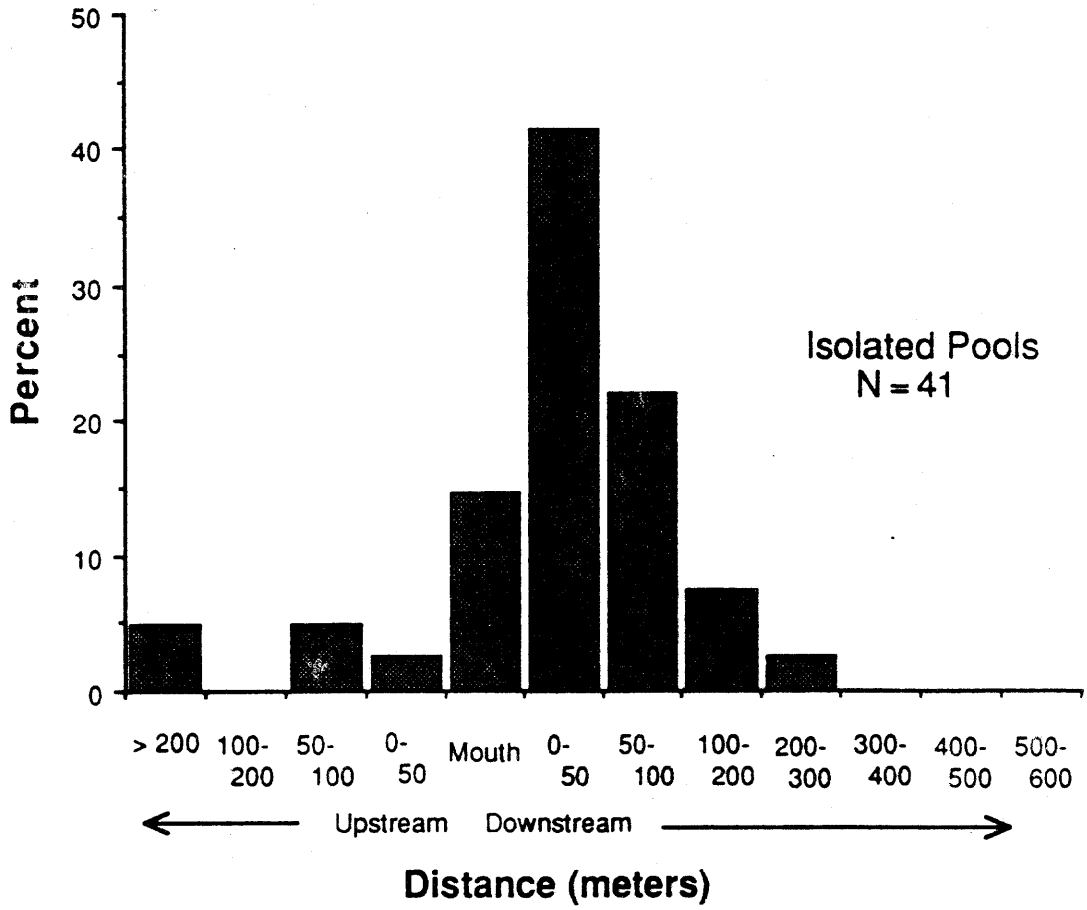


Figure A-3. Locations of Bald Eagle foraging attempts in isolated pools along the Colorado River within 600 m of Nankoweap Creek, Grand Canyon, February and March 1990.

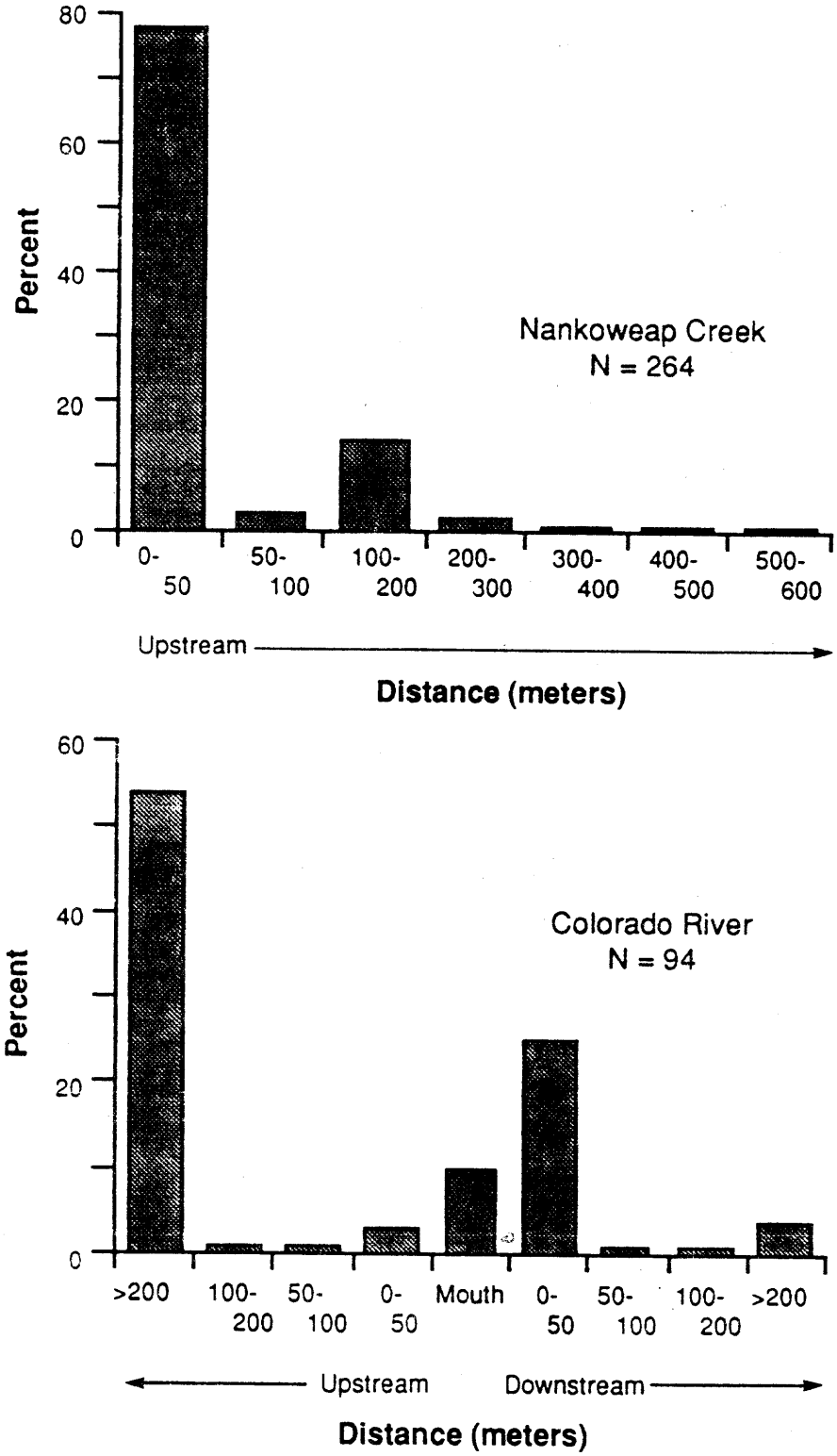


Figure A-4. Locations of Bald Eagle foraging attempts in Nankoweap Creek (top) and in the Colorado River within 1500 m of the creek mouth (bottom), Grand Canyon, January through March 1991.

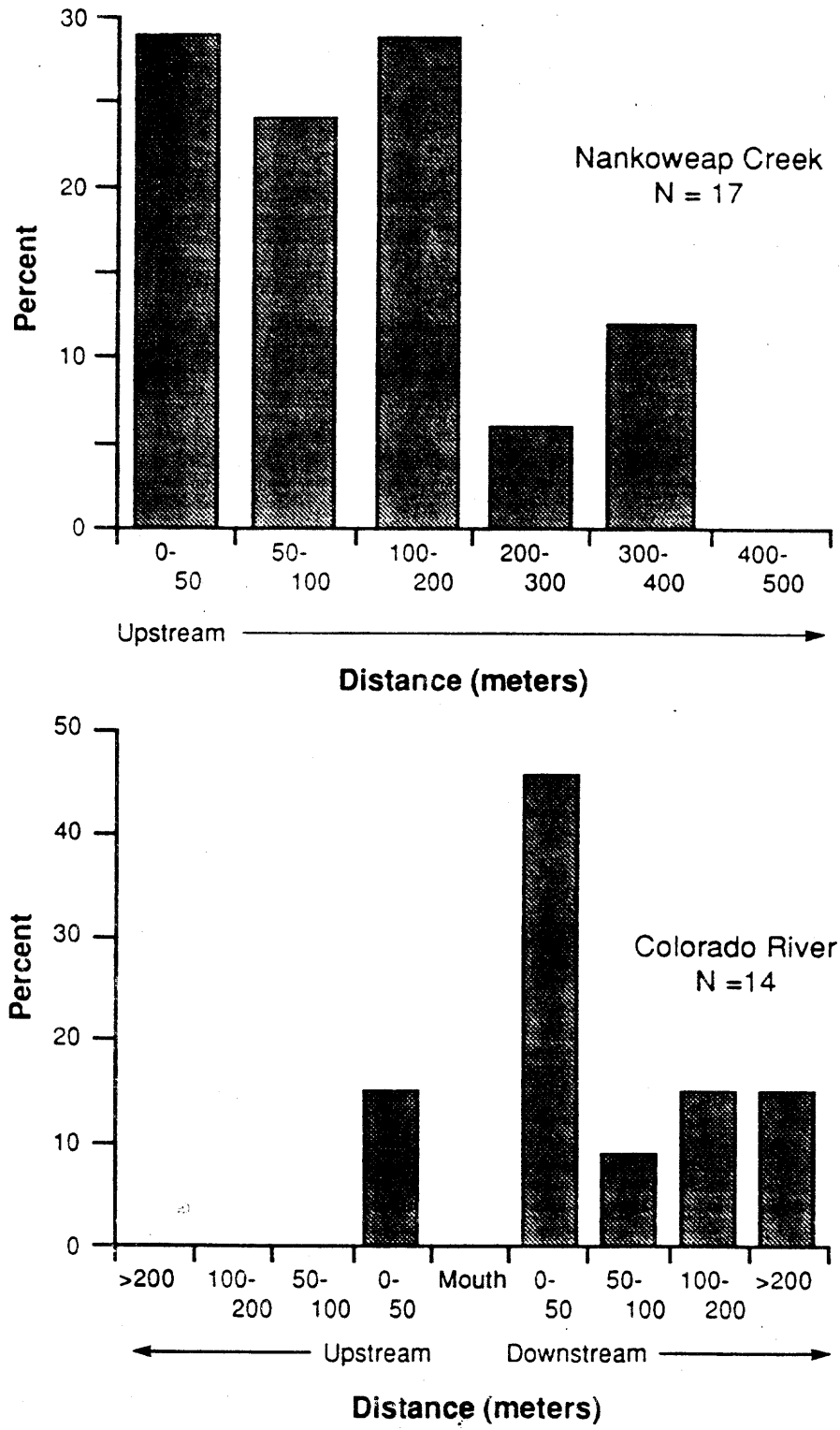


Figure A-5. Locations of Bald Eagle foraging attempts on shore along Nankoweap Creek (top) and on shore along the Colorado River within 1000 m of the creek mouth (bottom), Grand Canyon, January through March 1991.

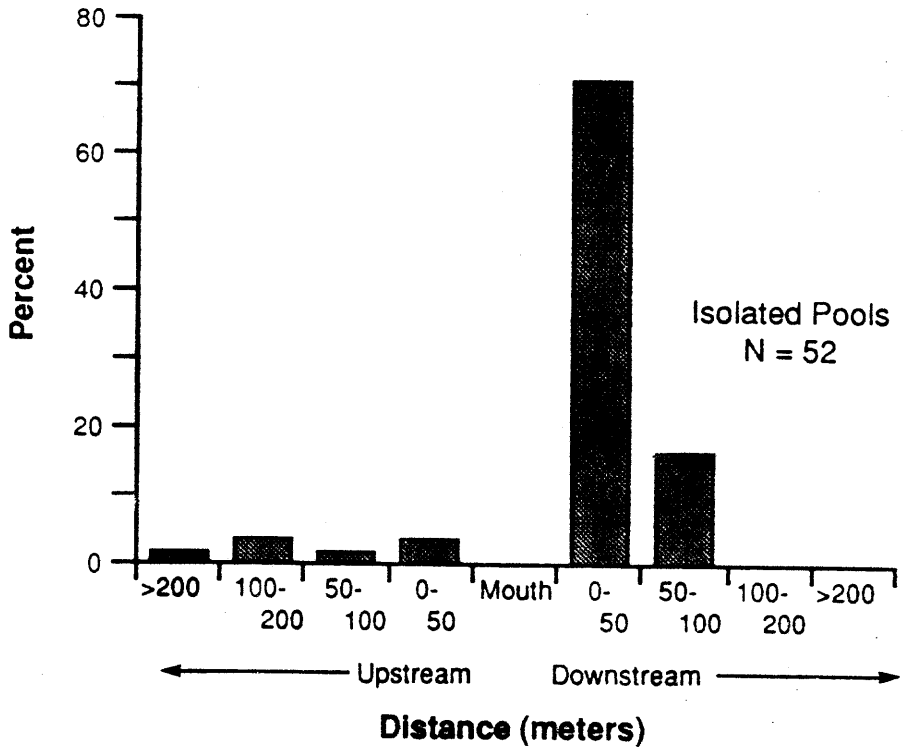


Figure A-6. Locations of Bald Eagle foraging attempts in isolated pools along the Colorado River within 600 m of Nankoweap Creek, Grand Canyon, January through March 1991.

APPENDIX B:

SUMMARY OF CLIMATOLOGICAL DATA FROM THE NANKOWEAP STUDY AREA, 1991

MATERIALS AND METHODS

A temporary weather station was established near the mouth of Nankoweap Creek along the Colorado River in Grand Canyon, Arizona, for a portion of the winter of 1991. This station was established to gather climatological data to document conditions under which the study took place.

The station was located at River Mile 52.0R (Stevens 1983), 150m upriver of the confluence of the river and Nankoweap Creek and 30m west of the 30,000 cfs high-water line of the river. This location was chosen because of its proximity to the mouth of Nankoweap Creek, where the majority of the eagles under study spent most daylight hours.

A recording thermometer capable of determining temperature to the nearest 0.01^{o}C was placed in a in white PVC plastic tube measuring 30cm in length and 4cm in diameter. Perforated, white plastic sheeting material was placed in the tube to impede, but not eliminate, the flow of air through the tube. The thermometer was electronically connected to a continuously-recording CR-10 data recorder, which took a temperature reading every 10 seconds. These readings were averaged to obtain the daily mean.

A recording anemometer capable of determining wind speed to the nearest 0.1 m/second was attached to the top of a 1.5m vertical metal pole that was secured with guy wires so that it would maintain a constant vertical attitude. The anemometer was electronically connected to the CR-10, which took readings every 10 seconds and averaged them to obtain the daily mean.

Percent cloud cover was visually estimated at 3-hour intervals each day. Cloud cover was defined as the percent of the visible sky covered by clouds (thick or thin, high or low), estimated to the nearest 10 percent. Eight daily estimates were averaged to obtain the daily mean.

Table B-1. Summary of climatological data on temperature (Temp), wind speed, and cloud cover (Cloud) recorded during a portion of the winter of 1991 near the confluence of the Colorado River and Nankoweap Creek, Grand Canyon, Arizona.

Date	Mean Temp (°C)	Min. Temp (°C)	Max. Temp (°C)	Wind Speed (m/sec)			Mean Cloud (%)
				Mean	Min.	Max.	
01/29	7.06	1.51	13.13	2.8	1.8	4.5	--
01/30	3.99	-1.91	14.49	1.2	0.5	1.6	--
01/31	4.35	-0.60	9.75	2.1	0.4	4.9	--
02/01	5.92	3.57	9.20	3.9	0.7	5.1	--
02/02	5.22	0.50	10.84	2.1	0.4	4.8	--
02/03	7.64	2.29	13.17	1.5	0.4	4.2	--
02/04	7.91	2.35	16.12	1.4	0.5	4.1	--
02/05	7.96	2.81	15.61	1.4	0.5	3.3	--
02/06	9.00	5.80	12.56	3.1	0.5	5.6	--

Table B-1. (Continued)

Date	Mean Temp (°C)	Min. Temp (°C)	Max. Temp (°C)	Wind Speed (m/sec) Mean	Min.	Max.	Mean Cloud (%)
02/07	8.86	3.63	13.15	1.8	0.4	5.0	23
02/08	10.19	4.77	18.61	0.9	0.5	1.5	29
02/09	9.29	3.84	18.95	0.8	0.4	1.5	0
02/10	9.50	4.06	16.08	1.6	0.4	4.1	0
02/11	9.64	5.05	14.12	1.8	0.4	4.2	18
02/12	11.26	8.06	16.90	0.8	0.3	2.3	53
02/13	10.73	4.07	21.80	0.8	0.6	1.2	12
02/14	12.59	6.48	24.08	0.9	0.4	1.6	0
02/15	11.94	5.91	21.12	0.7	0.3	1.2	56
02/16	12.82	8.89	20.30	1.1	0.6	1.9	90
02/17	10.75	6.90	16.48	1.5	0.4	4.5	26
02/18	9.22	6.02	13.98	3.6	1.9	4.9	4
02/19	9.62	2.93	19.12	1.8	0.3	4.2	0
02/20	9.41	3.64	17.63	1.1	0.5	3.2	0
02/21	9.89	3.87	17.95	1.0	0.4	2.8	1
02/22	11.01	6.27	17.75	0.8	0.4	1.8	40
02/23	11.97	5.91	21.95	0.8	0.4	1.2	43
02/24	11.63	4.81	21.55	1.9	0.5	4.4	0
02/25	11.57	5.38	22.06	1.3	0.4	3.0	0
02/26	11.55	5.01	21.80	1.3	0.3	2.0	9
02/27	10.85	5.00	17.12	1.2	0.5	2.5	44
02/28	10.56	8.30	12.41	2.2	0.7	5.1	90
03/01	6.32	5.44	7.43	1.5	0.8	2.4	100
03/02	9.92	4.14	17.93	1.3	0.7	2.4	6
03/03	10.63	3.60	20.99	1.1	0.4	2.2	3
03/04	11.73	6.10	17.04	1.4	0.5	3.3	76
03/05	14.07	11.89	16.42	3.1	1.6	5.8	95
03/06	11.25	6.47	17.92	1.9	0.6	3.7	21
03/07	8.15	4.31	14.34	2.8	1.0	4.8	4
03/08	8.55	1.87	19.40	1.5	0.4	2.2	0
03/09	9.91	3.59	17.49	1.2	0.5	1.9	31
03/10	11.90	7.76	18.15	2.3	0.5	4.6	95
03/11	11.17	7.25	14.16	3.1	0.8	5.2	24
03/12	9.70	2.62	20.17	1.3	0.6	1.9	3
03/13	10.65	4.18	18.63	2.1	0.5	4.4	45
03/14	6.52	5.14	10.10	2.2	1.5	3.6	--