HUMAN DISTURBANCE AFFECTS PARENTAL CARE OF MARSH HARRIERS AND NUTRITIONAL STATUS OF NESTLINGS

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Abstract: Most studies of the effects of human disturbance on reproduction in birds of prey have not quantified the subtle and potentially important aspects of such interactions. Thus, we studied the effects of human disturbance on parental care by marsh harriers (*Circus aeruginosus*) in spring 1991 at Dos Reinos Lake, Ebro Valley, Spain. Specifically, we assessed changes in reproductive activities and nutritional condition of nestlings due to low-level human disturbance during incubation and nestling phases. The number of food items delivered and the time spent by males and females in the nesting area and on the nest decreased during disturbed periods, especially during incubation ($P < 0.001$), whereas behaviors related to stress (alarm calls, chases against other intruding birds, and percentage flying time) increased ($P < 0.001$). Although annual productivity of the disturbed pairs was not affected, nestlings of disturbed birds exhibited levels of blood urea that were higher ($P < 0.001$) than those of undisturbed pairs. Thus, minor human disturbances may cause long-term effects on lifetime reproductive success of birds by increasing energy and time expenditure in non-reproductive activities and by reducing condition of nestlings.

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In recent years the impact of recreation on wildlife has intensified, especially on reserves where sensitive species nest. The effect of human disturbance on breeding success has been studied in numerous protected species (Boyle and Samson 1985, Pomerantz et al. 1988). Generally, these studies have concentrated on the short-term effects of disturbance, such as displacement (Andersen et al. 1990), nesting failures (Boeker and Ray 1971), and lower breeding success (Wiley 1975, White and Thurow 1985). However, it is possible that other more extensive and less documented effects, such as feeding disruptions or changes in reproductive activities (Stalmaster and Newman 1978, Stalmaster 1980, Knight and Knight 1984), may be of great importance in the long term, reducing the viability of fledglings (Korpimäki and Lagerström 1988) or threatening future reproduction (Drent and Daan 1980).

Herein, we quantified the effect of human disturbances due to outdoor recreation on the reproductive activities of the marsh harrier in a wetland which, although protected, is frequently visited. Our working hypothesis was that short-term low-level human disturbance does not affect annual breeding success, but it can affect the nutritional condition of nestlings and the energy expended by parents.

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STUDY AREA

We conducted the study during April–July 1991 at Dos Reinos Lake, Ebro Valley, Spain (Fig. 1). The reserve, is about 21 ha in size, includes approximately 4.2 ha of reeds (*Phragmites australis*) and bulrushes (*Typha augustifolia*) and supports 11 nesting pairs of marsh harriers (Fernández 1990). The lake receives a large number of human visitors (5–10 visits/day during the week and 50–100 on weekends).

The greatest disturbances are caused by fishermen of the marsh crayfish (*Procambarus clarkii*), who frequently penetrate the reedbeds to place their traps and to collect captured crayfish. Fishing has increased since the introduction of the marsh crayfish in 1984–85. As the number of fishermen has increased and the peripheral fishing zones (those nearest the paths) have become saturated, some of the fishermen have begun to penetrate the reeds, disturbing protected species nesting in the lake, including harriers (Fig. 1).

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METHODS

We observed 6 breeding pairs of harriers throughout the breeding period. A similar period of observation was dedicated to each pair (78 days, 549.5 hr of observation). We observed the harriers from a fixed point approximately 500 m from the nests. Observations were made alternately in the morning and afternoon in shifts of 7–8 hours, including public holidays when the number of visitors was greatest. We graded disturbances as: intense (penetration of the reeds by fishermen); medium (passers-by making noise, livestock controlled by dogs, or nearby noisy vehicles); and slight (silent passers-by and unaccompanied livestock). We compared harrier behavioral patterns in disturbed periods (intense or medium disturbances) with undisturbed periods (no disturbances or slight disturbances).

We studied 2 behaviors: those related to the care of eggs and chicks, including percentage of time that the adults spent on the nest, percentage of time that each adult spent in the nesting area (on the lake), and the number of food items delivered per hour; and other patterns related to stress and energy expenditure caused by disturbances, including percentage of time spent flying, series of alarm calls per hour, and the number of defenses against other birds per intrusion. We considered intruders those birds that entered a 50-m circle around the nest and flew $\leq$30 m above the ground. We noted intrusions only when $\geq$1 harrier was present in its territory. Responses to intrusions were recorded when harriers attacked or chased the intruders (see definitions in Anderson and Wiklund 1987). The marsh harriers studied never attacked fishermen visiting reedbeds. The length of time (once a disturbance had ceased) for adults to return to the nest after being disturbed was also recorded. This time interval was included in the disturbed period.

Given that there are important variations in the level of parental care throughout the breeding period (Altenburg et al. 1982, Fernández 1992), we delineated 3 breeding phases: incubation, first nestling phase (1–22 days), and second nestling phase (23–44 days after hatching). We observed harriers for 223.5 hours during incubation, 189.5 hours in the first nestling phase and 136.5 hours in the second nestling phase. During 52.2 hours (10.9% of the total time), some type of disturbance (either intense or medium) was observed in the proximity of the nests (24.7 hr during incubation, 12.6 hr in the first, and 14.9 hr in the second nestling phase). We compared breeding behavior between disturbed and undisturbed periods within the same breeding phase with a t-test. The number of defenses per intrusion was compared for the whole breeding period with a Chi-square test. To assess the relative breeding success between disturbed (n = 6) and undisturbed pairs (n = 5), the relationship between number of chicks successfully fledged and number of eggs laid was compared using a Chi-square test. We considered disturbed those pairs nesting near paths or crayfish fishing areas (Fig. 1) and enduring frequent intense and medium disturbances.

We estimated nutritional condition of the chicks via blood urea levels, a method which is more accurate than body mass or other indices of malnutrition in birds of prey (García-Rodríguez et al. 1987*a*, Ferrer et al. 1987). Blood urea returns slowly to normal levels when the young are fed after a prolonged fast (García-Rodríguez et al. 1987*a*). We followed the techniques described by Ferrer et al. (1987) and García-Rodríguez et al. (1987*a*,*b*) to obtain and analyze blood samples. We took blood samples when chicks were 38–40 days old (just before fledging) and in the morning (between 1000 and 1200 hr) to minimize the effects of circadian rhythm fluctuations (García-Rodríguez et al. 1987*b*).

To assess whether urea levels depended on the sex of the chicks, order of hatching, or size of the brood, we used t-tests to compare levels of urea in: male (n = 18) versus female chicks (n = 14); first and second chicks (n = 19) versus third and fourth chicks (n = 13); and fledglings at nests with 2 (n = 2), 3 (n = 18), and 4 chicks (n = 12). Also, we calculated Pearson's correlation coefficients (r) between levels of urea in fledglings and hatching dates of the chicks.

RESULTS

Parental Care

When human disturbances caused harriers to leave the nest they took between 1 and 89 minutes to return ($\bar{x}$ = 17.9 min, SD = 20.7, n = 33). There were no differences (t = 0.40, 31 df, $P > 0.05$) in the return time between the periods of incubation ($\bar{x}$ = 19.8 min, SD = 24.9, n = 12) and the first nestling phase ($\bar{x}$ = 16.8 min, SD = 18.5, n = 21).

Time spent in the nesting area by adults de-

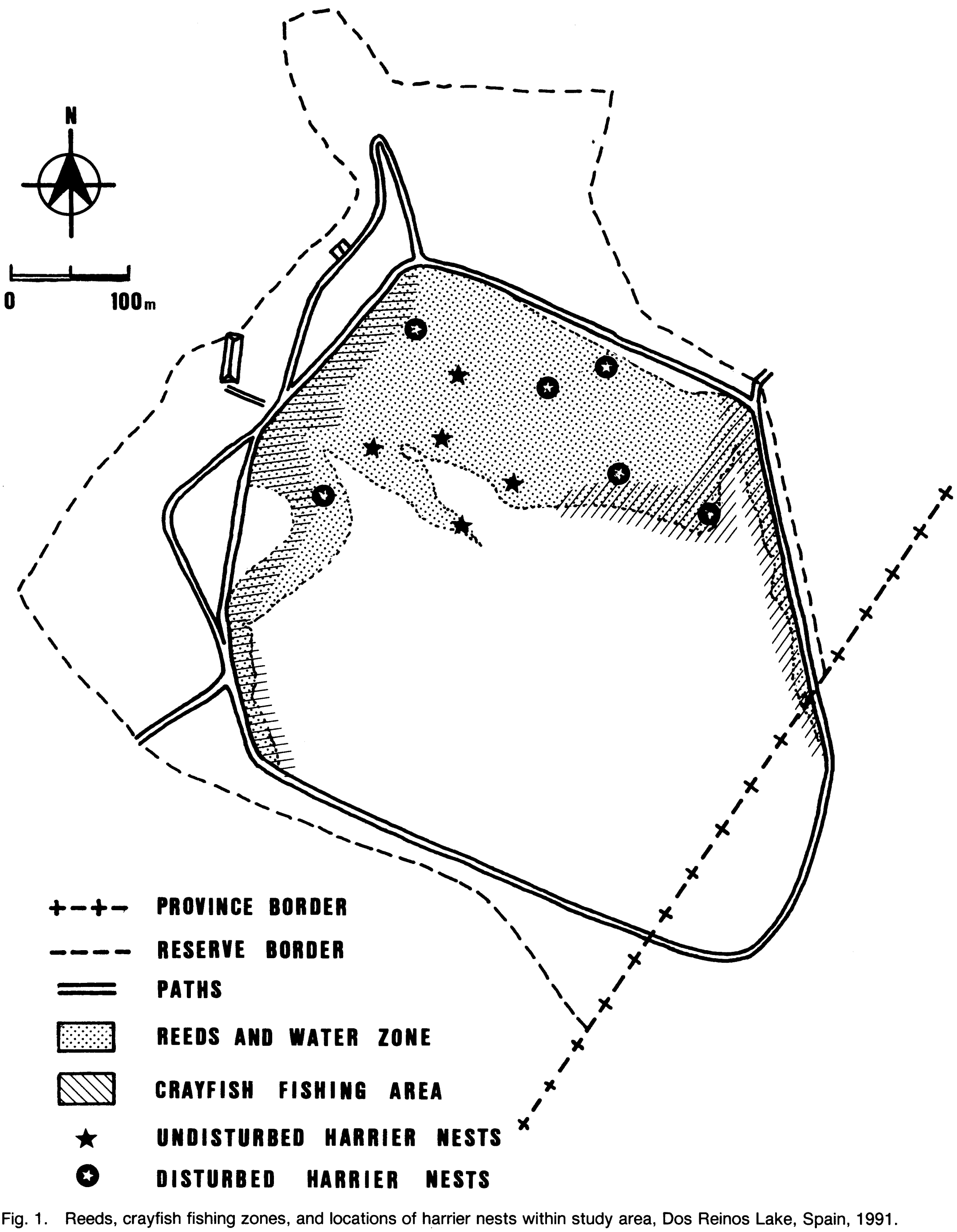

Fig. 1. Reeds, crayfish fishing zones, and locations of harrier nests within study area, Dos Reinos Lake, Spain, 1991.

creased during disturbed periods, especially among females and during incubation ($P < 0.001$) (Table 1). The decrease among males, which generally spent less of their time in the nesting area (an average of 30.9% in undisturbed periods) and hence suffered fewer direct disturbances, was smaller and not significant. Time during which the territory remained abandoned increased during disturbed periods, particularly during incubation ($P < 0.001$). Time spent on the nest was reduced, especially during incubation ($P < 0.001$) and the first nestling

Table 1. Parental care by marsh harriers during disturbed and undisturbed periods, Dos Reinos Lake, Spain, 1991.

		Undisturbed periods			Disturbed periods			
Parental care	Breeding phase	n	$\bar{x}$	SD	n	$\bar{x}$	SD	t
% of time with male present	Incubation	28	31.3	18.1	7	25.2	35.0	0.66
	1st nestling	26	21.5	14.0	4	19.2	25.4	0.28
	2nd nestling	18	13.6	11.7	4	6.3	7.1	1.18
% of time with female present	Incubation	28	96.9	8.3	7	35.6	30.6	9.71[a]
	1st nestling	26	88.8	19.3	4	78.9	28.1	0.90
	2nd nestling	18	47.9	28.3	4	29.7	9.1	1.29
% of time with area abandoned	Incubation	28	1.2	3.2	7	47.6	32.7	7.70[a]
	1st nestling	26	7.8	12.3	4	17.2	29.5	1.16
	2nd nestling	18	43.6	23.2	4	65.2	2.8	1.83
% of time with male or female in nest	Incubation	28	94.5	5.7	7	40.0	39.6	4.55[a]
	1st nestling	26	67.1	31.3	4	17.0	30.0	2.99[b]
	2nd nestling	18	2.7	5.4	4	0.1	0.3	0.92
Number of food items/hr	Incubation	28	0.39	0.22	7	0.12	0.18	2.97[b]
	1st nestling	26	0.53	0.28	4	0.12	0.23	2.81[b]
	2nd nestling	18	1.10	0.57	4	0.28	0.38	2.74[c]

[a] $P < 0.001$.
[b] $P < 0.01$.
[c] $P < 0.05$.

phase ($P < 0.01$), when the nest would normally be occupied for more than two-thirds of the time.

The number of food items delivered to the female by the male during incubation was reduced ($P < 0.01$) during disturbed periods (Table 1). Number of food items brought to the nest decreased both during the first ($P < 0.01$) and the second ($P < 0.05$) nestling phases. In total, the number of food items brought to the nest during disturbed periods was less than a third of that brought under normal conditions. There were no differences ($P > 0.05$) in the rates of food delivery between disturbed and undisturbed pairs outside the periods of disturbance ($t = 0.91$, during incubation; $t = 0.37$, in the first nestling phase; and $t = 1.42$ in the second nestling phase).

Stress and Energy Expenditure

The proportion of defended intrusions was higher ($P < 0.01$) during the disturbed periods than during undisturbed periods (Table 1). During disturbances, the frequency of alarm calls increased by a factor of 20 (Table 2). This behavior was habitually accompanied by high circling flights and other behaviors involving high energy expenditure, such as flapping flight and territorial displays involving dives from great heights.

During disturbed periods, the percentage of time spent in flight increased by a factor of three in males and ten in females (Table 3). For males, the increase was only significant during incubation ($P < 0.05$). The females increased ($P < 0.001$) their time in flight in all three of the studied periods (incubation, first, and second nestling phases).

Effect on Breeding Success

There was no difference ($P > 0.05$) in breeding success between disturbed and undisturbed pairs. Of the 25 eggs laid by the 6 disturbed pairs, 16 chicks fledged (64.0%), whereas the 5 undisturbed pairs produced 24 eggs from which 16 chicks were successfully reared (66.7%) ($\chi^2 = 0.04$, $P > 0.05$). One of the 11 nesting pairs in the lake failed to successfully incubate apparently due to continuous disturbances by cray fishermen. The other 10 pairs successfully reared their broods with an average of 3.2 chicks/pair, which led to an average productivity for the lake of 2.9 chicks/pair and 7.6 chicks/ha of reedbed (similar to the productivity of other wetlands in the region; Fernández 1990).

Nutritional Status of the Chicks

Levels of blood urea obtained from 32 chicks reared in the lake varied between 5 and 18 mg/dl ($\bar{x} = 11.9$, SD = 4.0). Samples from chicks of disturbed pairs contained levels of urea ($\bar{x} = 13.9$, SD = 3.9, $n = 16$) higher ($t = 3.10$, $P < 0.01$) than those raised by undisturbed pairs ($\bar{x} = 10.01$, SD = 3.2, $n = 16$).

There were no differences ($P > 0.05$) in levels of urea due to the sex of the chicks ($t = 1.25$),

Table 2. Stress patterns of marsh harriers during disturbed and undisturbed periods, Dos Reinos Lake, Spain, 1991.

Stress patterns	Breeding phase	Undisturbed periods No.	Undisturbed periods %	Disturbed periods No.	Disturbed periods %
Defenses/intrusions	Incubation	305	26.6	9	44.4
	1st nestling	293	35.2	8	75.0
	2nd nestling	203	33.5	1	100.0
	Total[a]	801	31.3	18	61.1
Alarm call series/hr	Incubation	15	7.6	4	15.6
	1st nestling	8	4.5	35	277.8
	2nd nestling	0	0.0	4	26.9
	Total	23	4.2	43	82.4

[a] $\chi^2 = 7.17$, $P < 0.01$.

order of hatching ($t = 1.22$), or size of the brood ($t = 1.70$). Levels of blood urea were not correlated ($r = -0.12$, $n = 32$, $P > 0.10$) with the hatching dates of the chicks.

DISCUSSION

The negative effects of low-level human disturbances on nesting birds are difficult to detect, given that the effects are difficult to quantify, are not immediate, and may affect birds in an indirect way (Boyle and Samson 1985, Pomerantz et al. 1988). Our results, however, suggest that minor human disturbance may increase breeding effort by the parents and affect the physiology of nestlings.

In the short term, human disturbance of harriers caused a reduction in parental care, characterized by decreases in incubation time, protection of the chicks, time spent in the territory, and quantity of food delivered. As with other species subjected to low-level human disturbance (Mathisen 1968, Grier 1969, Gargett 1977, Fraser et al. 1985), we found no differences in annual productivity between disturbed and undisturbed pairs, but differences were found in physiological condition of nestlings. It could be argued that the disturbed pairs, which usually occupied the peripheral territories on the lake, delivered food items less frequently. However, we found no differences in feeding frequency between disturbed and undisturbed pairs outside the disturbed periods.

The disturbances we observed resulted in greater breeding effort by the parents. First, the period of the disturbance can be considered time that could be used for delivering food items (Stalmaster 1980, 1983; Knight and Knight 1984), repairing the nest (Fernández 1992), and protecting the brood. Furthermore, disturbances stress the adults (and perhaps the chicks; Parsons and Burger 1982). Apart from other physiological effects, which are difficult to assess (Busch et al. 1978, MacArthur et al. 1982), stressors caused greater expenditure of energy, due to an increase in aggression against intruders, time spent in flight (especially flapping flight and high-altitude circling), and in other alarm behavior (such as calls and dives), all of which require high energy expenditure (Phillips et al. 1985).

The increase in energy expenditure during disturbances is greater among females. This is expected because they are responsible for the greater part of the parental care, at least during incubation and the first nestling phase (Alten-

Table 3. Percentage of time spent flying by marsh harriers during disturbed and undisturbed periods, Dos Reinos Lake, Spain, 1991.

% flying time	Breeding phase	Undisturbed periods n	Undisturbed periods $\bar{x}$	Undisturbed periods SD	Disturbed periods n	Disturbed periods $\bar{x}$	Disturbed periods SD	t
Males	Incubation	10	12.1	9.1	8	44.8	41.5	2.45[a]
	1st nestling	26	16.0	15.3	5	27.6	16.6	1.54
	2nd nestling	18	30.0	24.6	3	27.9	15.1	0.14
Females	Incubation	10	1.5	2.1	8	53.0	28.1	4.65[b]
	1st nestling	26	5.6	6.9	9	56.7	28.1	8.76[b]
	2nd nestling	18	10.2	6.6	5	57.5	33.0	6.06[b]

[a] $P < 0.05$.
[b] $P < 0.001$.

burg et al. 1982, Fernández 1992). Hence, stress and increased energy expenditure caused by disturbance may give rise to a reduction in the life span of adults due to increasing physical fatigue and risk of predation (Drent and Daan 1980), with females being more affected than males.

MANAGEMENT IMPLICATIONS

Our results show that, apart from the direct harm that abandonment of the nest and/or territory may cause to breeding success (loss of eggs or chicks; Boeker and Ray 1971, Wiley 1975, White and Thurow 1985), nonconsumptive human disturbance leads to an appreciable increase in reproductive effort and, in consequence, in the energy expenditure needed to produce the same number and quality of chicks (Stalmaster 1983, Knight and Knight 1984). Although, in the short term, minor human disturbances might not have had any appreciable effects on annual productivity, further study is needed to determine the long term effects of reduced physiological condition of nestlings on survival probability (Korpimäki and Lagerström 1988) and of supra-energy expenditure by parents to lifetime breeding success of adult birds (Drent and Daan 1980, Partridge 1989).

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CROSS-FOSTERING NEW ZEALAND'S BLACK STILT

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Abstract: To increase fledging success and recruitment of young birds into the breeding population of endangered black stilts (*Himantopus novaezelandiae*) in New Zealand from 1981 to 1987, we protected nest-sites from predators and manipulated egg production through multiple clutching and cross-fostering to pied stilts (*H. himantopus*). Pairs producing multiple clutches fledged more young ($P < 0.01$) than did unmanipulated pairs and more young fostered to black pairs were resighted than those fostered to hybrid (black × pied, pied × hybrid, and hybrid × hybrid) pairs. Juveniles cross-fostered to pied or hybrid stilt pairs migrated with foster parents but did not return to breed. More emphasis has been placed on increasing the success of chicks reared under black stilt parents since 1988. Black stilts did not benefit from inter-specific fostering because migratory behavior learned from foster parents was detrimental to long-term survival of this species.

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The black stilt survives as a single breeding population of 70 adult birds (10 breeding pairs) within the Mackenzie Basin in the South Island, New Zealand. The pied stilt expanded its range into New Zealand from Australia during the mid-nineteenth century. The species are morphologically, ecologically, and behaviorally distinct, but they hybridize (Pierce 1984*a*). Black stilts prefer black mates, but select others when these are not available. Hybrid matings are fertile, resulting in progeny intermediate in plumage between the 2 parent types (Pierce 1984*a*). Ninety percent of black stilts remain all year within the Mackenzie Basin; whereas most pied and hybrid stilts migrate during winter to the eastern coast of the South Island and northwards.

The reduction in numbers and breeding range of black stilts coincided with the introduction and spread of predators such as domestic cats (*Felis catus*), Norway rats (*Rattus norvegicus*), stoats (*Mustela erminea*), and ferrets (*Mustela furo*); large-scale modification of riverbed habitat through drainage or damming; and encroachment of exotic vegetation into nesting areas (Pierce 1984*b*). Without management, offspring from fewer than 2% of wild black stilt eggs survived to fledging (Pierce 1986) and predation accounted for 41% of egg losses (Pierce 1982).

In 1981, the New Zealand Wildlife Service began an intensive program to increase fledging success and recruitment of juveniles to the declining population resident within the Mackenzie Basin. This was attempted through the provision of predator-free nesting sites, multiple clutching, cross-fostering to pied and hybrid parents, and establishment of a captive population.

Cross-fostering has been used with mixed success as a management technique for endangered birds. Chatham Island black robins (*Petroica traversi*) have successfully increased from 5 individuals to over 100 through the use of cross-fostering (Reed and Merton 1991). Experiments with birds of prey (Fyfe et al. 1978, Spitzer 1978), Kirtland's warblers (*Dendroica kirtlandii*; Brewer and Morris 1984), and Newells race of the Manx shearwater (*Puffinus puffinus newelli*; Byrd et al. 1984), have also been successful.

Cross-fostering can increase productivity, but

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