FLUSH RESPONSES OF MEXICAN SPOTTED OWLS TO RECREATIONISTS

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Abstract: Mexican spotted owls (*Strix occidentalis lucida*) occupy narrow canyons on the Colorado Plateau, some of which are subject to high levels of recreational activity. These activities represent a potential threat to owls, yet due to the confines of canyon walls, spatial restrictions on recreational activities would likely eliminate all activity within these canyons. We assessed factors that influenced flush responses (flush or no flush), flush distances, distances of avoidance flights, and behavioral changes of owls in response to a single hiker that approached roosting owls. Increased perch height decreased the likelihood that adults (odds ratio = 0.09) and juveniles (odds ratio = 0.17) would flush in response to the presence of a hiker; having flushed previously the same day increased the likelihood of adults flushing on subsequent approaches (odds ratio = 6.83). Juveniles and adults were unlikely to flush at distances ≥12 m and ≥24 m from hikers, respectively, and neither age class was likely to alter its behavior in response to the presence of a hiker at distances ≥55 m. Based on these response thresholds, placing a 55-m buffer zone around roosting sites would eliminate virtually all behavioral responses of owls to hikers, but would restrict hiker access to 80% of canyons occupied by owls. A less conservative 12-m buffer zone would eliminate 95% of juvenile and 80% of adult flush responses, and restrict hiker access to 25% of canyons occupied by owls.

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Participation in outdoor recreation has increased since the 1950s (Walsh 1986) and is predicted to continue to increase over the next 50 years (Flather and Cordell 1995). Subsequently, intensity of recreational activities on available lands will continue to increase, which will likely increase the frequency of interactions between wildlife and humans. These interactions can potentially affect individual organisms and entire populations adversely and in complex ways, with both immediate (increased stress, altered behavior) and long-term (decreased survival and reproduction) consequences (Knight and Cole 1991). Raptors are particularly sensitive to disturbance from recreationists, especially when nesting and roosting (Holmes et al. 1993, Steidl and Anthony 1996). Effects observed on raptors have included decreased reproductive success (White and Thurow 1985), decreased nest attendance, decreased prey delivery rates (Fernández and Azkona 1993, Delaney et al. 1999, Steidl and Anthony 2000), and altered foraging behavior (Knight et al. 1991, McGarigal et al. 1991). In particular, pedestrian activities have been found to be more disruptive than many other activities, such as disturbances from automobiles, boats, and aircraft (Bèlanger and Bèdard 1989, McGarigal et al. 1991, Holmes et al. 1993). Suggested protection measures to mitigate adverse effects on sensitive species include use of buffer zones, which impose spatial and temporal restrictions on the amount of recreational activity allowed near key habitats (i.e., nest sites, foraging areas) and during critical time periods (i.e., nesting season, migratory stopovers; Richardson and Miller 1997).

The Colorado Plateau, where hiking is a popular activity (Zion National Park, unpublished data), draws millions of recreationists each year. The topography of the region, characterized by high plateaus bisected by deeply incised canyons, however, largely restricts hiking to canyon bottoms. Mexican spotted owls on the Colorado Plateau occupy steep-walled, rocky canyons (Willey 1998) that provide cool microclimates for nesting and roosting sites (Barrows 1981, Rinkevich and Gutiérrez 1996). Many canyons, particularly those in National Parks, are subject to intense recreational activity (U.S. Fish and Wildlife Service 1995) that peaks from March to October (Zion National Park, unpublished data) and coincides with the nesting season of the owls (Willey 1998). This spatial and temporal overlap of human and owl use of canyons exacerbates interactions between owls and recreationists and could

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adversely affect Mexican spotted owls in these regions (U.S. Fish and Wildlife Service 1995). Yet, due to the confines of canyon walls, buffer zones to protect these organisms may effectively eliminate recreation from entire canyon systems.

We examined factors influencing responses of owls to hikers in canyons. Our objectives were to identify factors that affected adult and juvenile rates of flush response and flushing distances, distances of avoidance flights, and duration of owl responses, as well as establishing a quantitative basis for creating thresholds beyond which owls would be unlikely to respond to the presence of hikers.

STUDY AREA

During 1997 and 1998, we examined responses of Mexican spotted owls to recreationists in southern Utah, specifically in Zion, Capitol Reef, and Canyonlands National Parks, and in Arizona on the Navajo Nation. Spotted owls in Canyonlands National Park (1,160 to 2,160 m) were located in slickrock canyons of Cedar Mesa sandstone, with pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) as the dominant vegetation. Owls in Capitol Reef National Park (1,150 to 2,500 m) were located in slickrock canyons of Navajo and Kayenta sandstone, with pinyon pine, Utah juniper, ponderosa pine (*Pinus ponderosa*), and boxelder (*Acer negundo*) as the dominant vegetation. Owls in Zion National Park (1,100 to 2,650 m) and the Navajo Nation (1,220 to 2,990 m) were located in slickrock canyons of Navajo sandstone, with ponderosa pine, boxelder, Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and Gambel oak (*Quercus gambelli*) as the dominant vegetation.

METHODS

We located roosting owls during daylight by checking known roosts with binoculars; we minimized our effects on the birds by approaching as quietly as possible. After detecting an owl, a single hiker then approached it directly at 1 step per sec until the owl flushed or the hiker reached a point directly beneath the perched owl. If an owl did not flush on the first approach, we retreated ≥50 m from the owl, allowed it to resume its predisturbance activity, waited an additional 5 min, then approached the owl again up to a maximum of 3 approaches. If adults flushed, we allowed them to return to predisturbance activity, waited an additional 5 min, then approached them again to assess the effects of repeated approaches on owl responses. We did not approach juvenile spotted owls after the first flush response per day.

We recorded 5 responses of owls to the approaching hiker: *time to initial response*—from start of approach to first visible head or eye movement; *response distance*—from hiker to owl at initial response; *flush distance*—from hiker to owl when flushed; *flight distance*—of avoidance flight; and *response duration*—elapsed time from initial response to resumption of predisturbance activity for ≥1 min (this 1 min was not included in response duration). We recorded and examined the influence of disturbance context (Steidl and Anthony 1996) for each human–owl encounter (Table 1).

Statistical Analyses

We analyzed data from adult and juvenile owls separately because juveniles often roosted on or near the ground in areas with little vegetation cover. We used logistic regression to identify factors affecting flush responses (flush or not) for the first approach per day and separately for subsequent approaches. We used multiple linear regression to identify factors affecting flush distance, flight distance, and response duration. For both age classes, we fit full models containing all variables (Table 1), then systematically eliminated variables with little explanatory power ($P > 0.05$) using drop-in-deviance tests and extra sum-of-squares F-tests for

Table 1. Factors examined to assess responses of Mexican spotted owls to single hikers, Colorado Plateau, 1997–98.

Factor
Perch height (m)[a]
Perch substrate (cliff or tree)[a]
Perch cover (yes or no)[a]
Canyon height (m)[a]
Canyon width (m)[a]
Canyon use-level (high or low)[a]
Beginning distance of approach[a]
Time of day (morning or evening)[a]
Year[a]
Temperature (°C)[a]
Sex (adults only)[a]
Number of other owls in vicinity[a]
Age (juveniles only)[a]
Closest approach (m)[b]
Flush response (yes or no)[c]
Previously flushed[d]

[a] Examined for flush response, flush distance, flight distance, response duration.

[b] Examined for flight distance, response duration.

[c] Examined for response duration.

[d] Examined for flush response.

logistic and multiple linear regression, respectively. We used paired *t*-tests to assess if owls used a higher perch after being flushed and 2-sample *t*-tests to compare responses between adults and juveniles. Data were transformed as necessary to meet assumptions of statistical tests, and all parameter estimates are reported as means ± 1 SE.

We established threshold distances for both initial and flush responses, based on cumulative frequencies at which 95% of adults and juveniles responded to approaching hikers (Stalmaster and Newman 1978, McGarigal et al. 1991).

RESULTS

Flush Response

Adult owls flushed in response to 42% of approaches by a single hiker (n = 129) with 95% of all adults flushing ≤9 m from the hiker (Fig.1). The likelihood of adults flushing when first approached decreased strongly with increasing perch height and increased if owls were perched in trees rather than on cliffs (Table 2). Having been flushed previously increased the odds of being flushed on subsequent approaches nearly 7 fold (Table 2). Juvenile owls flushed in response to 39% of approaches (n = 166), with 95% of all juveniles flushing ≤6 m from the hiker (Fig.1). The likelihood of juveniles flushing on the first approach per day decreased strongly with increasing perch height (χ^2_{108} = 21.44, P < 0.0001, odds ratio = 0.17) and decreased slightly with increasing age (χ^2_{108} = 9.32, P < 0.0023, odds ratio = 0.96).

Table 2. Factors that influenced (P < 0.05) flush responses of adult Mexican spotted owls to single hikers, Colorado Plateau, 1997–98.

Approach	*n*	Factor	Odds ratio	χ^2	*P*
First approach	81	Perch height[a]	0.09	23.3	<0.001
		Perched on trees	1.91	4.4	0.036
		Time of day	0.57	4.5	0.034
Subsequent approaches	45	Previously flushed	6.83	20.2	<0.001

[a] ln transformed.

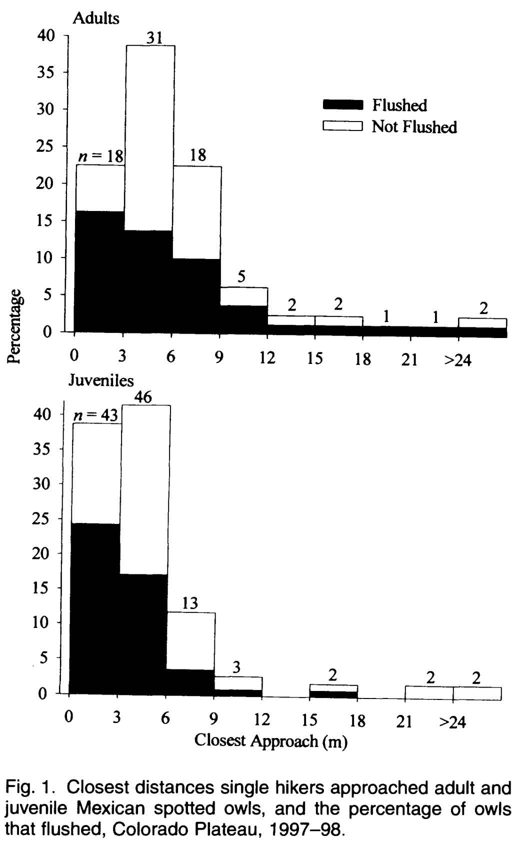

Fig. 1. Closest distances single hikers approached adult and juvenile Mexican spotted owls, and the percentage of owls that flushed, Colorado Plateau, 1997–98.

Response and Flush Distances

Often the first visible response to hikers involved owls becoming alert and observing the approaching hiker. We found moderate evidence that juveniles responded at slightly greater distances (23.0 ± 1.27 m) than adults (21.1 ± 1.43 m; t_{169} = 1.77, P = 0.078) when first approached; 95% of both adults and juveniles that responded became alert within 55 m (Fig. 2). Adults flushed at considerably

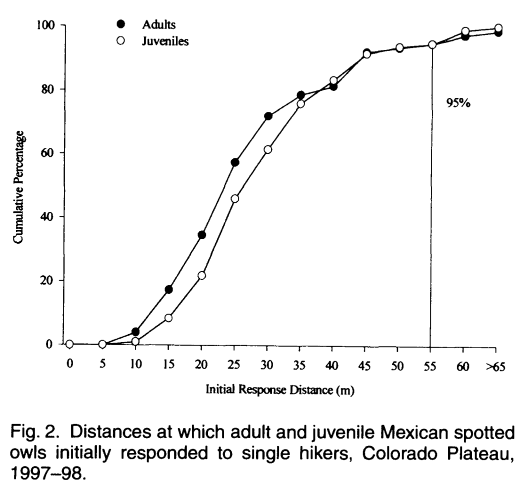

Fig. 2. Distances at which adult and juvenile Mexican spotted owls initially responded to single hikers, Colorado Plateau, 1997–98.

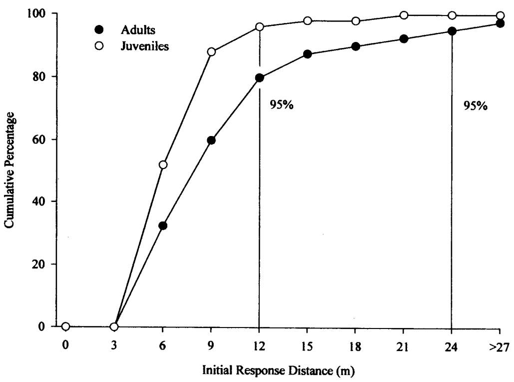

Fig. 3. Distances at which adult and juvenile Mexican spotted owls flushed in response to single hikers, Colorado Plateau, 1997–98.

greater distances from hikers (7.8 ± 1.12 m, n = 40) than juveniles (3.1 ± 0.98 m, n = 54; t_{90} = 3.12, P = 0.0024), with 95% of flushes occurring within 24 m and 12 m, respectively (Fig. 3). Flush distance for adults increased with increasing perch height (slope = 0.39 ± 0.18 m, t_{40} = 2.14, P = 0.039). Adults flushed at greater distances in 1997 (13.0 ± 3.70 m) than 1998 (5.7 ± 1.20 m; t_{40} = 2.19, P = 0.035), whereas flush distance of juveniles was not influenced strongly by any factor we measured (Table 1; Full Model: $F_{12,38}$ = 1.29, P = 0.26).

Avoidance Flights and Perch Heights

There was no appreciable difference in average length of avoidance flights between adults (26.5 ± 3.56 m, n = 42) and juveniles (24.1 ± 3.14 m, n = 54; t_{94} = 0.61, P = 0.26) (Fig. 4). Length of adult avoidance flights was influenced only by year (t_{38} = 2.06, P = 0.046), with longer flights in 1997 (36.6 ± 7.01 m, n = 14) than 1998 (19.0 ± 3.47 m, n = 25); juvenile avoidance flights, however, increased with increasing perch height (slope = 0.55 ± 0.21 m, t_{52} = 2.70, P = 0.0095) and also were longer in 1997 (37.6 ± 5.28 m, n = 20) than 1998 (16.1 ± 1.87 m, n = 34; t_{52} = 4.32, P < 0.0001).

Adults used initial perches in higher locations (5.5 ± 0.43 m) than juveniles (4.5 ± 0.37 m; t_{182} = 2.73, P = 0.0068), suggesting that juveniles may be more vulnerable to disturbance than adults. Both adults and juveniles chose perches that were higher that the original perch after being flushed (adults: 1.3 ± 0.70 m higher, t_{40} = 1.87, P = 0.035; and juveniles: 2.0 ± 0.44 m higher, t_{57} = 4.52, P < 0.0001).

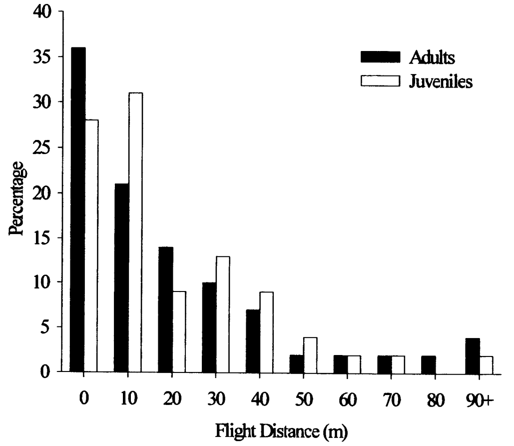

Fig. 4. Distribution of avoidance flights in adult and juvenile Mexican spotted owls, Colorado Plateau, 1997–98.

Response Duration and Vocalizations

The response duration of juveniles (403.6 ± 38.35 sec, n = 77) was somewhat longer than adults (348.5 ± 42.41 sec, n = 63; t_{138} = 1.94, P = 0.054), likely because juveniles became alert at greater distances from the approaching hiker than adults. Response duration in both adults and juveniles was influenced most strongly by being flushed and less strongly by several other factors (Table 3).

Lastly, 11% of adults and 23% of juveniles vocalized in response to first being approached by a hiker. Birds that flushed were more likely to vocalize, with 20% of flushed adults (χ^2_{81} = 7.26, P = 0.03, odds ratio = 10.24) and 36% of flushed juveniles vocalizing (χ^2_{108} = 9.07, P = 0.0026, odds ratio = 4.18).

DISCUSSION

Owl responses to hikers depend on a complex interaction of variables associated with the encounter and are most likely influenced by their previous experience with humans. Perch height, however, largely explained whether or not owls flushed in response to an approaching hiker; as owls perched higher, they were less likely to flush, a relationship identified in other raptors (Holmes et al. 1993, Steidl and Anthony 1996). Furthermore, perch height largely determined the distance at which adults flushed and the duration of their response as each of these responses increased with higher perch heights (Tables 2 and 3). Higher perches afford greater visibility of approaching disturbances at greater distances, which has been shown to increase flush response rate and flush distance in bald eagles (*Haliaeetus leucocephalus*; Steidl

Table 3. Factors that influenced ($P < 0.05$) response duration (sec) of adult and juvenile Mexican spotted owls to single hikers, Colorado Plateau, 1997–98.

Age class	*n*	Factor	Parameter estimate	SE	*t*	*P*
Adult	62	Flush response	−221.1	39.71	5.57	<0.001
		Perch height (ln)	125.8	51.00	2.47	0.017
		Perch cover	−119.6	50.26	2.38	0.021
		Year	−132.5	36.03	3.68	<0.001
		Intercept	−90.7	101.97	0.90	0.370
Juvenile	75	Flush response	−159.2	32.96	4.83	<0.001
		Perch substrate	85.9	33.40	2.57	0.012
		Canyon height (ln)	−97.0	32.57	2.98	0.004
		Number of other owls in vicinity	−83.4	36.40	2.29	0.025
		Intercept	819.8	134.35	6.10	0.001

and Anthony 1996). Furthermore, female owls that nested in higher locations changed their activity budgets in response to hikers, more so than females that nested in lower locations (Swarthout 1999).

There are direct costs associated with responding to disturbance, such as energetic demands of avoidance flight and time lost that would be allocated to other activities. Mexican spotted owls have a narrow thermal neutral zone (Ganey et al. 1993) and consequently are found in cool microclimates (Rinkevich and Gutiérrez 1996). Energetic demands of avoidance flights increase heat production, which may be exacerbated by flying during the day, and which could increase heat-related stresses. Flushed owls vacate their selected roosts that likely meet their thermoregulation requirements, perhaps forcing them to occupy roosts that may not meet these demands as effectively. In 1 case, we observed a flushed owl begin gular fluttering on a secondary perch. Flushing potentially exposes owls to predation from diurnal predators such as peregrine falcons (*Falco peregrinus*) and harassment from common ravens (*Corvus corax*), both of which are common in areas occupied by owls. Although we avoided approaching owls in the presence of predators, on 3 occasions we observed ravens harassing owls after being flushed.

MANAGEMENT IMPLICATIONS

The appropriate strategy employed to protect Mexican spotted owls from effects of recreational activity will depend on management objectives for the species and recreational demands for the shared wilderness resource. Canyon systems present a particular challenge because the concentration of recreational activity increases potential conflicts with wildlife and topography limits escape routes. Further, even the smallest buffers could effectively exclude all recreational activity from within these narrow canyons. Using a 205-m-radius buffer zone (Swarthout 1999) to reduce disturbance to nesting Mexican spotted owls from hikers, for example, would limit access completely in all canyons used by owls in this study.

There are 2 owl responses to hikers that provide useful information for establishing meaningful buffer zones and for which we calculated 95% threshold distances: initial response and flush response. We found that 95% of adults and juveniles became alert to approaching hikers at distances ≤55 m (Fig. 2). Establishing a buffer zone based on initial responses is a conservative option that would also eliminate flush responses from virtually all owls. This distance also would restrict recreational activity in 80% of canyons occupied by owls (Table 4). Establishing a buffer zone based on 95% of flush responses in juveniles is a less conservative option, would exclude 80% of adult flush responses (Fig. 2), and would eliminate recreational activity from 25% of canyons occupied by owls (Table 4). Ideally, buffers should be placed around commonly used roosting sites, which may change among years and even within years, to minimize unnecessary restrictions on recreationists. However, this approach would likely be impractical to implement. Therefore, we recommend that buffers be established on a site-specific basis for each occupied Mexican spotted owl territory in high-use canyons, which were defined as receiving ≥2 hikers per hr (Swarthout 1999). Although many canyons occupied by owls were used by hikers, most received little use (≤0.1 hikers/hr) and few hikers ventured to remote portions of canyons used as roosting locations (Swarthout and Steidl, unpublished data). The process used to establish these buffer zones could

Table 4. Management options to minimize effects of hikers on Mexican spotted owls on the Colorado Plateau.

Management level	Buffer zone	Other consequences
95% of alert response	≥55m	Exclude 100% of observed flush responses.
		Exclude access to 80% of canyons.
95% of adult flush response	≥24m	Exclude 100% of juvenile flush responses, 70% of adult alert, and 60% of juvenile alert responses.
		Exclude access to 50% of canyons.
95% of juvenile flush response	≥12m	Exclude 80% of adult flush responses, 20% of adult alert, and 12% of juvenile alert responses.
		Exclude access to 25% of canyons.

be used for any desired management scenario and extends the options of managers to protect a threatened species, yet allows flexibility to accommodate recreational demands for canyon access.

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