

ROCK CLIMBING AND RAVEN *CORVUS CORAX* OCCURRENCE DEPRESS BREEDING SUCCESS OF CLIFF-NESTING PEREGRINES *FALCO PEREGRINUS*

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SUMMARY.—*Rock climbing and Raven Corvus corax occurrence depress breeding success of cliff-nesting Peregrines Falco peregrinus.*

Aims: To assess the significance of rock climbing-induced disturbance and Raven *Corvus corax* occurrence on the breeding output of a cliff-nesting Peregrine *Falco peregrinus* population.

Location: Northern Italy- southern Switzerland.

Methods: Breeding success, productivity and fledgling rate of 29 Peregrine pairs were analysed in relation to the occurrence of rock climbing activities and Ravens at nesting cliffs.

Results: Breeding success and productivity were lower for pairs coexisting alternatively with Ravens or climbers, compared to undisturbed pairs. In addition, pairs settled at cliffs simultaneously occupied by Ravens and frequented by climbers did not fledge any young, suggesting that Raven predation on Peregrine eggs/chicks may be predisposed by human disturbance.

Conclusion: It is proposed that rock climbing should be regulated or banned in the proximity of Peregrine nests, in particular at sites hosting Ravens.

Key words: Breeding success, cliff nesting, *Corvus corax*, *Falco peregrinus*, rock climbing.

RESUMEN.—*La presencia de escaladores y Cuervos Corvus corax reduce el éxito reproductor del Halcón Peregrino Falco peregrinus.*

Objetivos: Determinar el efecto de la presencia de escaladores y Cuervos *Corvus corax* en el resultado final de la reproducción de la población de Halcón Peregrino *Falco peregrinus*.

Localidad: Entre el norte de Italia y el sur de Suiza.

Métodos: Se analizó el éxito reproductivo, la productividad y tasa de pollos volados de 29 parejas de Halcón Peregrino en relación a la presencia de escaladores o Cuervos en los cortados con nidos de Halcones.

Resultados: El éxito reproductor y la productividad fue menor en parejas que presentaban o bien escaladores o bien Cuervos en los cortados, en comparación con parejas sin su presencia. Además, en las parejas establecidas en cortados ocupados simultáneamente por Cuervos y que frecuentemente son visitadas por escaladores no consiguieron sacar ningún pollo adelante. Esto sugiere que la depredación por Cuervos en los nidos de Halcones Peregrinos se puede ver favorecida por la presencia de escaladores.

Conclusiones: Proponemos que la práctica de la escalada en cortados que presenten nidos de Halcones Peregrinos ha de ser regulada o prohibida, especialmente cuando en esos mismos cortados existen nidos de Cuervo.

Palabras clave: Éxito reproductor, nidificación en cortados, *Corvus corax*, *Falco peregrinus*, escalada en roca.

INTRODUCTION

In recent decades, raptors have become gradually more protected in almost all European countries, but their decline often persists, due to pollution, habitat alteration and fragmentation, or to human direct/indirect disturbance (Tucker & Heath, 1994). Peregrine *Falco peregrinus* populations suffered a dramatic decline during the 1950s and 1960s in the boreal hemisphere,

following the adoption of organochlorine pesticides in agriculture (Ratcliffe, 1993). Subsequent banning of DDT and some cyclodienes (dieldrin, aldrin, heptachlor) enabled recovery later on, but the species is still classified as rare, with 6.200-11.000 pairs in Europe (Tucker & Heath, 1994; Forsman, 1999), and populations are still below the pre-crash levels in many countries (but see e.g. UK, Crick & Ratcliffe, 1995; Spain, Gainzarain *et al.*, 2002).

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In several parts of the breeding range, Peregrines nest on cliffs alongside the Raven *Corvus corax*, the world largest passerine. The two species frequently compete for nest-sites at shared cliffs, Peregrines usually being dominant over Ravens during territory settlement (Ratcliffe, 1993; Monneret, 2000). However, Ravens are opportunistic predators, and may represent a potential threat for Peregrine reproduction: in fact, they have been reported as preying on eggs or chicks when parent falcons are away from the nest (Juillard, 1992; Ratcliffe, 1993; Monneret, 2000).

Vertical rock faces also attract human recreational climbers, who often choose the same cliffs inhabited by Peregrines and Ravens for their activities. Disturbance induced by human climbing has been reported as a cause of temporary or definitive nest abandonment by Peregrine pairs (Monneret, 2000). However, definitive nest abandonment is rare: in fact, if disturbance events occur when chicks have already hatched, Peregrines tend to continue providing parental cares until fledging (*pers. obs.*). In fact, nest abandonment is more likely to occur at the beginning of the breeding season, during territory settlement and egg laying, in accordance with theories of parental investment (Trivers, 1972; Knight & Temple, 1986).

This paper investigates whether human climbing and the occurrence of Ravens at nesting cliffs threaten reproduction in a cliff-nesting Peregrine population (central pre-Alps, across Italy and Switzerland). Specifically, it was investigated whether the regular presence of climbers and/or occurrence of Ravens at nesting cliffs were associated with a reduced breeding output of Peregrine pairs compared to undisturbed ones. It was hypothesized that the simultaneous occurrence of Ravens and climbing activities at a same cliff may severely increase the risk of breeding failure for Peregrines compared to the occurrence of a single potential threat.

MATERIAL AND METHODS

The study area covers 2100 km² across the pre-Alpine relieves (between 45°44' N - 46°11' N and 08°33' E - 09°30' E) of the provinces of Varese, Como and Lecco (northern Italy) and of the Canton Ticino (southern Switzerland). Elevation ranges between 190 and 2.400 m

a.s.l. The landscape is mostly covered by broadleaved forest, farmland and towns, with Alpine grassland at the highest elevation. The climate is temperate and wet (pre-Alpine wet climate), with abundant precipitation (> 1200 mm per year) and reduced temperature variation. The area hosts several rock faces, which hold a healthy Peregrine population and breeding Ravens (Brambilla, 2003; Brambilla *et al.*, 2003a), and attracts high numbers of rock climbers, from several Italian regions and nearby countries, due to the large availability of precipitous cliffs suitable for sport climbing.

Data were collected in 2002 at known Peregrine breeding sites in the study area (Brambilla, 2003), and locally in 2003; for the analyses, we used 2002 data, which refer to 26 occupied Peregrine territories, with the addition of data from 3 new territories which were detected in 2003; the occupation of these 3 new territories involved in 2 cases different individuals from those which bred in the previous year, while the occupation of a third site may be due to a nest-site shift of an already known breeding pair. Peregrine cliff occupancy was checked in February-March, when courtship and territorial flights are most frequent (Gainzarain *et al.*, 2000; Brambilla, 2003; Brambilla *et al.*, 2003b). Each pair was carefully monitored until the end of June to record the number of fledglings, which varied between 0 and 4 in the study years. The occurrence of Raven pairs at Peregrine cliffs was also recorded by means of a similar protocol. A cliff was defined as an uninterrupted and homogeneous rocky face. A cliff was considered as occupied by a Peregrine pair when a nest was found, or pair members were observed during copulation and nest preparation (Monneret, 2000), and occupied by a Raven pair if a current nest or nesting attempt was recorded on it. A cliff was considered as used for rock climbing if it had been provided with fixed protection, such as permanent anchors, bolts and chains, and if climbers regularly frequented it during the Peregrine breeding season. Overall, breeding Ravens were detected at 13 cliffs, while regular climbing activities occurred at 7 sites (5 of which hosted breeding Ravens too); moreover, on 2 Peregrine cliffs climbing activity was totally or partially banned to allow undisturbed reproduction: these sites were assigned to the undisturbed group. The distance between Peregrine nests and Raven nests or climbing

ways on a same cliff varied between a few and c. 300 m. Cliffs hosting only Ravens ($n = 8$) and those hosting only climbers ($n = 2$) were pooled into a single category, because of the small sample size of the latter group. Therefore, breeding parameters of Peregrine pairs were compared according to 3 cliff categories: controls (sites hosting Peregrine pairs only, $n = 14$), sites hosting Ravens or climbing activities ($n = 10$) and sites hosting both Ravens and climbers ($n = 5$). The following parameters were considered as estimates of breeding output: breeding success (percentage of successful pairs), productivity (mean number of fledglings per territorial pair) and fledging rate (mean number of fledglings per successful pair). Breeding success was a dichotomous variable (0: failure, no young fledged; 1: success, at least one young fledged). Data are presented as means \pm SE, unless stated otherwise.

RESULTS

Overall breeding success was 51.7% ($n = 29$), productivity was 1.24 ± 0.26 ($n = 29$) and

fledging success 2.40 ± 0.25 ($n = 15$). Breeding success showed a marked variation between the three groups of cliffs: it was highest for pairs breeding at control cliffs (78.6%, $n = 14$), intermediate at sites hosting Ravens or climbing activities (40.0%, $n = 10$), and lowest at sites hosting both Ravens and climbers, where none of the 5 pairs fledged young (likelihood-ratio $\chi^2 = 12.16$, $df = 2$, $P = 0.002$). One out of the 2 pairs occupying cliffs frequented by climbers but not occupied by Ravens was successful. A similar pattern was recorded for productivity (Kruskal-Wallis test, $\chi^2 = 9.58$, $df = 2$, $P = 0.008$; Fig. 1). However, the number of fledglings per successful pair did not differ between pairs settled at control cliffs and those settled at sites hosting Ravens or climbing activities (Mann-Whitney U -test, $z = -0.95$, $P = 0.341$). Results remained qualitatively unchanged whether or not the 3 pairs recorded in 2003 were excluded from the analyses (details not shown).

Variation in breeding output could also arise because of differing territory features between cliff groups: therefore, cliff categories were compared with respect to several variables which possibly influenced habitat quality and

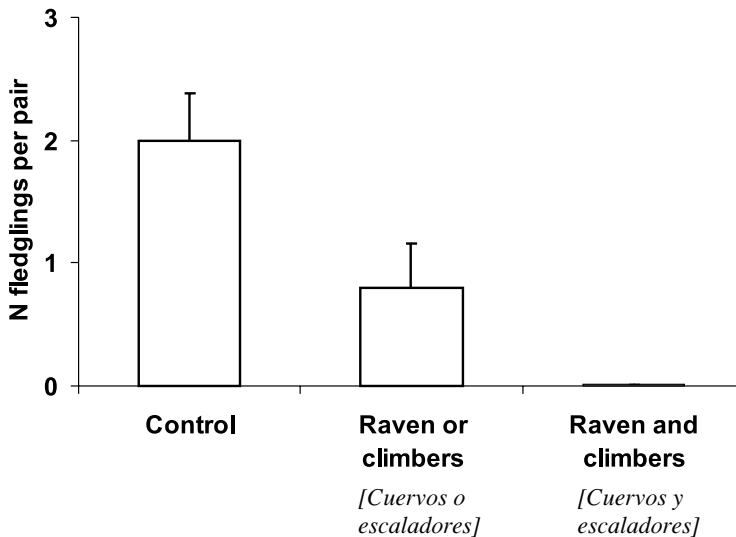


FIG. 1.- Number of fledglings per territorial pair (mean \pm SE) according to different breeding conditions: control cliffs (sites hosting only undisturbed Peregrine pairs, $n = 14$), sites hosting Ravens or climbing activities ($n = 10$) and sites hosting both Ravens and climbers ($n = 5$).

[Número de pollos volados por parejas (media \pm ES) acuerdo a las diferentes condiciones reproductoras: cortados controles (lugares con sólo parejas de Halcones Peregrinos sin molestias, $n = 14$), sitios con Cuervos o escaladores ($n = 10$) y sitios con Cuervos y escaladores ($n = 5$).]

breeding success. A previous study of this Peregrine population revealed that cliff inclination (value of depth/height ratio measured at the barycentre of the cliff), cliff length (linear development of the cliff) and urbanised land in the surrounding landscape (extension of villages and towns in a radius of 1.167 m around the cliff; this radius represents half of the nearest-neighbour distance between Peregrine cliffs, and the variable was $\sqrt{\text{arcsin}}$ transformed before analyses) were the main cliff attributes discriminating between occupied and unoccupied sites, which may therefore affect habitat suitability for Peregrines (Brambilla, 2003; *unpubl. data*). Cliff inclination and cliff length did not differ between cliff groups (Kruskal-Wallis test, both $P > 0.3$), while a significant difference ($P = 0.03$) was detected for urbanised land, which showed lower values for cliffs hosting both Ravens and climbers compared to the other cliff groups (Table 1); this is probably because climbing cliffs are mainly located in precipitous and crag-rich areas, where towns and villages are scarce. In any case, the degree of urbanization *per se* does not seem to influence the breeding parameters of the species in the study area, even if it may influence cliff occupancy (Brambilla, 2003; *unpubl. data*); in fact, animals can make a disproportional use of some resources with respect to their availability even if they do not assure any apparent fitness benefit (Van Horne, 1983).

DISCUSSION

In this study a first quantitative assessment is given of the consequences of both Raven occurrence and climbers disturbance at breeding cliffs on Peregrine breeding success, highlighting that the simultaneous occurrence of both of these threats may severely depress breeding output: despite of the relatively small sample size, a lower percentage of successful pairs and a lower number of fledglings per pair were detected among Peregrine pairs coexisting with Ravens or climbers compared to control (undisturbed) cliffs, while pairs breeding at cliffs occupied by Ravens and simultaneously frequented by human climbers did not fledge any young in 5 cases out of 5. Our findings largely agree with previously reported anecdotal information: both rock climbing and Raven occurrence had been considered among possible causes of breeding failure in the Peregrine (Mearns & Newton, 1988; Juillard, 1992; Monneret, 2000). It is not known whether the effect of Ravens or of climbers or of both together produced the breeding failure in the group of 5 cliffs hosting both Ravens and climbers. It may be possible that climbing disturbance almost invariably produces failure and that the difference between climbers alone (one out of two cases) and climbers alongside Ravens (5 out of 5 cases) is due to chance. However, it is reasonable to argue that Raven predation on Pere-

TABLE 1

Mean (\pm SD) for habitat variables involved in cliff selection process by Peregrines in the study area, according to different breeding conditions. Differences were not significant except for urbanized land ($P = 0.03$, Kruskal-Wallis test).

[Media (\pm DT) para las variables del hábitat envueltas en el proceso de selección del lugar de nidificación por los Halcones Peregrinos en el área de estudio, de acuerdo a las diferentes condiciones. Las diferencias no fueron significativas excepto para la superficie de suelo urbano ($P = 0,03$, prueba de Kruskal-Wallis)].

Variable	Control (n = 14)	Raven or climbers [Cuervos o escaladores] (n = 10)	Raven and climbers [Cuervos y escaladores] (n = 5)
Inclination ^a [Inclinación ^a]	0.40 \pm 0.17	0.49 \pm 0.25	0.68 \pm 0.36
Cliff length (m) [Longitud del cortado (m)]	749.13 \pm 689.32	1118.78 \pm 862.16	651.08 \pm 388.47
Urbanised land (%) ^b [Suelo urbano (%) ^b]	15.42 \pm 10.41	10.71 \pm 12.53	1.50 \pm 1.37

^a Value of the depth/height ratio measured at the barycentre of the cliff.

^b Test performed on square-root arcsine transformed variable.

grine nests is predisposed by climber disturbance. The failure of Peregrines at sites frequented by climbers and hosting breeding Ravens can be explained by the higher tolerance of human disturbance showed by Ravens compared to Peregrines (Monneret, 2000). Thus, in the presence of human disturbance, Peregrines may leave the site before Ravens, which then have the opportunity to take eggs or small chicks from the falcon nest without facing aggressive (and potentially lethal, see Ratcliffe, 1993) defensive reactions by parents (Monneret, 2000).

On the other hand, the number of fledglings per successful pair did not differ between control cliffs and disturbed ones: it is likely that Raven presence and climbers presence cause the loss of all the eggs or chicks in the nest but do not influence the number of chicks fledged, consistently with previous observations reporting Raven predation over the entire brood (Julliard, 1992; Monneret, 2000) and climbers' influence on breeding success (Mearns & Newton, 1988). This effect may be mediated by interindividual variation in parental quality (Sergio & Bogliani, 2001).

Nest predation by Ravens has been reported as a threat at the egg or chick stage for a large number of avian species (e.g. Gaston & Elliot, 1996; Alvo & Blancher, 2001). In cliff and mountain habitats, corvids are the most important nest predators (Cramp, 1998); moreover, human activities may increase their abundance, thus exacerbating the problem (Watson & Moss, 2004). In the Egyptian vulture *Neophron percnopterus*, human activities in the proximity of nest sites caused adults to leave the nest unattended, and thus eggs or chicks prone to predation by Ravens (Liberatori & Penteriani, 2001). Therefore, nest-sites of other cliff-nesting raptors should be adequately protected from human disturbance, limiting recreational activities near the nest, in particular when Ravens or other nest predators occur at the same site. In southern Europe, special attention should be given to Lanner *Falco biarmicus feldgii* nest sites, an endangered (sub)species (Tucker & Heath, 1994), which share similar nest-site requirements with Peregrines (Forsman, 1999), and may be likely vulnerable to the presence of both climbers and corvids.

Finally, future long-term studies may also reveal lower occupancy rates at sites hosting

Ravens or climbers, and even lower ones at sites hosting both, compared to undisturbed cliffs, which would support these results (Sergio & Newton, 2003). In any case, this study further suggests that climbing activities should be partially or totally banned at cliffs hosting Peregrines or other endangered raptors. At Peregrine cliffs, the period when climbing should be prohibited ranges between the end of January and the end of July (for the pre-Alpine region). At largest cliffs, such as huge rocky complexes or extensive rock faces, a partial climbing prohibition may be sufficient, at least for Peregrines. However, a total climbing ban should be imposed at such cliffs at the beginning of the breeding season (until egg laying), to enable an unconstrained choice of nest-site by Peregrine pairs. Moreover, a partial climbing ban involving the portion of a cliff close to a Peregrine nest (as sometimes done by local authorities in the study area) could not be sufficient to allow a safe reproduction if the site hosts also a Raven territory. In such instances, the protected cliff portion should span at least 200 m from each side of the nest. Clearly, in the case of smaller cliffs hosting a Raven territory, climbing activity should be banned on the whole rocky face.

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