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VIGILANCE PATTERNS OF BALD EAGLES FEEDING IN GROUPS

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ABSTRACT.—Patterns of vigilant behavior of wintering Bald Eagles (*Haliaeetus leucocephalus*) feeding on spawned salmon were examined in 1983-1984 on the Nooksack River in northwestern Washington. Vigilance in feeding birds has, in general, been attributed to predator detection; however, we proposed an additional function of vigilance in socially feeding birds that are vulnerable to food robbery and possible injury by conspecifics. We tested predictions of two nonexclusive hypotheses: (1) eagles look up while feeding to detect danger from humans, and (2) eagles look up while feeding to detect pirating attempts or avoid injury by conspecifics.

Results suggest that the function of vigilance varies, depending on the size of the feeding group. Vigilance patterns of eagles feeding in small groups (1-4 eagles) and medium groups (5-7 eagles) are consistent with hypothesis 1, whereas those of eagles feeding in large groups (8-14 eagles) are consistent with hypothesis 2. Eagles in small groups were more vigilant (measured as scanning time and rate of head raising) when feeding near potential danger (riverbank cover) than when far from danger. Adult eagles feeding in areas of intense human activity were more vigilant than immatures feeding at the same site and were more vigilant than both adults and immatures feeding at secluded sites. Vigilance declined as group size increased from 1 to 4 eagles, and increased as group size ranged from 8 to 14 eagles. Feeding eagles that were looking up at the time of a pirating attempt were more successful in keeping their food than eagles with their heads down. In feeding areas where human activity was minimal, eagles formed larger groups than at more disturbed sites.

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SOCIAL feeding in birds presumably reduces the risk of predation. Birds feeding in groups respond to approaching predators at greater distances (Powell 1974, Kenward 1978, Greig-Smith 1981, Knight and Knight 1984) and are less vulnerable to attack than solitary birds (Page and Whitacre 1975, Kenward 1978). In addition, individuals in flocks can spend less time looking for predators and more time feeding without reducing their level of safety. The time devoted to vigilance by feeding birds decreases as flock size increases in House Sparrows (*Passer domesticus*; Barnard 1980, Elcavage and Caraco 1983), Yellow-eyed Juncos (*Junco phaeonotus*; Caraco et al. 1980b), European Starlings (*Sturnus vulgaris*; Powell 1974, Jennings and Evans 1980), Eurasian Curlews (*Numenius arquata*; Abramson 1979), and Ostriches (*Struthio camelus*: Bertram 1980). A primary assumption of these studies is that vigilance (looking up) while feeding functions to detect avian or mammalian predators.

Bald Eagles (*Haliaeetus leucocephalus*) have no known natural predators. Despite legal protection, however, eagles are persecuted by humans throughout their range. Shooting is a frequent cause of death, accounting for nearly 20% of recently reported mortalities (Reichel et al.

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1984). Bald Eagles exhibit avoidance behavior in response to people (Stalmaster and Newman 1978, Knight and Knight 1984), suggesting that eagles perceive humans as a potential threat. Vigilant behavior of feeding eagles may be important for detecting danger from humans.

Bald Eagles also may look up while feeding for other reasons. Eagles, adept hunters and scavengers, also acquire food by inter- and intraspecific food robbery. Food piracy is common while feeding on salmon carcasses along Pacific Northwest rivers (Knight and Knight 1983, Hansen 1984, Stalmaster and Gessaman 1984). Because eagles use their talons when attacking feeding birds, injury to food holders is possible. We know of no other flocking species whose members regularly rob food from conspecifics and have the capacity to injure food holders. Vigilant behavior may allow a feeding eagle to detect a pirating attempt and thereby increase its likelihood of keeping food and avoiding injury.

In this paper we present two nonexclusive hypotheses for the function of vigilance in foraging eagles (formulated a priori) and discuss tests of these hypotheses.

HYPOTHESES AND PREDICTIONS

Hypothesis 1.—Bald Eagles look up while feeding to detect danger from humans. Four predictions follow from this hypothesis. (1) Feeding eagles are more vigilant when near to than when far from potential danger from people. In our study area, human activities are primarily restricted to the riverbanks; therefore, we were able to vary the risk of danger by observing eagles that were feeding at different distances from riverbanks. (2) Feeding eagles are more vigilant in areas where humans are frequently present than in areas where humans rarely visit. Bald eagles in our study area are not resident; rather, they range widely throughout the western United States and Canada (Young 1983, Hansen 1984, Washington Dept. Game unpubl. files), where they are actively persecuted (Reichel et al. 1984). (3) Adult eagles are more vigilant than immature eagles. Adult eagles, when approached by humans on foot, fly at greater distances than immatures (Stalmaster and Newman 1978), suggesting that adults are more wary or less tolerant of people than immatures. (4) Because many eyes are more likely to detect danger, individuals may decrease scanning time as group size increases without sacrificing safety. Therefore, eagles are more vigilant when feeding alone than when feeding in groups. Above a certain group size, however, additional members may no longer contribute to predator detection (Pulliam 1973, Elgar et al. 1984).

Hypothesis 2.—Eagles look up while feeding to detect pirating attempts or avoid injury by conspecifics. Two predictions are generated from this hypothesis. (1) Detection of a pirating attack increases the likelihood of keeping food. (2) Eagles are more vigilant when feeding in large groups than when feeding in smaller groups. Stalmaster and Gessaman (1984) found that when flock size exceeded 5, the rate of piracy attacks per eagle increased exponentially; therefore, we assume that feeding eagles face increasing risk of piracy or injury from attacks as flock size increases.

STUDY AREA AND METHODS

Our study was conducted from 27 December 1983 to 13 January 1984 along the north fork of the Nooksack River, Whatcom County, Washington (48°54'N, 122°8'W). As many as 300 Bald Eagles at a time congregate here during winter to feed on carcasses of salmon (*Oncorhynchus* spp.) that have spawned and died (Knight et al. 1980, Knight and Knight 1983, Stalmaster and Gessaman 1984). Because a salmon is too heavy to be carried by an eagle, birds feed along gravel bars where salmon carcasses are deposited by river waters. To distinguish between our two hypotheses, we placed carcasses of known weight in sites that are normally used by feeding eagles and that differ in level of human activity. At one site, Welcome Bridge (WB), human activity was frequent. Within 0.5 km of this site there were a boat launch, a waterfowl hunting area, two public parking areas, a primary road, a picnic area, a popular eagle-viewing area, a county fire department building, and eight residences. At a second site, the Larry Harris Farm (LHF), there was no human activity other than occasional activity around the farm buildings. At two additional sites, Kendall Hatchery (KH) and Maple Creek (MC), human activity rarely occurred.

Before dawn on each observation day we placed two piles of salmon at the edge of gravel bars; the piles averaged 129 m (range 55–180 m) from human activity (i.e. primary roads, occupied residences). At each pile we placed three salmon (average total weight = 7.4 kg, range 3.1–11.5 kg) 0.5–2.0 m apart; on each day, the piles were of equivalent weight. Salmon were cut open to expose flesh and viscera. One pile was placed close to cover (riverbank trees and shrubs) that might conceal humans (median distance = 17 m, range 8–18 m) while the second pile was placed far from cover (median distance = 34 m, range 34–85 m). We report medians here because the distributions are strongly skewed. The two piles were placed an average of 50 m (range 40–70 m) apart. From a blind entered before daylight, we filmed eagles using a video camera equipped with a 200-mm lens. We began filming when the first eagle began to feed at the salmon piles, and we attempted to film the two piles for comparable periods of time. Eighteen hours of feeding were filmed during 17 days. In addition, in scan samples at 10-min intervals, we recorded numbers of eagles and other species (e.g. American Crows, *Corvus brachyrhynchos;* Common Ravens, *Corvus corax;* and Glaucous-winged Gulls, *Larus glaucescens*) at the salmon piles and in the vicinity of the feeding area (within 500 m of salmon piles).

We analyzed the video tapes using a color television receiver and observed all birds that fed for at least 1 min. We began recording behavior of focal birds soon after they began feeding and ended observations either after 5 min of feeding, when eagles left food, or when feeding eagles were supplanted. Samples were truncated at 5 min to eliminate the effects of satiation on vigilance behavior. For each focal bird we recorded age class (eagles with heads and tails that were mostly white were recorded as adults, eagles with brown or mottled plumage as immatures), the duration of head raises (when head was held above a horizontal position), the duration of intervals between head raises (interscan intervals), interactions of the focal bird with other eagles, and the duration of feeding. We categorized the level of human activity at the feeding sites as frequent (WB) or infrequent (LHF, KH, and MC). The distance of the focal bird from vegetative cover was designated as near (<20 m) or far (>30 m). The numbers of eagles at the salmon pile and in the vicinity (within 500 m of salmon piles) were determined by averaging scan samples before and after each focal eagle sample.

We calculated the following variables for each focal bird: the percentage of time spent scanning (total seconds eagle's head was raised divided by total seconds of feeding; total feeding time includes head raises between bites, but not time spent in agonistic interactions), number of head raises per minute, mean duration of head raises, and mean duration of interscan intervals. When feeding eagles detected humans nearby or eagles flying overhead, they often raised their heads for extended periods before resuming feeding. Because we were interested in vigilance patterns of eagles before detection of danger or pirating attempts, we did not include head raises longer than 10 s in the above calculations. We chose 10 s based on the distribution of a sample of head raises; 96% of the durations of 2,400 head raises were between 1 and 10 s (median = 2.0 s, range 1–67 s).

Using stepwise multiple regression analyses, we examined the influence of five independent variables (distance to cover, age of the feeding eagle, frequency of human activity in the feeding area, group size at the salmon pile, and the total number of eagles in the vicinity of the feeding site) on vigilant behavior of feeding eagles. We used coded values for distance to cover (near or far), age of eagle (immature or adult), and frequency of human activity (rare or frequent). Actual numbers for group size were entered in the model.

We expected these variables might have differential effects depending on group size. Abramson (1979) found that scanning rates did not decrease in flocks of Eurasian Curlews larger than 4–5 birds, suggesting that scanning for predators may be especially important in small groups. Stalmaster and Gessaman (1984) reported a substantial increase in the frequency of agonistic interactions among feeding eagles when group sizes exceeded 7–8 birds, suggesting that detection of food pirates may be increasingly important in large groups. We therefore examined data for birds feeding in small (1–4 eagles), medium (5–7), and large (8–14) groups separately. Stepwise multiple regression, linear regression, analyses of variance, and Student's t-tests were performed using the Minitab Statistical Computing System (Ryan et al. 1976). Residuals of regression models were examined and statistical results were interpreted according to Zar (1984).

Results

In 189 feeding bouts (91 of adults and 98 of immatures) at the four sites, most (90.5%) of the observations were at WB and LHF. On average, feeding eagles looked up 6.3 times per minute (range 2.7–12.5) and spent 32.7% of the time scanning (range 13.8–56.5). The duration of head raises averaged 3.2 s (range 1.5–6.4 s), and interscan intervals averaged 6.9 s in duration (range 2.6–18.2 s). The size of the foraging group in which focal eagles fed averaged 3.7 eagles (range 1–14; Fig. 1). We documented the behavior of 110 eagles feeding in small groups, 50 eagles in medium groups, and 29 eagles in large groups. Because eagles feeding in large groups frequently were displaced by pirates, few eagles fed long enough to be included in the sample. On average 14.4 (range 1–42) eagles were in the vicinity of the feeding area (Fig. 1) during our observations.

Detection of danger from man.—During focal eagle observations, we recorded significantly larger groups of eagles at salmon piles placed at secluded sites (LHF, KH, and MC) than at WB, and larger groups of feeding eagles at piles

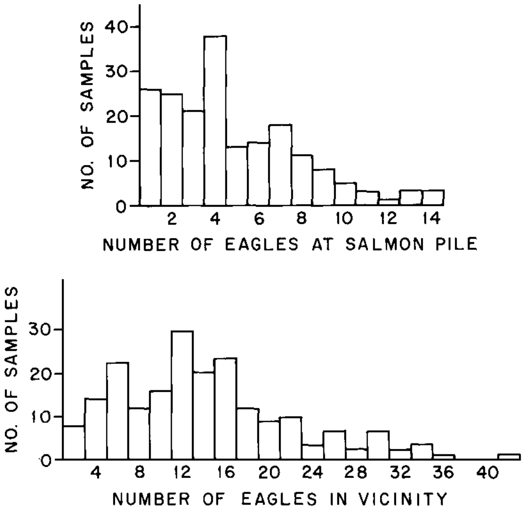

Fig. 1. Distribution of group sizes at the salmon pile and in the vicinity of the feeding site during 189 focal-eagle samples.

far from than near cover (Table 1). Scan samples revealed a similar trend; more eagles were present at far piles than at near piles in 62.5% (40 of 64) of the scan samples ($\chi^2 = 129.24$, df = 1, $P < 0.001$). For stepwise multiple regression analyses, group size was entered into the model after distance to cover, age of eagle, and frequency of human activity; these variables, therefore, do not confound the effects of group size on vigilance behavior.

Patterns of vigilance of eagles feeding in small groups were consistent with predictions 1 and 2 of hypothesis 1, that eagles look up to detect danger from humans. In small groups eagles spent more time scanning and raised their heads more frequently when feeding near cover than when feeding farther away (Tables 2 and 3). The duration of head raises did not vary with distance from cover, but the interscan intervals were shorter for eagles feeding near cover (Table 3).

The interaction of eagle age and the frequency of human presence at the feeding site also significantly influenced vigilant behavior in small and medium groups. Adults feeding at WB spent more time scanning ($F = 4.03$, df = 3,156, $P < 0.01$) and raised their heads more frequently ($F = 7.50$, df = 3,156, $P < 0.001$) than immatures feeding at WB and adults and immatures at more isolated sites (LHF, KH, and MC) (Fig. 2). These differences also were due to shorter interscan intervals (partial $t = -2.08$, df = 5,104, $P < 0.05$) rather than longer durations of head raises of adults at WB. There was no difference between sites in the proportion of adults recorded during scan samples (50% adults at WB and 42.6% adults at LHF, $\chi^2 = 2.016$, df = 1, $P > 0.10$). These findings support predictions 2 and 3 of hypothesis 1, that eagles look up while feeding to detect danger from humans.

TABLE 1. Mean group size of feeding eagles at salmon piles placed near (<20 m) and far (>30 m) from cover.

Feeding site	Frequency of human activity	Distance of salmon pile to cover	Mean group size ±1 SD (n)
Welcome Bridge	Frequent	Near	2.7 ± 1.29 (30)
		Far	3.7 ± 1.89 (32)
Secluded sites	Rare	Near	4.6 ± 2.78 (63)
		Far	5.9 ± 3.79 (64)

TABLE 2. Regression coefficients, partial t-values, and levels of significance (P) of the effects of 4 independent variables and their interactions on the vigilant behavior of 110 eagles feeding in small groups (1–4 eagles).

	Percentage of time scanning			Head raises/min		
Independent variable	Regression coefficient (B)[a]	Partial t-value	P[b]	Regression coefficient (B)[c]	Partial t-value	P[b]
Distance to cover	−3.510	−2.33	<0.05	−0.670	−2.00	<0.05
Age of eagle	—[d]	—	—	−0.711	−1.57	NS
Level of human activity	—	—	—	−2.638	−2.55	<0.05
Age–human activity interaction	—	—	—	2.352	3.52	<0.01
Group size at salmon pile	—	—	—	−0.315	−2.21	<0.05

[a] Coefficient of determination (r^2) = 0.048.
[b] All tests of null hypotheses are one-tailed.
[c] Coefficient of determination (r^2) = 0.230.
[d] Values are presented only for variables included in the multiple regression model.

TABLE 3. Vigilant behavior of eagles feeding in small groups (1–4 birds) near (<20 m, n = 58) and far (>30 m, n = 52) from cover.

	Near	Far	t	P[a]
Mean percentage of time scanning	34.2	30.7	2.32	0.011
Mean head raises/min	6.8	5.9	2.59	0.006
Mean duration of head raises (s)	3.0	3.1	0.46	0.325
Mean duration of interscan intervals (s)	5.9	7.5	3.11	0.001

[a] Test of hypotheses are one-tailed.

As the number of feeding birds increased from 1 to 4, the rate of looking up declined (Table 2, Fig. 3). Interscan intervals were positively correlated with group size at the salmon pile (partial t = 2.17, df = 5,104, $P < 0.05$), whereas the duration of head raises remained constant as group size increased. These findings support prediction 4 of hypothesis 1.

Distance to cover had no significant influence on vigilance patterns of eagles foraging in medium groups ($F = 0.31$, df = 5,44, $P > 0.50$ for percentage of time scanning; $F = 0.47$, df = 5,44, $P > 0.50$ for rate of looking up). However, the interaction of age of the feeding eagle and the frequency of human activity at the feeding site acted in the same manner as with small groups (Table 4), suggesting that eagles in medium groups also look up to detect danger from humans. There was a significant negative relationship between vigilance variables (percentage of time scanning and rate of head raising) and the total number of eagles in the vicinity of the salmon piles (Table 4).

Distance to cover did not influence vigilance behavior of eagles feeding in large groups. Because large groups of feeding eagles formed only at LHF, we were unable to evaluate the effect of human activity on vigilance patterns.

Detection of piracy attempts.—Feeding eagles that were looking up at the time of a pirating attempt were significantly more successful at keeping their food than eagles with their heads down. During 243 recorded pirating attempts, birds that looked up kept their food in 40.8% (69 of 169) of the attacks, while eagles that had their heads down kept their food in only 16.2% (12 of 74) of the cases ($\chi^2 = 14.722$, df = 1, $P < 0.001$). None of the birds with their heads down displayed or retaliated against the attacking eagle, whereas 53.8% of the birds with their heads up did so. By displaying, a bird significantly increased its chances of retaining its food; 75.8% of 91 displaying eagles kept their food, where-

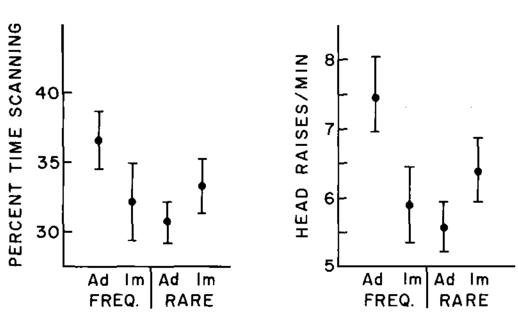

Fig. 2. Means and 95% confidence intervals of the percentage of time spent scanning and head raises per minute of adult and immature eagles feeding at Welcome Bridge (frequent human activity) and secluded sites (human presence rare).

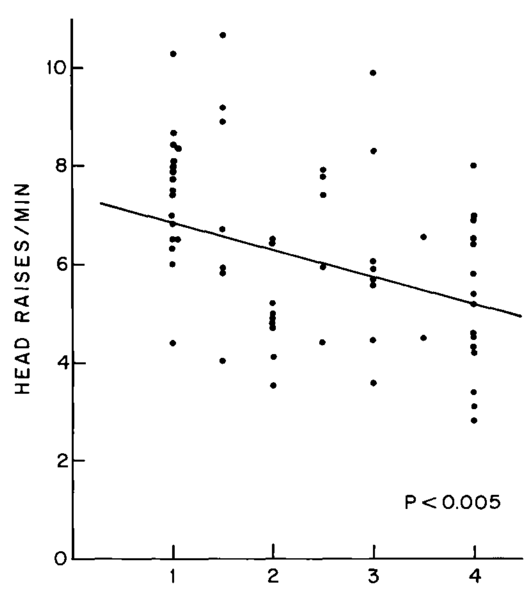

Fig. 3. Relationship between rate of head raising and group size of eagles feeding in small groups. The line represents line of best fit from linear regression analysis.

TABLE 4. Regression coefficients, partial *t*-values, and levels of significance (*P*) of the effects of 3 independent variables and 1 interaction on the vigilant behavior of 50 eagles feeding in medium groups (5–7 eagles).

	Percentage of time scanning			Head raises/min		
Independent variable	Regression coefficient (B)[a]	Partial t-value	P[b]	Regression coefficient (B)[c]	Partial t-value	P[b]
Age of eagle	−5.220	−2.28	<0.05	−0.642	−1.01	NS
Level of human activity	−19.552	−2.42	<0.02	−4.465	−1.98	<0.05
Age–human activity interaction	10.649	2.26	<0.05	2.562	1.95	<0.05
Total eagles in vicinity	−0.375	−2.85	<0.01	−0.075	−2.05	<0.05

[a] Coefficient of determination (r^2) = 0.283.
[b] All tests of hypotheses are one-tailed.
[c] Coefficient of determination (r^2) = 0.177.

as only 5.3% of 152 birds that did not display kept their food (χ^2 = 131.192, df = 1, $P <$ 0.0001). These findings are consistent with hypothesis 2 and suggest that by looking up eagles can more effectively deter pirating attempts.

The percentage of time spent scanning was correlated positively with group size at the salmon pile (Table 5, Fig. 4). Interscan intervals did not account for the increase in percentage of time scanning; rather, birds in larger groups raised their heads longer as total group size increased (partial t = 2.08, df = 2,26, $P < 0.05$). In contrast to the percentage of time scanning (Table 5), the rate of looking up did not change as group size increased from 8 to 14 (F = 0.41, df = 1,27, $P > 0.50$). Additionally, as the total number of birds in the area increased, the amount of time spent scanning increased (Table 5). Data from eagles feeding in large groups support prediction 2 of hypothesis 2.

DISCUSSION

Detection of danger from humans.—Eagles may select feeding sites where the probability of encountering humans is lowest. Even with the additional constraints of food availability, dominance status, and territoriality at feeding areas, we might expect eagles to prefer sites far from cover and in isolated areas rather than near cover or in areas used more frequently by humans. The distribution of feeding eagles during our focal-animal samples supports this supposition and is consistent with hypothesis 1, that eagles look up to detect danger from humans.

Vigilance of eagles feeding in small groups was correlated positively with proximity to human activity, thus supporting the hypothesis that eagles look up while feeding to detect danger from people. Feeding eagles experience a greater risk of danger from encounters with humans when feeding closer to the riverbank. Eagles responded to this increased risk by scanning more and raising their heads more frequently. Similarly, Yellow-eyed Juncos and House Sparrows scan more when feeding far from protective cover than when feeding near cover (Barnard 1980, Caraco et al. 1980b), and Blue Tits (*Parus caeruleus*) increase scanning rates in response to increasing risk of predation when feeding closer to the ground (Lendrem 1983). Feeding juncos also spend more time scanning when a hawk is present (Caraco et al. 1980a). Knight (1984) found that differences in responses of nesting Common Ravens to human intruders at their nests were associated with the likelihood of the ravens being persecuted by humans. Ravens that nested in areas where they were likely to be shot and their nests destroyed were less aggressive to nest intruders than ravens that nested in more secure areas.

Adult eagles were more vigilant when feeding near intense human activity than at isolated sites, yet vigilant behavior by immatures did not differ between sites. This interaction of age of eagle and level of human activity at the feeding site suggests that adult eagles have learned to associate humans with danger and to determine the likelihood of encountering humans in different locations.

Vigilance decreased as the size of the feeding group increased from 1 to 4 eagles, supporting the hypothesis that eagles watch for danger from people. This trend did not continue in groups of 5–8 eagles. These findings are con-

TABLE 5. Regression coefficients, partial t-values, and levels of significance (P) of the effects of 2 independent variables on the vigilant behavior of 29 eagles feeding in large groups (8–14 eagles).

	Percentage of time scanning		
Independent variable	Regression coefficient $(B)^a$	Partial t-value	P^b
Group size at salmon pile	2.382	3.96	<0.001
Total eagles in vicinity	0.370	1.92	<0.05

[a] Coefficient of determination (r^2) = 0.384.
[b] Tests of null hypotheses are one-tailed.

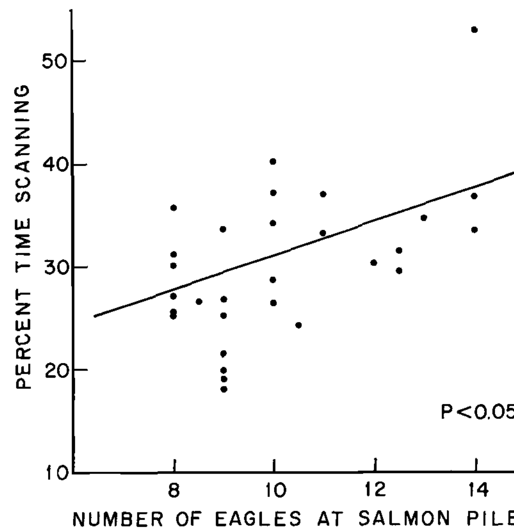

Fig. 4. Relationship between percentage of time spent scanning and group size of eagles feeding in large groups. The line represents line of best fit from linear regression analysis.

sistent with patterns reported in other avian species. In general, scanning rates do not decrease in flocks of passerines larger than 5–10 birds (Caraco 1979, Barnard 1980, Elgar and Catterall 1981) or in flocks of curlews larger than 4 or 5 birds (Abramson 1979). Pulliam (1973) demonstrated that the probability of detecting a predator levels off quickly as flock size increases.

Even though eagles feeding in small groups spend less time scanning than solitary birds, their combined efforts may be more effective in detecting potential danger. Eagles feeding in groups respond to human presence at greater distances than eagles feeding alone (Knight and Knight 1984). Similarly, Zebra Doves (*Geopelia striata*) feeding in groups have longer flight distances than solitary doves when approached by a human observer (Greig-Smith 1981). In experiments with trained hawks, Kenward (1978) noted greater response distances of Wood Pigeons (*Columba palumbus*) in groups of increasing sizes; Powell (1974) reported that European Starlings respond to model hawks more quickly when feeding in groups than when alone. Barnard (1980), however, found no difference in flight distances of House Sparrows feeding in flocks of different sizes.

Detection of pirating attempts.—Looking up while feeding has generally been attributed to predator detection. Feeding birds that monitor the behavior of surrounding individuals may benefit from social learning (Turner 1965, Krebs et al. 1972, Krebs 1973), yet vigilance while feeding seldom has been discussed in this context. Wood Pigeons (Murton 1971) and curlews (Abramson 1979) may look up while feeding to locate conspecifics enroute to other feeding grounds; Bertram (1980) suggested that Ostriches look up to watch for conspecifics to display to or to drive away. Thompson and Barnard (1983) described vigilance of foraging Northern Lapwings (*Vanellus vanellus*) and Greater Golden-Plovers (*Pluvialis apricaria*) that were kleptoparasitized frequently by Common Black-headed Gulls (*Larus ridibundus*). They did not suggest, however, that scanning functioned to detect robbery attempts; rather, they assumed that scanning reflected vigilance for predators.

We present evidence for another explanation of vigilance in socially feeding birds that are vulnerable to food robbery and possible injury during agonistic encounters. One eagle feeds from a salmon carcass at a given time (Hansen 1984, pers. obs.). As the size of the feeding flock increases, additional eagles must either wait until a carcass is available or supplant a feeding bird. Stalmaster and Gessaman (1984) found that agonistic encounters occur at a rate of 0.05 interactions per bird-minute in groups of 5 eagles. The rate more than doubles in groups of 8 and increases fourfold when 10 eagles are present. Aggression among conspecifics increases with increasing group size in other species as well. Interference from aggressive encounters increases with increasing flock size of Yellow-eyed Juncos (Caraco et al. 1980b).

Scanning time decreases, however, because larger flocks are better able to detect predators. We found that eagles feeding in groups of 8 or more increased their vigilance as group size, and thus the likelihood of being attacked, increased. Eagles feeding in large groups also scanned more as the total number of eagles in the area increased. Eagles perched in nearby trees, as well as birds waiting at carcasses, may pirate from feeding birds.

Evidence from this study strongly supports the hypothesis that vigilance in eagles feeding in large groups functions to detect piracy attacks. The risk of injury to feeding eagles from pirating attacks may be fairly high. Eagles that were looking up as attacking eagles approached were more successful in keeping food than eagles that were taken by surprise. Eagles may successfully defend against attackers in a variety of ways. Descriptions of agonistic behaviors are detailed by Stalmaster (1981), Knight (1981), and Hansen (1984). Feeding eagles that defended food against oncoming pirates were successful in keeping the food with a frequency of 89% (Hansen 1984) and 76% (Knight and Knight in prep.). It is reasonable to assume that feeding birds that are aware of approaching attackers are better able to retaliate forcefully.

In addition, a marked contrast in the percentage of time spent in scanning by feeding Bald Eagles (average 32.7%) and a Golden Eagle (*Aquila chrysaetos*, 2.0%) in our study area provides indirect evidence in support of hypothesis 2. Golden Eagles usually do not feed in large groups and are less vulnerable to food piracy than Bald Eagles.

Patterns of vigilant behavior.—In small and medium groups, one might expect to see different changes in vigilance patterns of wary birds depending on the most likely source of danger. Eagles increased both the time spent scanning and the rate of head raises when the risk of encounters with humans increased. There are two ways to accomplish this. Eagles can shorten the duration of interscan intervals and keep the duration of head raises constant, or eagles can shorten the duration of head raises but shorten the interscan intervals more. Although there was a slight decrease in duration of head raises, our data show a significant change only in the duration of interscan intervals. We might expect scan durations to be fairly constant because a limited period of time is necessary to assess the entire area. Similarly, Lendrem (1983) found that as the risk of predation to foraging Blue Tits increased, their scan durations remained constant while their interscan durations decreased.

As the size of feeding groups increased from 8 to 14, individual eagles devoted more time to scanning yet did not change the rate of head raising. This can be accomplished by increasing the duration of head raises and decreasing the duration of interscan intervals. Although these trends did occur, they were not statistically significant. Eagles significantly increased the duration of head raises in response to increasing numbers of eagles in the area, suggesting that the time required to assess possible attacks increases with the number of potential food pirates. Feeding eagles are not likely to be taken by surprise by attacks from perched birds if the interscan duration is slightly shorter than the time required for a food pirate to fly from a perch to the food holder. Interscan intervals therefore can remain constant without increasing the risk of losing food.

Several forces may act in concert to promote or limit social feeding in eagles. Eagles may benefit by feeding in small groups because intrusions by humans may be detected sooner and because less time is required for vigilance than when feeding alone. Additional benefits of group feeding include an increase in a bird's ability to find food (Turner 1965, Krebs et al. 1972, Powell 1974, Barnard 1980, Waite 1981, Knight and Knight 1983) and a reduction in the risk of not finding food when food is limited (Thompson et al. 1974). The costs to eagles feeding in large groups include greater risks of being pirated, more time devoted to scanning, and lower feeding efficiency (Stalmaster and Gessaman 1984). Depending on an individual's dominance status and ability to acquire food, the costs of group foraging may at times exceed the benefits.

Sensitivity of eagles to human activity has been examined previously in terms of flushing responses and flight distances (Stalmaster and Newman 1978, Russell 1980, Skagen 1980, Knight and Knight 1984). We have documented that in areas that are highly disturbed by humans, feeding efficiency necessarily declines because eagles spend more time scanning as the possibility of human encounters increases. Management strategies to protect Bald Eagles should include measures to reduce human activity in critical feeding areas. Finally, because food robbery is so prevalent in birds (Brockmann and Barnard 1979), we believe vigilance in detecting piracy attempts is applicable over a wide range of species in which both intra- and interspecific food piracy occurs. This hypothesis has not been previously considered in studies of the foraging ecology of species involved in food robbery.

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