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REVIEW

A systematic review of the effects of recreational activities on nesting birds of prey

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Abstract

Human disturbance to wildlife is a growing topic of concern owing to increasing human access to the countryside. Here we use systematic review methodology to specifically synthesize available information on the impact of recreational activities on raptor breeding parameters. Presently there is insufficient information to quantitatively meta-analyze this topic. The most frequent effect turned out to be decreased time for nest attendance but information on effects on breeding parameters was inconclusive. The only outcome susceptible to quantitative meta-analysis was the influence on nest location of a number of anthropic structures. Out of these we chose distance to the closest paved road, because it was the metric recorded in the largest number of studies, and because it can be taken as a surrogate of recreational access to the countryside. We detected an overall statistically significant impact on the displacement of nests from roads from a total of 25 studies, compared to random points in unoccupied areas suitable for breeding. The magnitude of the displacement was probably a biologically relevant magnitude (back-transformed ln response ratio 1.28; 1.07–1.57 bootstrap 95% CI). Importantly, statistical modelling of effect sizes as a function of raptor body size and nesting site substrate (tree nesting vs. cliff nesting) identified an effect of both nesting habitat and body size on nest placement by raptors in relation to roads. Big raptors nesting in trees exhibited greater displacement distances from nests to roads than big raptors nesting in cliffs, and hence we suggest that conservation efforts should take special attention to this vulnerable raptor group which includes some threaten species.

Zusammenfassung

Die Störung durch Menschen ist ein Grund für zunehmende Besorgnis, da Menschen in steigendem Maße Zugang zur Landschaft haben. An dieser Stelle nutzen wir eine systematische Review-Methode um ganz spezifisch die verfügbare Information darüber zusammenzutragen, wie groß der Einfluss von Erholungsaktivitäten auf die Brutparameter von Greifvögeln ist. Zur Zeit gibt es keine ausreichenden Informationen, um diesen Punkt quantitativ einer Metaanalyse zu unterziehen. Als häufigste Auswirkung stellte sich eine geringere Zeit der Anwesenheit am Nest heraus, aber die Information über die Auswirkung auf die Brutparameter war nicht schlüssig. Das einzige Ergebnis, das

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sich für eine quantitative Metaanalyse als geeignet herausstellte, war der Einfluss einer Anzahl von anthropogenen Strukturen auf den Neststandort. Aus diesen wählten wir den Abstand zur nächsten befestigten Straße, weil es eine Maßangabe war, die bei der größten Anzahl der Untersuchungen festgehalten wurde, und weil es als ein Ersatzmaß für den Zugang zur Landschaft in der Freizeit gesehen werden kann. Wir stellten bei insgesamt 25 Untersuchungen einen statistisch signifikanten Einfluss des Abstandes des Nests von einer Straße fest, wenn wir einen Vergleich mit Zufallspunkten in nichtbesetzten, für die Brut geeigneten Arealen, durchführten. Die Größenordnung des Abstandes war möglicherweise eine biologisch relevante Größe (rücktransformierte ln Reaktionsrate 1.28; 1.07–1.57 Bootstrap-Methode 95% Konfidenzintervall). Besonders wichtig war, dass das statistische Modellieren der Wirkgrößen als Funktionen von Körpergröße und Nistsubstrat (Baumnest vs. Felsnest) einen Effekt sowohl des Nisthabitats als auch der Körpergröße auf den Abstand des Neststandortes zu Straßen feststellte. Große Greifvögel, die in Bäumen nisten, halten einen größeren Abstand zu Straßen als große Greifvögel, die in Felsen nisten, und deshalb schlagen wir vor, dass Schutzmaßnahmen dieser empfindlichen Greifvogelgruppe, die einige bedrohte Arten enthält, besondere Aufmerksamkeit schenken sollten.

Keywords: Recreational activities; Roads; Birds of prey; Systematic review; Meta-analysis; Disturbance; Nesting

Contents

Introduction

The impact of recreational activities (i.e. any non-profit human activity performed outdoors such as hiking, climbing, camping, photography or biking, among others) on wildlife is a growing topic of conservation concern. Extensive work on this matter has been carried out for a number of bird groups such as seabirds (Beale & Monaghan, 2004; Burger & Gochfeld, 1993, 1999; Fowler, 1999; Hunt, 1972; McClung, Seddon, Massaro, & Setiawan, 2004; Yorio, Frere, Gandini, & Schiavini, 2001), waterbirds (Blanco, Yorio, & Bertellotti, 1999; Bolduc & Guillemette, 2003; Carney & Sydeman, 2000; Ikuta & Blumstein, 2003; Safina & Burger, 1983; Tremblay & Ellison, 1979) and forest birds (Fernández-Juridic, 2000). Globally they conclude that human disturbance can affect different aspects of the avian reproductive cycle, such as incubation time, feeding time, time at nest, foraging success or reproductive success, but also that human presence can be compatible with bird observation if properly managed.

Specifically, the risk of impact of recreational human activities to wild-ranging breeding birds of prey is a topic commonly addressed in environmental impact assessments (Martínez et al., 2003; Pomerantz, Decker, Goff, & Purdy, 1988), owing to the dramatic worldwide increase of human access to the countryside during recent decades (Turner, Pearson, Bolstad, & Wear, 2003). However, often environmental impact studies provide poor evidence of impact, or poor evidence of absence of impact, of these activities on breeding parameters of individual raptor pairs, and especially on the population and meta-population consequences of human activities (Martínez et al., 2003; Suárez et al., 2003). Faced with this uncertainty, managers typically make decisions based on their own experience overlooking the alternative procedure of systematically reviewing the information available to make proper decisions based on scientific evidence (Pullin & Knight, 2001; 2003; Pullin, Knight, Stone, & Charman, 2004; Sutherland, Pullin, Dolman, & Knight, 2004).

Here we explore the literature dealing with human recreational effects on nesting-site occupancy and breeding performance of diurnal and nocturnal raptor species. To the best of our knowledge Sidaway (1990) and Woodfield and Langston (2004) did traditional (non-systematic) reviews on the disturbance caused to birds by human access on foot. However, these studies dealt mainly with the effect of human presence on birds other than raptors. Boyle and Samson (1985) and Knight and Skagen (1987) performed non-quantitative reviews on the effect of recreational disturbance on birds of prey. They concluded that recreational disturbance can alter normal activity patterns of raptors by altering their distribution, disrupting nest attentiveness, causing abandonment of breeding territories, reducing productivity and affecting foraging behaviour, and also highlighted the need for empirical information on the influence of outdoor recreation on raptors. The aim of this work is to systematically review the literature, using a highly standardized technique (Pullin & Stewart, 2006) that maximises repeatability and transparency, to meta-analyze the available information and achieve a quantitative research synthesis of the topic.

Material and methods

The specific study question: What are the impacts of human recreational activity on the distribution, nest-occupancy rates and reproductive success of breeding raptors? was formulated through discussion between the environmental authorities of the regional government of Comunidad Valenciana (i.e. Generalitat Valenciana, Eastern Spain), and the population ecology researchers at the Mediterranean Institute for Advanced Studies, based on Majorca Island (Spain). Articles dealing with the question were identified through computerised searches, with no time constraints (see Appendix A: Table 1 for details of the search). In addition to the electronic searches, the library of the Royal Society for the Protection of Birds (RSPB) was hand searched. Bibliographies of articles accepted for full text viewing and relevant review articles were searched too. We also contacted some experts and practitioners in the field of raptor study to identify possible sources of data and also to request unpublished data or information missing in published articles. The title and abstract of all articles in the final library were read, and studies with the following inclusion criteria: (a) Subject: all world breeding diurnal and nocturnal birds of prey, (b) Intervention: any kind of human recreational activities performed close to the nests of breeding raptors and during the breeding period, and (c) outcomes: change in breeding success or nest-site fidelity after intervention compared to the situation before (before/after information) and/or change in breeding success or nest-site fidelity in areas affected by intervention compared to control areas (control/impact information) (i.e. BACI experiments, see e.g. Block, Franklin, Ward, Ganey, & White, 2001). A subset of 300 articles was assessed for relevance by a second independent reviewer. Agreement on inclusion between the reviewers was deemed to be substantial (Cohen's Kappa test: $K = 0.664$). However, it became evident during the process of critical appraisal that the only outcomes addressed in a consistent and comparable way among studies were the displacement distances of nests in relation to a number of anthropic structures such as human settlements, recreation areas, or paved and unpaved roads. Out of these we selected distance to the nearest paved road, because it was the metric recorded in the largest number of studies and can be taken as a proxy of human access to the countryside. Hence, we completed our initial search with a second one including a habitat selection component using the terms: "Habitat selection" and raptor* and "Habitat preference" and raptor*, and "Habitat selection" and "bird of prey" using Web of Science. Studies finally selected were subjected to a process of quality assessment. Accordingly we built two main groups of studies for data extraction: (a) those providing quantitative data on effects of human disturbance on reproduction that were not suitable for meta-analysis owing to high heterogeneity of outcomes recorded, and (b) those containing quantitative data suitable for meta-analysis owing to consistent measures of the same outcome among studies. Quality of data regarding effects on breeding parameters was assessed by taking into account quality of design (especially regarding sample size), levels of dispersion of data and uncertainty in parameter estimation, as well as magnitude of the effects observed. Quality of data suitable for meta-analysis was appraised by assessing consistency in the way in which the outcome was measured, independence of data points, and availability of means, standard deviations and sample size both for control and "treatment" areas. Supplementary information on the papers both discarded and finally analyzed are available at http://www.environmentalevidence.org/Documents/SR27.pdf.

Data synthesis was performed by combining means, standard deviations and sample sizes for treatment and control, considering 25 studies with suitable data, using random effects meta-analysis (which assumes that all variations among studies is random variation), by means of softwares Metawin 2.1 (Rosenberg, Adams, & Gurevitch, 2007) and Stata 10 (StataCorp 2007). Two metrics of effect size were considered: a standardized difference between control and treatment means

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(Hedge's *d*) and a relative metric (ln response ratio). In order to explain heterogeneity in the individual effect sizes obtained by meta-analysis we built nested models which accounted for different alternative ecological hypotheses. Modelling was performed by means of generalized linear mixed models, with Gaussian error structure and the identity link, using both effect size metrics as response variables and study as a random effect (by means of software R http://www.r-project.org/, library lme4 and lmer function; R Development Core Team, 2009). We hypothesized that effect size could be influenced either by raptor size (henceforth "Size" as a continuous variable) or nesting substrate (hereon "Site" as a categorical variable: tree nesting vs. cliff nesting), or a combination of both, and built several mathematical models to test multiple specific ecological hypotheses simultaneously. Models were compared and selected by means of information theoretic criteria, including AIC for model ordination and Akaike weights (w_i) as a tool to judge about the relative strength of evidence of each model. Since the number of parameters (K) to be estimated was large relative to sample size (n) we used the small-sample version of AIC (AICc), to prevent any bias owing to small sample size. Models selected were those minimising the loss of theoretical (Kullback–Leibler) information, that is the ones representing the best compromise between model fit to data (explained deviance) and complexity of the model (number of estimated parameters) (Burnham & Anderson, 2002).

Results

Literature searching

An initial library of 3887 articles was compiled after our systematic literature search, but only 18 fulfilled inclusion criteria. Inclusion of 39 studies dealing specifically with nest displacement in relation to roads (coming from our second specific search) increased our final pool of articles to 57. From these, the final number of data points suitable for meta-analysis was 24 (see Appendix A: Table 2 for a complete list of references).

Vote counting

Only 24 studies dealt with the effect of recreational activities on breeding parameters. A classical vote-counting procedure (Mullen, 1989) of these studies indicated that seven studies found negative effects of variable magnitude on breeding raptors, whereas five studies did not show any substantial effect on reproduction. A small number of papers ($n = 2$) found changes in distribution (increased or decreased homeranges when faced with recreational activities). The most common impact reflected in the studies was decreased nest attendance ($n = 10$). The raptor species for which most information is available so far on effects of recreational activities is the Bald Eagle (31%), out of the 24 different species for which information was found. Specific information on impact of recreational activities on raptor breeding parameters was available for 11 species, although Peregrine Falcon, together with Bald Eagle, comprised 42% of the studies (see summary of the content of the papers in Appendix A: Table 3). Although the search had no geographical constraints 66.6% of the papers dealing with human influence on breeding parameters were North American studies, whereas the remaining 33.3% were European cases.

Meta-analysis

Random effects meta-analysis of 25 independent datasets, dealing with 13 different raptor species, showed that in 10 datasets the effect of road presence in relation to nest location was clearly "negative" for seven different raptor species (positive values of the effect size metric reflecting displacement of nests in relation to roads in Fig. 1), in two datasets it was clearly "positive" for two raptor species, and in 12 more datasets it was not possible to conclude anything because the 95% confidence interval of the effect size included the value 0 as

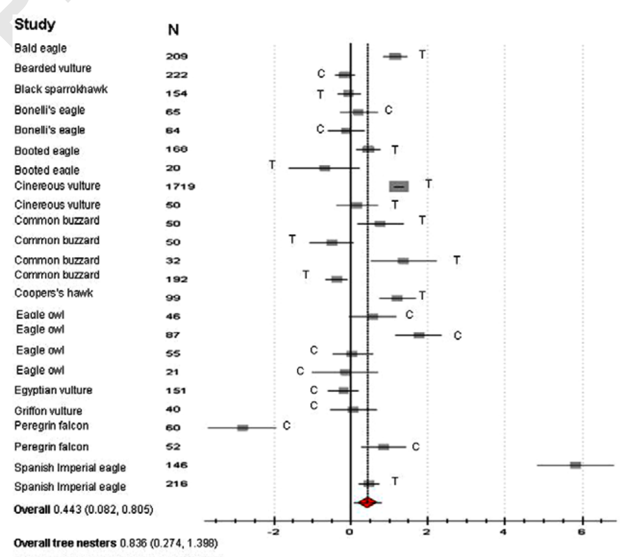

Fig. 1. Forest plot showing the effect of distance from roads on nest location. Positive effect size values mean that raptors placed their nests farther from roads than expected by chance. Size of solid boxes represent the sample size of individual studies; error bars are 95% confidence intervals; the solid black diamond is the pooled effect size (Hedge's *d*) generated using standardized mean difference random effects meta-analysis. The diamond width indicates the pooled 95% confidence interval. T = breeding on trees; C = breeding on cliffs. Q1

one of the possible values of the parameter. Hence, the meta-analysis identified an overall positive and statistically significant impact of roads on nest location of a magnitude which could be biologically relevant (ln response ratio 0.25; 95% bootstrap CI 0.067–0.451); Back-transformed response ratio 1.28; 95% CI 1.07–1.57; Hedges' *d* 0.44; 95% CI 0.082–0.805) (Fig. 1). Species negatively affected by roads included Cooper's Hawk, Spanish Imperial eagle, Cinereous Vulture, Booted Eagle, Eagle owl, Common Buzzard, Bald Eagle and Peregrine Falcon, some of them endangered species. Species which showed a tendency to be attracted by road presence included Peregrine Falcon, Booted Eagle and Common Buzzard. Interestingly some species, such as Booted Eagle and Common Buzzard, were present in both categories (see Table 2 for scientific names of raptors mentioned in the text).

Modelling heterogeneity

As suggested by previous exploratory analyses of our data, which pointed towards big size raptors nesting on trees as the group affected to a largest extent, modelling indicated that both nesting habitat (site) and body size (size) had an influence on the response variable. When using the ln response ratio as the dependent variable, nesting habitat (tree vs. cliff) was shown to be more influential on the effect size metric than body size; however, when using Hedges' *d* as response variable the influence of both body size and nesting substrate was similar (Table 1). Cliff-nesting raptors showed a low magnitude positive and statistically non-significant overall effect size, whereas tree-nesting raptors showed an overall positive effect of much higher magnitude which was statistically significant.

Publication bias

Meta-analysis relies on the assumption that the literature search performed is unbiased. Hence, it is important to provide evidence of lack of publication bias. In our study there was some overrepresentation of effect sizes at low and high quantiles suggesting some publication bias (Fig. 2). This was probably due to the difficulty of accessing grey literature on this topic. Also our search, although intended to be worldwide, was skewed towards papers from Europe and North-America, probably because it is in these geographical areas where most research is published on this topic. A further factor introducing further bias is the use of English search terms. However, 21% of the studies dealing specifically with effects on reproductive parameters (Appendix A: Table 3) and 56% of studies with data suitable for quantitative meta-analysis were written by Spanish authors, which has been interpreted by us as a real and rapid change within the Spanish society from active persecution to active conservation of this bird group (Martínez-Abraín & Crespo et al. 2008).

Table 1. Models corresponding to different ecological hypotheses regarding the influence of body size (size) and nesting substrate (site: tree-nesting vs. Cliff-nesting) on raptor nest location in relation to paved roads compared to random points (ESM = effect size metric used as response variable). Corrected Akaike's information criterion (AICc), *K* = no. of estimable parameters, w_i = Akaike weight. '+' symbol indicates an additive relationship between variables (same slopes and different intercepts); symbol '*' indicates an interaction (different slopes but similar intercepts).

ESM	Hypotheses	AICc	ΔAICc	*K*	w_i
ln Response ratio	Site*size	29.36	4.27	6	0.06
ln Response ratio	Site+size	27.79	2.7	5	0.14
ln Response ratio	Site	25.09	0	4	0.55
ln Response ratio	Size	26.67	1.58	4	0.25
Hedge's *d*	Site*size	67.27	6.26	6	0.02
Hedge's *d*	Site+size	64.17	3.16	5	0.10
Hedge's *d*	Site	61.01	0	4	0.46
Hedge's *d*	Size	61.20	0.19	4	0.42

Table 2. Common and scientific names of the raptor species cited in the text.

Common name	Scientific name
Cooper's Hawk	*Accipiter cooperii*
Spanish Imperial eagle	*Aquila adalberti*
Peregrine Falcon	*Falco peregrinus*
Bearded Vulture	*Gypaetus barbatus*
Cinereous Vulture	*Aegypius monachus*
Booted Eagle	*Hieraaetus pennatus*
Eagle owl	*Bubo bubo*
Bonelli's Eagle	*Hieraaetus fasciatus*
Griffon Vulture	*Gyps fulvus*
Common Buzzard	*Buteo buteo*
Black Sparrowhawk	*Accipiter melanoleucus*
Bald Eagle	*Haliaetus leucocephalus*
Egyptian Vulture	*Neophron percnopterus*
Golden Eagle	*Aquila chrysaetos*
Osprey	*Pandion haliaetus*

Discussion

A knowledge gap

We identified a knowledge gap regarding the effect of human recreational activities on breeding parameters of birds of prey, since only a small number of articles was retained from our literature searches and was not suitable for quantitative meta-analyses. Traditional vote counting indicated that evidence for influence on breeding parameters by recreational activities is

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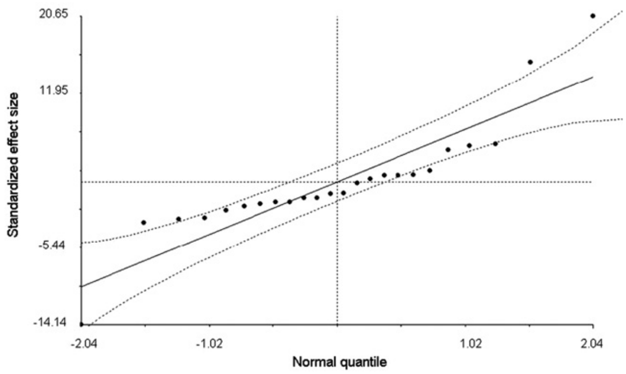

Fig. 2. Distribution of the standardized effect sizes (ln R) along quantiles of a normal distribution (dotted lines are 95% CIs) showing some publication bias in our meta-analysis. See text for discussion of the possible causes.

inconclusive (roughly the same number of articles found or failed to find effects), with decreased time for nest attendance being the most common outcome of human disturbance. Hence, currently there is little scientific base for decision making available to wildlife managers owing to the scarcity and heterogeneity of published information available for quantitative meta-analysis. Knowledge gaps in relation to bird tolerance to human disturbance have already been highlighted recently (Whitfield, Ruddock, & Bullman, 2008). The scarcity of BACI experiments in relation to the study topic is understandable because it would be irresponsible in most cases to perform experiments with raptor species which are typically rare, and hence information can only be obtained comparing simultaneously different nests with different regimes of human impact on them or taking advantage of unintentional ("natural") experiments affecting nests from which previous information was available. As a management implication, the long-term monitoring of a large sample of nests would be necessary to allow the collection of unequivocal information on this topic. Our systematic review indicated a bias towards European and North American species implying that even less is known about the effect of recreational activities on tropical raptors. Considering the growth in ecotourism in some tropical countries, rigorous experimental studies are needed not only for temperate latitudes but also for the tropics.

Impact of roads on nest location

Evidence regarding our second objective, the impact of roads on nest location, was more conclusive, although the relatively small sample size calls for some caution regarding generalizations of our results. There seems to be a negative effect of roads on a number of raptor species. Big raptors nesting in trees, placed their nests farther away from roads than big raptors nesting

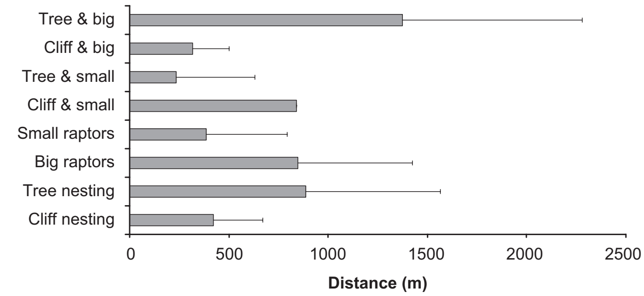

Fig. 3. Difference (in meters) between treatment (nests) and control (suitable random points for breeding in unoccupied areas) by subgroup for species negatively affected by roads. Only the upper part of the 95% CI is shown for the sake of simplicity.

in cliffs (Fig. 3), suggesting a higher vulnerability to human presence, probably because trees can be accessed more easily than cliffs, and also because big size raptors can be spotted from the distance with greater ease on trees than on cliffs. This is consistent with previous works in which all flight distance components have been shown to increase linearly with body size in forest birds (Fernández-Juridic et al. 2004). Also tree-nesting raptors, such as the Cinereous Vulture, have already been highlighted in the past as species sensitive to human disturbance (Poirazidis, Goutner, Tsachalidis, & Kati, 2007). As a corollary, this finding may imply that areas holding big raptor species nesting in trees, despite their most common nesting site (i.e. cliffs) not being scarce, are probably little impacted by human disturbance. On the contrary, areas holding big raptors typically nesting in trees, but found locally nesting in cliffs, could indicate higher human disturbance, provided that the availability of appropriate trees is high (Anthony & Isaacs, 1989; Rosenvalda & Löhmus, 2003). Cases of medium to large raptors breeding facultatively on trees or cliffs include at least Golden eagle, Bonelli's eagle, Booted Eagle and Osprey (unpublished data).

The fact that two species were found to be influenced both positively and negatively by road presence suggests that distance to roads is a population-specific trait, rather than a species-specific trait. This fact could be related to local differences in habituation to humans owing to higher or lower levels of exposure to human presence (Bautista et al., 2004; Ferrer, Negro, Casado, Muriel, & Madero, 2007; Martínez-Abraín & Oro et al., 2008), reflecting regional historical differences between areas, such as differential human densities or traffic intensities. Many cases of different populations of the same species breeding on cliffs or trees are known (see e.g. Garza & Arroyo, 1996). Further research is needed on individual flexibility to shift from trees to cliffs during an individual's life time, in relation to changing levels of human disturbance, to tease apart selection processes and phenotypic plasticity.

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The overall effect represents a 20–30% increase in distance from nests to roads compared to control random points taken in unoccupied suitable areas. The absolute magnitude of the displacement distance of raptor nests in relation to roads ranged between 200 and 800 m, but it was as high as 1400 m for tree nesting raptors of big size, such as large eagles and vultures, many of which are rare species (e.g. Spanish Imperial eagles, Cinereous Vulture). We think this magnitude of nest displacement could be a biologically relevant disturbance. Although most available information deals with behavioural responses of birds when faced with disturbance (Boyle & Samson, 1985; Richardson & Miller, 1997; Steidl & Powell, 2006), these might not reflect fitness or population effects. The fact that an individual reacts by flying away or moving farther from the point of disturbance to breed might only reflect that there is abundant suitable habitat available to do so (Gill, Norris, & Sutherland, 2001). However, in countries where forested areas are very fragmented the fact that tree-nesting raptors tend to nest far from roads can be a serious handicap for reproduction, since availability of alternative sites may be lower.

Final remarks

Although raptors are typically long-lived species and hence their population growth rate is most sensitive to adult mortality, rather than fecundity, it is important, especially in the case of rare species with small populations and hence more susceptible to demographic stochasticity, to guarantee a successful reproduction annually in order to have viable populations (see e.g. Igual, Tavecchia, Jenouvrier, Forero, & Oro, 2009).

Specific research applied to the consequences of human disturbance on reproductive success or the consequences of changing territories due to human pressure on raptors with small populations is highly needed; specially in order to properly manage human activities in a world in which direct persecution of raptors is increasingly uncommon but the indirect and unwanted consequences of infrastructure development are increasingly common (Martínez-Abraín, Crespo, Jiménez, Gómez, & Oro, 2009).

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.baae.2009.12.011.

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