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RESPONSES OF NESTING BALD EAGLES TO EXPERIMENTAL PEDESTRIAN ACTIVITY

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ABSTRACT.—In 1993 and 1994, I tested effects of pedestrian activity on Bald Eagles (*Haliaeetus leucocephalus*) at nests on 21 territories in western Washington. A pedestrian walked around each nest 10 min/hr for 6 hr during 65 trials. Eagles averaged 8.0 ± 1.8 (SE) responses/trial (i.e., per hr of pedestrian activity, N = 524 combined responses), and 10.7 ± 2.0 min of response time/trial (N = 681 min combined response time). Responses accounted for 23 ± 3% by frequency, and 3 ± 0.3% by time, of all perch behaviors on treatment days. I observed no damage or injury to eggs or young from the encounters, although nest flushes had a mean of 3.1 ± 0.9 responses/trial. Treatments resulted in a two-fold increase in mean egg exposure time/trial ($\bar{x}$ = 7.8 ± 1.6 min/exposure) compared to controls ($\bar{x}$ = 3.3 ± 0.8 min/exposure). Precipitation reduced the time adults left eggs and young exposed from a mean of 7.9 ± 0.9 min/hr to 5.1 ± 1.0 min/hr on control days. Nest height, nest screening, pedestrian distance, and phenology affected eagle responses; responses were substantially reduced at nests that were >40 m high and highly-screened, when pedestrian distance to nests increased from 60–120 m, and during incubation compared to the brood period. To reduce risks from increased exposure of eggs and young, I recommend that pedestrian activities be restricted near Bald Eagle nests during incubation and the first 3 wk of brooding. For Bald Eagle nests in forested, non-pristine areas of residential development, pedestrian activity less than 120 m from nests can be restricted as a function of nest height and screening to minimize disturbance.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *behavior*; *disturbance response*; *human activity*; *Washington.*

RESPUESTA DE *HALIAEETUS LEUCOCEPHALUS* NIDIFICANTES ANTE ACTIVIDAD PEATONAL EXPERIMENTAL

RESUMEN.—En 1993 y 1994, evalué los efectos de la actividad de peatones sobre águilas *Haliaeetus leucocephalus* en nidos ubicados en 21 territorios en el oeste de Washington. Un peatón caminó alrededor de cada nido 10 min/hr por 6 hr durante 65 ensayos. Las águilas presentaron en promedio (±SE) 8.0 ± 1.8 respuestas por ensayo(i.e., por hora de actividad peatonal, N = 524 respuestas combinadas), y 10.7 ± 2.0 min como tiempo de respuesta/ensayo (N = 681 min combinando el tiempo de respuesta). Del total de comportamientos de percha en los días de estudio, las respuestas correspondieron al 23 ± 3% en términos de frecuencia y al 3 ± 0.3% en términos de tiempo. No observé daños o lesiones en los pichones o huevos como consecuencia de los encuentros, aunque en promedio las aves fueron espantadas del nido en 3.1 ± 0.9 ocasiones por ensayo. Los tratamientos condujeron a un incremento del doble en el tiempo promedio de exposición de los huevos ($\bar{x}$ = 7.8 ± 1.6 min/exposición) en comparación con controles ($\bar{x}$ = 3.3 ± 0.8 min/exposición). La precipitación redujo el tiempo por el cual los adultos dejaron expuestos los huevos y pichones de un promedio de 7.9 ± 0.9 min/hr a 5.1 ± 1.0 min/hr en días de control. La altura del nido, su nivel de protección, la distancia al peatón y la fenología afectaron la respuesta de las águilas; las respuestas fueron sustancialmente reducidas en nidos que estaban ubicados a más de 40 m de altura y altamente protegidos, cuando la distancia al peatón se

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incrementó de 60–120 m, y durante la incubación, en comparación con el período de empollamiento. Para reducir los riesgos del incremento en la exposición de los huevos y pichones, recomiendo que las actividades peatonales sean restringidas cerca de los nidos de *H. leucocephalus* durante la incubación y las tres primeras semanas de cría de los pichones. Para áreas forestales no prístinas con desarrollo residencial, la actividad de los peatones a menos de 120 m de los nidos puede restringirse en función de la altura y protección de los nidos para minimizar el disturbio.

[Traducción del equipo editorial]

As Bald Eagle (*Haliaeetus leucocephalus*) populations recover, increasing numbers of eagles are nesting in landscapes subject to human activities and habitat alteration. Post-recovery persistence of some populations, such as in Florida and the Chesapeake Bay region, may be directly tied to the ability of eagles to reproduce successfully in urban and residential environments (Buehler et al. 1991). Human impacts are common in Washington, where in the past 25 yr increasing eagle populations and residential development in Puget Sound led to the development of >1150 eagle management plans with private landowners (Stinson et al. 2001). Management plans attempt to minimize effects of human activities primarily by imposing restrictions near nests during the nesting period, maintaining nest screening, and maximizing distances between human activities and nesting eagles. The effectiveness of management planning depends on our ability to understand how Bald Eagles respond to human activities near residential developments.

Behavioral changes of Bald Eagles that might precede nest failure often are not studied because they are difficult and time-consuming to assess (Anthony and Isaacs 1989). Human activities can change behavior of nesting eagles through auditory and visual disturbance (Grier 1969, Fraser et al. 1985, Grubb and King 1991, Steidl and Anthony 1996). Such activities may cause reductions in incubation time, brooding time, feeding time, and other adult behaviors that affect attendance of eggs or young, and potentially survival of young. These changes in adult behavior may be possible indicators of impending nest failure of raptors (Holthuijzen et al. 1989).

Experimental studies of human activities on Bald Eagles provide an opportunity to understand how eagles respond to different types of disturbance and variable disturbance parameters (e.g., distance) in controlled situations. Fraser et al. (1985) were first to evaluate experimentally flush distances of nesting Bald Eagles in response to a pedestrian approaching the nest directly, and made recommendations for buffer zones based on those distances. McGarigal et al. (1991) experimentally tested responses of foraging eagles to stationary boating activity and demonstrated that Bald Eagles were affected by passive human activities. More recently, in interior Alaska, Steidl and Anthony (2000) found experimental recreational activity resulted in significant behavioral changes to Bald Eagles nesting, potentially leading to reduced nestling survival.

To better understand the impact of human activities on behavior and reproduction of Bald Eagles in rural areas undergoing residential development, I conducted an experiment in western Washington in 1993–94. I used a walking pedestrian to simulate the most common human activity in the rural environment, and recorded the frequency and duration of Bald Eagle responses to the pedestrian during different nest stages, at different nest heights, with different degrees of screening cover, and at varying distances from nests. Analysis of these factors provided guidelines for reducing the effects of human activity in areas of residential development.

STUDY AREA

The Puget Sound region in northwest Washington is characterized by diverse saltwater, brackish, and freshwater ecosystems. Bald Eagles nest in coniferous stands dominated by Douglas-fir (*Pseudotsuga menziesii*) along marine shorelines, and in riparian stands dominated by black cottonwood (*Populus trichocarpa*) along lakes and rivers. Nests are typically placed in dominant or codominant trees in forest stands. High annual precipitation (e.g., 100–150 cm) results in closed forest canopies and dense understories, except where stands have been recently logged, or trees have been limbed. Thus, visibility of human activities from eagle nests varies. Land development in recent years has resulted in increased residential activities near nesting eagles (D. Stinson, J. Watson, and K. McAllister unpubl. data). The statewide Bald Eagle population has increased exponentially in the past 25 yr and growing numbers of eagles are nesting along Puget Sound (Watson et al. 2002), where humans commonly approach within 400 m of Bald Eagle nests (unpubl. data).

METHODS

Eagle responses to human activity were assessed by comparing eagle behaviors when a pedestrian was present (treatments) and absent (controls). Six-hour treatments and controls were applied to each eagle nest on consecutive days beginning at dawn. The order of each trial was randomized (treatment–control vs. control–treatment). During each treatment, a person walked a circular path around the nest tree once/hr (i.e., six times/treatment) to simulate naturally occurring pedestrian activity near the eagle nest, as opposed to direct nest approaches which are atypical (pers. obs.). An observer recorded the following information: duration (sec) of the pedestrian activity; frequency, duration, and type of eagle disturbance responses (i.e., none, flush and reperch, perch, vocalize, return flight to nest, fly in and respond, surveillance flight, flush and soar, flush and respond, redirected aggression toward conspecific); and perch locations and flight paths of eagles on 1:12000 aerial photos. Photos were used for measuring the distance of the eagle to the pedestrian at the point of response. On both control and treatment days the observer recorded time and duration (sec) of all behaviors for both adult eagles <200 m from the nest tree (i.e., nest building, incubating, brooding, feeding young, resting), and at distances >200 m where visibility allowed. Behavior frequencies and duration were summed for both adults on each territory because response was sometimes cued by the behavior of the other adult. Wind speed (low = calm or slight breeze; high = brisk or gusty winds), cloud cover (≤50% vs. >50%), and precipitation (yes/no) were recorded.

I conducted trials (i.e., one control–treatment on consecutive days) at a 60-m radius from each nest once during incubation and once during the first 3 wk of brooding (i.e., 42 trials). Trials conducted at the same nest were separated by >5 wk to minimize possible effects of repeated treatments (e.g., habituation) on responses. To assess the effect of pedestrian distance, I repeated the experiment at the seven nests with partial screening during incubation and brooding at 30 and 120 m (i.e., 28 trials). This resulted in a total of two trials/nest at each of the three distances. I standardized the total time and distance traversed by pedestrians among treatments by walking the circumference of the 120-m distance once, the circumference of the 60-m distance twice, and circumference of the 30-m distance four times. Duration of pedestrian activity was ca. 10 min long ($\bar{x}$ duration = 9.0 ± 2.5 min [SD]) for a total of 60 min of activity/6-hr treatment, with variability due to differences in ground cover and topography.

I described screening cover at nests by scoring nest visibility as high (0), partial (50), and low (100) at 30 m, 60 m, 120 m, and 200 m along four transects at each cardinal direction from the nest. Screening was assessed prior to leafout in January and after leafout in May, and categorized by the mean score as: ≤33 = little or no screening; 34–66 = partial screening; or ≥67 = high screening. Seven nests were identified for each screening category. Height of each nest was measured with a clinometer and categorized (20–29 m, 30–39 m, 40–49 m, >49 m) for analysis.

Nests on 21 Bald Eagle territories were studied; 12 adjacent to Puget Sound, six along rivers, and three at lakes. These were randomly selected from 323 nests with one to five homes <400 m away, which was typical of human activity levels near eagle nests in Puget Sound. I did not select nests that were at remote locations isolated from human activities because my intent was to provide recommendations for Bald Eagles with moderate prior exposure to human activity. Nests were chosen in settings with varied vegetative screening that still afforded an observer, stationed >400 m away, good visibility of the area <200 m from the nest tree.

Data Analysis. I summarized the frequency and duration of eagle disturbance responses and perch behaviors during controls and treatments by computing the grand mean and standard error from means computed at each nest. Paired t-tests were used to evaluate the significance of changes in responses and behaviors between controls and treatments.

I used multivariate analysis of variance to test effects of nest height, nest screening, distance to pedestrian, and nest phenology on standardized frequencies and durations of three eagle disturbance responses (total responses, nest flushes only, and combined nest responses including flushes, perch alert, and vocalization) and six eagle behaviors (perching <200 m from nest, nest building, incubation, brooding, feeding young, resting). Effects of treatments on eagle responses and behaviors were computed as the arithmetic difference between controls and treatments. I tested full models that included interactive effects. If no interactions were identified ($P \geq 0.10$), effects found to be significant were tested in reduced models, and factor level effects were identified with the Bonferroni's method (Miller 1981).

I used t-tests to compare mean exposure time (sec) for eggs and young on control days, on treatment days while the pedestrian was present, and on treatment days after the pedestrian activity. Also, t-tests were used to compare exposure times (sec) for eggs and young on control days among categories of precipitation, wind, and cloud cover I did not assess the effects of weather on egg and young exposure during pedestrian activity because I intentionally avoided conducting trials on days with inclement weather. Repeated measures analysis of variance was used to assess if eagles habituated to treatments among the six exposures to the pedestrian on treatment days.

Where appropriate, variables were tested to verify the assumption of normality. No transformations were necessary for variables deemed significant in final models Significance level for all tests was $\alpha = 0.05$.

RESULTS

Behavioral Responses. I conducted 65 of 70 scheduled trials during the 2-yr study (nest failures eliminated five brooding trials). Disturbance responses accounted for 23 ± 3% (SE) by frequency and 3 ± 0.3% by time, of all behaviors on treatment days. Eagles had a mean of 8.0 ± 1.8 disturbance responses/nest for each trial, or each hr of pedestrian activity (N = 524 combined responses). The typical response sequence was a flush from the nest, followed by reperching on the nest, and eventual resumption of pretreatment perch behavior. Eagles flushed and perched a mean of 3.1 times/

Table 1. Bald Eagle responses to experimental pedestrian activity in northwestern WA, 1993–94. Response rates (number of responses/nest, $N = 21$) are standardized per trial (1 hr of pedestrian activity).

	FREQUENCY/hr		DURATION (sec/hr)	
RESPONSE	MEAN	SE	MEAN	SE
Flush and reperch	3.1	0.9	123.2	39.1
Perch or vocalize	2.7	0.9	271.4	67.8
Return flight to nest	1.1	0.3	74.2	29.5
Fly in and respond	0.2	0.1	25.2	12.1
Surveillance flight	0.2	0.1	64.1	56.3
Flush and soar	0.1	0.1	37.4	23.8
Flush and respond	0.2	0.1	8.3	3.8
Redirected aggression	0.2	0.1	33.0	22.8

nest (±0.9) during each trial (Table 1). Eagles averaged 10.7 (±2.0) min of response time/nest for each hr of pedestrian activity ($N = 681$ min combined response time), and typically perched or vocalized half of that time (Table 1).

Eagles were initially perched on the nest a mean of 48 ± 1% of time when pedestrian activity was initiated during trials. For eagles on nests, the mean encounter distance for flush responses was 76 ± 9 m/nest, and 72 ± 9 m/nest for combined responses. For eagles perched anywhere on the territory, the mean encounter distance for flush responses was 72 ± 10 m/nest, and 71 ± 10 m/nest for all responses.

Pedestrian activity caused changes in eagle behavior, manifested as increased frequency of combined perch behaviors <200 m from nests (Table 2). Accordingly, frequency of pedestrian-induced responses increased, while frequency of nest building decreased. Pedestrian activity had less of an effect on duration of combined behaviors (Table 2). Although incubation time per trial was not reduced by pedestrian activity, duration of individual egg exposures/trial was longer ($t = 3.39$, $P = 0.009$, $N = 21$) during treatments ($\bar{x} = 7.8 \pm 1.6$ min/exposure; range = 0.3–59.0) compared to controls ($\bar{x} = 3.3 \pm 0.8$ min/exposure; range = 0.1–110.2), and was also longer ($t = 9.25$, $P < 0.0001$) than egg exposures immediately after treatments ($\bar{x} = 1.9 \pm 0.5$ min/exposure; range = 0.1–27.1). Mean duration of posttreatment egg exposure was partially dependent on mean duration of treatment exposure; eagles reduced posttreatment egg exposures by 30 sec for every 5 min increase in egg exposure during treatments (linear regression, $r = 0.29$, $P = 0.018$). During incubation, eagles responded a mean of 23 ± 5% of the time the pedestrian was present (14 ± 3 sec/min of experimental human activity). Total brood time decreased due to pedestrian activity (Table 2), but time that young were exposed/trial during the brood period was the same ($P = 0.101$) for treatments ($\bar{x} = 33.1 \pm 9.4$ min/exposure; range = 1.3–316.7), controls ($\bar{x} = 35.4 \pm 14.1$ min/exposure; range = 0.1–360.0), and immediately after treatments ($P = 0.432$; $\bar{x} = 29.5 \pm 11.4$ min/exposure; range = 0.1–319.4). For nests with young ($N = 19$), eagles responded a mean of 43 ± 10% of the time the pedestrian was present (26 ± 6 sec/min).

I did not observe direct effects to eggs due to treatments (e.g., eggs rejected or broken by flushing adults). Hatching success was unaffected at a nest where eggs were exposed for 59 min. Direct effects from weather were mixed; total time eggs and young were exposed was higher ($t = 2.05$, $P = 0.045$) in the absence of precipitation (7.9 ± 0.9 min exposure/hr) than when there was some level of precipitation (5.1 ± 1.0 min exposure/hr). There was no effect of wind ($P = 0.325$) or cloud cover ($P = 0.370$) on exposure time. Nest success averaged 1.14 young/occupied territory during the experiment, and 1.11 young/occupied territory in 1994, the year following the experiment. All nine territories treated in 1993 were reoccupied in 1994.

The presence of other raptors increased eagle responsiveness. Seventy-eight encounters with conspecifics and four encounters with Red-tailed Hawks (*Buteo jamaicensis*) were recorded during trials. Sixty-six encounters (85%) with other eagles involved a non-incubating or non-brooding adult chasing an intruder. Eight encounters (10%) were of an incubating or brooding bird vocalizing or standing above the eggs or young in response to

Table 2. Effects of pedestrian activity on the frequency and duration of Bald Eagle behaviors during 65 experimental trials. Each trial consisted of a 6-hr control and a 6-hr treatment in which pedestrian activity was conducted <200 m away for 10 min/hr. Effects were examined with paired *t*-tests.

	CONTROL		TREATMENT				
BEHAVIOR	GRAND $\bar{x}$	SE	GRAND $\bar{x}$	SE	PERCENT CHANGE	t	P
Frequency							
All perch behaviors							
Nest building/main-	25.8	1.4	30.8	2.1	19.4	2.36	0.029
tenance	9.9	0.9	7.2	0.8	−27.3	3.11	0.006
Incubate	9.4	0.7	8.6	0.7	−8.5	1.43	0.169
Brood	6.5	0.7	6.2	0.6	−6.2	0.62	0.544
Feed young	3.9	0.4	3.7	0.5	−5.1	0.41	0.698
Rest	4.6	0.7	5.2	0.7	13.0	1.09	0.289
Response[a]	0.01	0.01	8.0	1.8	>100	4.46	0.0003
Duration							
All perch behaviors	456.6[b]	17.8	439.3	16.8	−3.9	0.99	0.333
Nest building/main-							
tenance	33.9	6.7	28.7	6.7	−15.3	0.71	0.484
Incubate	324.8	9.7	318.9	7.0	−1.8	1.19	0.247
Brood	223.2	21.0	178.7	22.4	−19.9	2.25	0.038
Feed young	26.8	3.3	33.0	5.6	23.1	0.95	0.355
Rest	108.9	20.0	103.0	17.4	−5.4	0.13	0.902
Response[a]	<0.001	<0.001	10.7	2.0	>100	5.31	<0.0001

[a] Pooled disturbance responses included flushes, standing in alert posture before and after flushing, and flight (evasion, surveillance, or aggression) before eagles resumed pre-disturbance activity.
[b] Behavior of both adults on each territory was pooled so duration of all perch behaviors exceeded 6 hr.

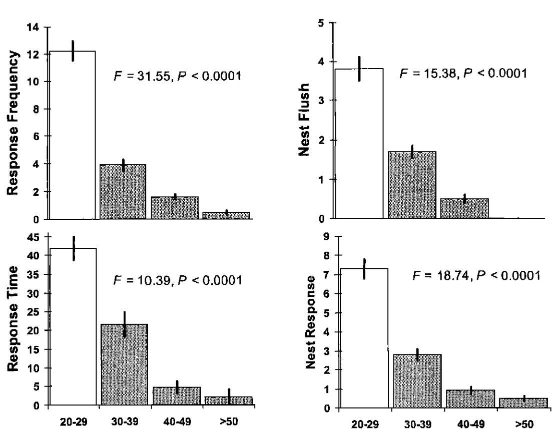

Figure 1. Effect of nest height on responses of Bald Eagles to experimental pedestrian activity at 21 nests in western Washington. Response rates (number of responses or min of response/hr of activity) were compared with the Bonferroni procedure. Responses included flushes, alert posture, and flight before eagles resumed previous activity. Means with different shading are statistically different (error bars = SE).

an intruding eagle. The remaining four encounters (5%) involved incubating or brooding adults engaged in physical aggression with an intruder on the nest, or leaving the eggs or young unattended while pursuing an intruding adult. Two encounters on the nest occurred during treatments.

Eagles did not habituate during six pedestrian exposures on a treatment day based on frequency ($P = 0.192$) or time ($P = 0.663$) of responses.

Effects of Nest Height, Screening, Distance, and Nesting Stage. No interactions were identified between the four factors on nine eagle behaviors ($P > 0.116$), but individual factor effects were significant. Nest height mitigated the effects of pedestrians near nests; four eagle responses were reduced at nests >29-m high (Fig. 1). Combined responses of eagles on the nest were reduced to <1/hr of pedestrian activity at nests >40-high, and eagles did not flush from nests >50-m high. Nest screening also ameliorated effects of pedestrian activity for three responses (Fig. 2). There was a mean decrease of three responses/hr between low and partially-screened nests, and a further reduc-

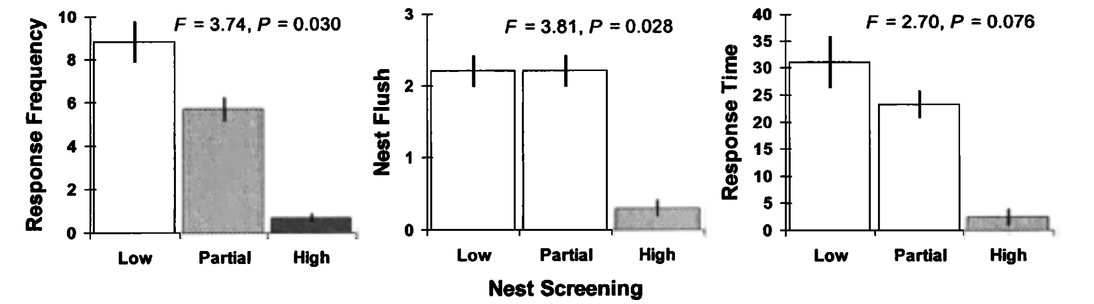

Figure 2. Effect of nest screening on responses of Bald Eagles to experimental pedestrian activity at 21 nests in western Washington. Response rates (number of responses or min of response/hr of activity) were compared with the Bonferroni procedure. Responses included flushes, alert posture, and flight before eagles resumed previous activity. Means with different shading are statistically different (error bars = SE).

tion of five responses/hr when nests were highly-screened. Highly-screened nests also significantly reduced eagle response time and nest flushes compared to other screening classes. Pedestrian distance to nests only affected eagle response time ($F_{8,56}$ = 4.01, P = 0.024). Eagle response time at 30 m ($\bar{x}$ = 19.9 ± 3.7 min/hr of activity) was not significantly different from 60 m ($\bar{x}$ = 18.4 ± 2.8 min/hr of activity), but both were significantly greater than at 120 m ($\bar{x}$ = 11.9 ± 4.4 min/hr of activity). Nest stage only affected total responses ($F_{8,56}$ = 7.37, P = 0.009). Eagles responded almost twice as often during the brood period ($\bar{x}$ = 6.5 ± 1.4 responses/hr of activity) compared to incubation ($\bar{x}$ = 3.3 ± 0.7 responses/hr of activity).

At given levels of screening and nest height the predicted eagle response frequency was reduced by a mean of 1.6/hr when pedestrian distance increased from 60–120 m (Table 3). At nests 20–29 m in height, response frequencies were reduced up to 18% at specific screening levels when distance increased from 60–120 m. At nests 30–39 m in height, response frequencies were reduced up to 33% at specific screening levels when distance increased to 120 m. At nests >40 m in height, responses were reduced from 50–100% as pedestrian distance increased from 60–120 m.

DISCUSSION

Successful management of Bald Eagle habitat depends, in part, on identifying factors that affect eagle responses to human activity, and understanding how to manipulate those factors to reduce their impacts. This study illustrates that in non-pristine, forested environments, nest height, and vegetative screening are important factors for mitigating eagle responses to brief exposures of a single pedestrian. Height of nests in which eagle responses were reduced to insignificant levels (i.e., >40 m) was considerably less than average response distance to pedestrians (i.e., 72 m). This suggests that nest height affords eagles a more substantial buffer against disturbance than horizontal distance. Nest height was a significant predictor of call rates, dive rates, and minimum approach distances that Red-tailed Hawks exhibited toward an observer (Andersen 1990). Flushes from nests are potentially the most detrimental eagle response, and this re-

Table 3. Predicted reduction in mean frequency (95% Confidence Interval) of Bald Eagle responses per hr of pedestrian activity when distance to the nest is increased from 60–120 m (N = 21 nests).

	NEST SCREENING					
NEST	LOW		PARTIAL		HIGH	
HEIGHT (m)	60 m	120 m	60 m	120 m	60 m	120 m
20–29	11.5 (2.1)	9.9 (2.8)	10.2 (1.8)	8.6 (2.7)	8.9 (3.1)	7.3 (3.6)
30–39	7.4 (2.1)	5.8 (2.8)	6.1 (1.1)	4.5 (2.2)	4.8 (2.2)	3.2 (3.0)
>40	3.3 (2.8)	1.7 (3.3)	2.0 (1.6)	0.4 (2.4)	0.7 (2.0)	0.0 (0.9)

sponse was ameliorated only by nest height and vegetative screening. Screening had marked effects on the frequency of flush and flight responses for eagles both on and away from the nest. Earlier research found nesting eagles responded to human activity when the activity first became visible (Grubb et al. 1992, Steidl and Anthony 1996). Partial screening reduced response time by 32% compared to open nests, and in some situations appeared to allow just enough visibility of the pedestrian to alert the eagle, but prevent it from monitoring pedestrian activity, resulting in a flush. Seventy-two percent of surveillance flights, when eagles circled the nest site during and after treatments, involved situations with the nest partially screened.

Manipulation of encounter distance produced less dramatic changes in responses. Mean response distance (71 m) and flush response distance (72 m) of eagles I studied were similar to breeding eagles at 33 nests in western Washington that flushed in response to humans in nonexperimental settings at a mean distance of 86 m, and exhibited alert responses at 143 m (J. Watson unpubl. data). Similarly, camping <100 m from Bald Eagle nests affected eagle behavior, compared to >500 m away (Steidl and Anthony 2000). The distances that breeding eagles in Washington responded to pedestrians were less than has been documented in other studies in the United States (e.g., 185 m, Grubb et al. 1992; 275 m, Grubb and King 1991; 57–991 m, Fraser et al. 1985), possibly reflecting a higher degree of habituation to human activities by eagles in western Washington. Studies which evaluated six characteristics of Bald Eagle responses in Arizona and Michigan, found distance to be the most important characteristic of pedestrian disturbance, followed by duration or sound of activity, and then visibility (Grubb and King 1991, Grubb et al. 1992).

Nest stage affected eagle tolerance to pedestrian disturbance with brooding eagles responding twice as long, on average, than incubating eagles. For both periods most response time was spent passively perching following flushing, prior to resuming the previous activity. During incubation, eagles usually sat more tightly on nests, resulting in fewer responses while the pedestrian was present. After treatments, incubation resumed more quickly than did brooding. Bald Eagles exhibited the same differences in nesting responses to close helicopter approaches in northwest Washington (Watson 1993). Control comparisons for exposure of eggs (3 min) and young (57 min) showed eagles exhibited a natural decrease in tenacity to nests throughout nesting, which amplified the time they spent off nests in the brood period. Eaglets begin to thermoregulate at ca. 15 d (Bortolotti 1984) and require less brooding thereafter. Coincident increases in daytime temperatures and decreasing precipitation throughout nesting may have progressively reduced the need for parental attendance. Wetter and colder days in early spring corresponded to increased time on eggs and small young after exposures. Such compensation is important during incubation to reheat cooled eggs of nesting raptors, especially during frequent exposures between 30–60 min that lower egg temperatures to <35°C (Fox 1995). I found mean egg exposure times decreased 3 min/hr in the absence of pedestrian activity, with an additional reduction in exposure time of 3 min/hr on days with precipitation. Captive Bald Eagles reduced the length of time they left eggs exposed from ca. 2 min/hr to 0.6 min/hr at ambient temperatures <7.2°C and wind velocities >16.2 km/hr (Gerrard et al. 1979). Thus, Bald Eagles exhibit flexibility in their incubation strategies depending on human disturbance and weather conditions. This flexibility probably explains the unexpectedly long exposure times for eggs even on control days (e.g., maximum 110 min).

Among nesting pairs of Bald Eagles there is a wide range of tolerance to pedestrians that may result from certain pairs being more habituated to higher existing human-activity levels on their territories (McGarigal et al. 1991). Research on raptors and American Crows (*Corvus brachyrhynchos*) indicated that increased human interactions from urbanization influenced bird behavior in such a way that they have become more tolerant of human intrusion near nests (Newton 1979, Knight et al. 1987, Grubb et al. 1992). However, I did not find that eagles habituated to experimental activity during a treatment day. Steidl and Anthony (2000) found short-term (e.g., daily) habituation of eagles, but no long-term (e.g., weekly) habituation to human activity levels. Different tolerance limits of individuals may, in part, result from past experience and nestling imprinting (Newton 1979, Harmata 1984).

This study illustrated the potential for detrimental behavioral responses of Bald Eagles during brief exposures to human activity. Because intensity of pedestrian activity during the study (10.0 min/hr for 6 hr) was in the range observed in typical circumstances in western Washington (J. Watson unpubl. data), I believe the results are representative of existing conditions. The need to reduce human activities that elicit eagle responses is based on the assumption that such efforts will increase survival and productivity (e.g., Fraser 1981, Grier and Fyfe 1987, Anthony and Isaacs 1989, Steidl and Anthony 2000). I did not detect damage or injury to eggs or young that occurred when adults were flushed from nests (Grier and Fyfe 1987, Yates and McClelland 1989); although nearly half of the eagles were on nests during pedestrian activity and flushes from nests constituted half of the responses. I observed no predation of eggs or young (Yates 1989), although exposure during two treatment episodes provided the opportunity for conspecifics to attack young, and for adults to incidentally harm them during violent agonistic encounters. A twofold increase in mean egg exposure time increased the likelihood that eggs would be affected by cooling, overheating, or loss of moisture (Gerrard and Bortolotti 1988). A mean reduction in incubation time by 14 min/hr was related to nest failure at 40 Bald Eagle nests in western Washington (J. Watson unpubl. data).

MANAGEMENT RECOMMENDATIONS

Effects of pedestrian activity <120 m from nests on Bald Eagles with some previous exposure to human activities in non-pristine, rural environments can be reduced by regulating the distance of disturbance as a function of nest height and screening vegetation on a site specific basis (Table 3). Guidelines to promote reduced disturbance include maintaining and enhancing vegetative and topographic features that totally screen Bald Eagle nests from pedestrian activities. A high degree of screening, as opposed to partial screening, is particularly critical when pedestrian activity must be allowed ≤60 m from nests. Where partial screening exists, or is proposed by removal of vegetation on undeveloped property (e.g., creating "view windows" or limbing), maintaining some degree of screening vegetation is preferred to completely removing the cover, but will provide eagles substantially less protection from disturbance compared to dense cover. Planting trees or vegetation near exposed nests will not reduce responses of eagles in the short term unless they effectively conceal human activities from the nest, but should be encouraged to provide future nesting habitat.

Management plans should not reduce pedestrian restrictions based solely on nest tree height, because eagles will select new trees and build nests at different heights over time. On eagle territories with limited management options, maintaining an adequate number of trees >40 m tall may reduce the long-term impacts of reduced screening and closer human activities.

Timing conditions in Bald Eagle management plans should restrict pedestrian activities during incubation and the first 3 wk of brooding when adults exhibit similar flush rates and subject eggs and young to the possibility of being crushed or ejected from nests (e.g., second wk of February through the fourth wk in May for western Washington; J. Watson unpubl. data). Time away from eggs or small young would be more critical during inclement weather, in harsher climates, and at higher elevation sites. Restrictions during later brooding (4–5 wk) through fledging (e.g., 12 wk), a period not specifically addressed in this research, should address activities that may inhibit delivery of prey to young, potentially affecting their survival (Bortolotti 1989, Anthony et al. 1994, Steidl and Anthony 2000).

Outreach programs explaining Bald Eagle management should inform the public that untrained observers may greatly underestimate their disturbance of nesting Bald Eagles. Incubating and brooding eagles will respond roughly 30% of the time pedestrians are present <120 m from nests, and nearly 70% of the eagle response time will be spent perching passively, exposing eggs and young to the elements and predators. Because Bald Eagles nesting in pristine environments may exhibit greater sensitivity to pedestrians than those in this study, similar experiments should be conducted in those areas to evaluate distance and cover relationships before management conditions are implemented.

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