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Effective conservation measures to mitigate the impact of human disturbances on the endangered Egyptian vulture

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Abstract

A consistent body of literature suggests that migratory species, ecological specialists and/or populations living on the borders of their distribution ranges are expected to be among the most seriously affected by alterations in environmental conditions. In this framework, we tested the combined effects of human disturbance and weather conditions on the breeding performance of a long-lived endangered scavenger, the Egyptian vulture, in a study area (Biscay, northern Spain) located close to the edge of its worldwide range. Furthermore, we tested the effect of specific management strategies aimed at preventing the impact of human disturbance on the species' breeding output. Our results showed that the breeding success was negatively correlated with weather conditions, mainly rainfall and number of rainy days in June, that is the rearing period of small nestlings. Importantly, human disturbance was the main factor affecting Egyptian vultures' productivity. In fact, during the study period (2000–2012), we detected cases of high-level disturbance in 59 nests (30.9%) within 17 of the 22 monitored territories, which only produced three fledglings overall. In 2010, we started the application of management actions for preventing human disturbance, first in a few control territories and later, in 2011 and 2012, across the whole study area. The measures were found to be successful, as the breeding success increased to levels similar to those previously detected in non-disturbed nests. Our results showed that management strategies aimed at preventing human disturbance are of paramount importance in order to assure the conservation of this endangered species.

Introduction

Human activities are among the most important factors affecting biodiversity (Erb, McShea & Guralnick, 2012). Several studies link human density to declining wildlife populations (Woodroffe, 2000; Parks & Harcourt, 2002). Therefore, the Network of Protected Areas will be obligated to ensure minimum natural values (i.e. biodiversity, richness and preservation of natural resources) while facing more frequent human use–wildlife conflicts. In fact, tourism is one of the largest and fastest-growing industries in the world, and there is concern about the impacts of this growing activity on the environment and biodiversity (Kaisanlahti-Jokimäki *et al.*, 2008), abundance of key indicator species (Patthey *et al.*, 2008), or habitat use (Cardoni, Favero & Isaac, 2008). The effects of human pressure on increasingly isolated habitats, sometimes even greater than habitat loss, are not usually considered in ecological studies or in the design of Networks of Protected Areas, not adequately measured in environmental impact assessments, and could have a gradual, deleterious effect on certain sensitive species (O'Brien, Kinnaird & Wibisono, 2003; Pangle & Holekamp, 2010).

The conservation measure most often used by managers and conservationists to avoid disturbance is the establishment of spatial and temporal buffer zones around potentially sensitive areas (e.g. breeding sites), where the disturbing activities are limited or prohibited (Finney, Pearce-Higgins & Yalden, 2005; Margalida *et al.*, 2011, but see López-López, García-Ripollés & Urios, 2014). However, although many scientific papers describe the effect of disturbances and recommend measures to mitigate their impact, very few experimental studies have been developed in order to test the efficacy of the proposed measures (i.e. before and after control impact experiments, Martínez-Abraín *et al.*, 2010).

The effects of human disturbances can also be difficult to ascertain when other factors, such as weather, simultaneously affect the breeding performance of birds (Trathan *et al.*, 2008). It is widely accepted that alterations in rainfall patterns, global warming, and changes in the frequency of dramatic meteorological events will affect wildlife distribution and conservation (Mawdsley, O'Malley & Ojiva, 2009). Migratory species, ecological specialists and/or populations living on the borders of their distribution ranges are likely to be the most affected by changes in future environmental conditions (Brommer & Moller, 2010).

The Egyptian vulture *Neophron percnopterus* is a good example of one of these species. It is a cliff-nesting, medium-sized, long-lived scavenger distributed mainly across southern Europe, Africa and the Indian subcontinent. Some populations are sedentary (mainly insular populations and those breeding in the Sahel region, India and Arabian Peninsula), whereas those ranging from western Europe through the Mediterranean, Turkey, the Caucasus and central Asia to northern Iran, Pakistan, northern India and Nepal are migratory (Ferguson-Lees & Christie, 2001; BirdLife International, 2013). The species distribution range overlaps with those regions in which human population is growing faster than average (United Nations, 2013). Worldwide, the species is catalogued as Endangered according to the International Union for Conservation of Nature Red List owing to a recent and extremely rapid population decline in India (Cuthbert *et al.*, 2006), combined with severe long-term declines in Europe (>50% over the last three generations) and West Africa, plus ongoing declines through much of the rest of its African range (Thiollay, 2006; Iñigo *et al.*, 2008; Virani *et al.*, 2011; Angelov, Hashim & Oppel, 2013; Vickery *et al.*, 2014). In Europe, it is estimated that there are 3300–5050 breeding pairs, most of them concentrated in the Iberian Peninsula (36%) and Anatolia (54%; Iñigo *et al.*, 2008). High adult mortality because of both lead and intentional poisonings, collisions with man-made infrastructures such as wind turbines and power lines, electrocution, habitat loss, and food shortages are included among the main threats, which have led to population decline (Iñigo *et al.*, 2008; Carrete *et al.*, 2009; Cortés-Avizanda, Ceballos & Donázar, 2009; Donázar, Margalida & Campión, 2009; Grande *et al.*, 2009; Hernández & Margalida, 2009; Sarà, Grenci & Di Vittorio, 2009; García-Ripollés & López-López, 2011). In addition, human disturbance at breeding sites is a growing threat that can jeopardize population viability in areas with high human density (Zuberogoitia *et al.*, 2008).

The aim of this study was twofold. (1) First, we determined the effect of human disturbance, weather conditions (i.e. rainfall, number of rainy days) and their interaction, on the productivity of the Egyptian vulture. (2) Then, after reporting that human disturbances clearly reduce breeding success (Zuberogoitia *et al.*, 2008), we tested whether management strategies aimed at minimizing disturbances in nesting areas resulted in statistically significant improvements in breeding success.

Methods

Study area

The study area covered the whole administrative area of Biscay (northern Spain; surface = 2384 km^2; coordinates from 43°11′00″ to 43°12′70″N and from 3°12′70″ to 2°13′10″W). Human density is among the highest in Western Europe (531 inhabitants per km^2; Instituto Nacional de Estadistica, 2013). The territory is hilly and is characterized by the presence of extensive urban and industrialized areas. Barely 50 km separate sea level from the highest altitude (1480 m a.s.l.). More than 50% of the area is dedicated to forestry, at the expense of traditional small-scale farming. Most of the wood produced comes from plantations of *Pinus radiata* and *Eucalyptus* spp., while the traditional patchwork of woodland, pasture and small holdings has been greatly reduced (see Zuberogoitia *et al.*, 2011). Weather of the study area is deeply conditioned by a wet and warm Atlantic influence and it is included within the rainiest regions of Europe (World Climate, 2014).

Field monitoring

Considering the whole study area, the number of Egyptian vultures' breeding territories ranged between 18 and 22 during the 2000–2012 period, of which 64% were included in the protected areas of the Natura 2000 Network (Fig. 1). We defined territories as being the exclusive nesting sites plus the surrounding areas and resources defended by territory holders against intruders. All territories were monitored during the breeding period from February to August. Territory occupation and breeding performance were recorded by means of field observation from viewpoints located at least 1 km from the nesting cliff (Zuberogoitia *et al.*, 2008). Following the terminology proposed by Steenhof (1987), a breeding pair was one that laid eggs whereas a successful pair was one that fledged at least one young. The following breeding parameters were used for the analysis: percentage of breeding success (i.e. the annual percentage of nests which fledged at least one chick per nesting pair) and productivity (i.e. the number of young fledged per nesting pair). At least five visits were conducted to determine whether the pairs had begun reproduction (egg laying and incubation), nestlings' development, and breeding failure, and its causes when possible. Moreover, we followed the first flights and monitored the development of the fledglings during the early independence period.

Explanatory variables

We measured nesting site variables for each breeding attempt (Table 1). Some pairs used alternative nests within their breeding territory, while others used only one nest all through the study period. We described the typology of the nests when we climbed down to ring the nestlings and measured the variables included in Table 1 using geographic information system software (gvSIG; gvSIG Association, 2013).

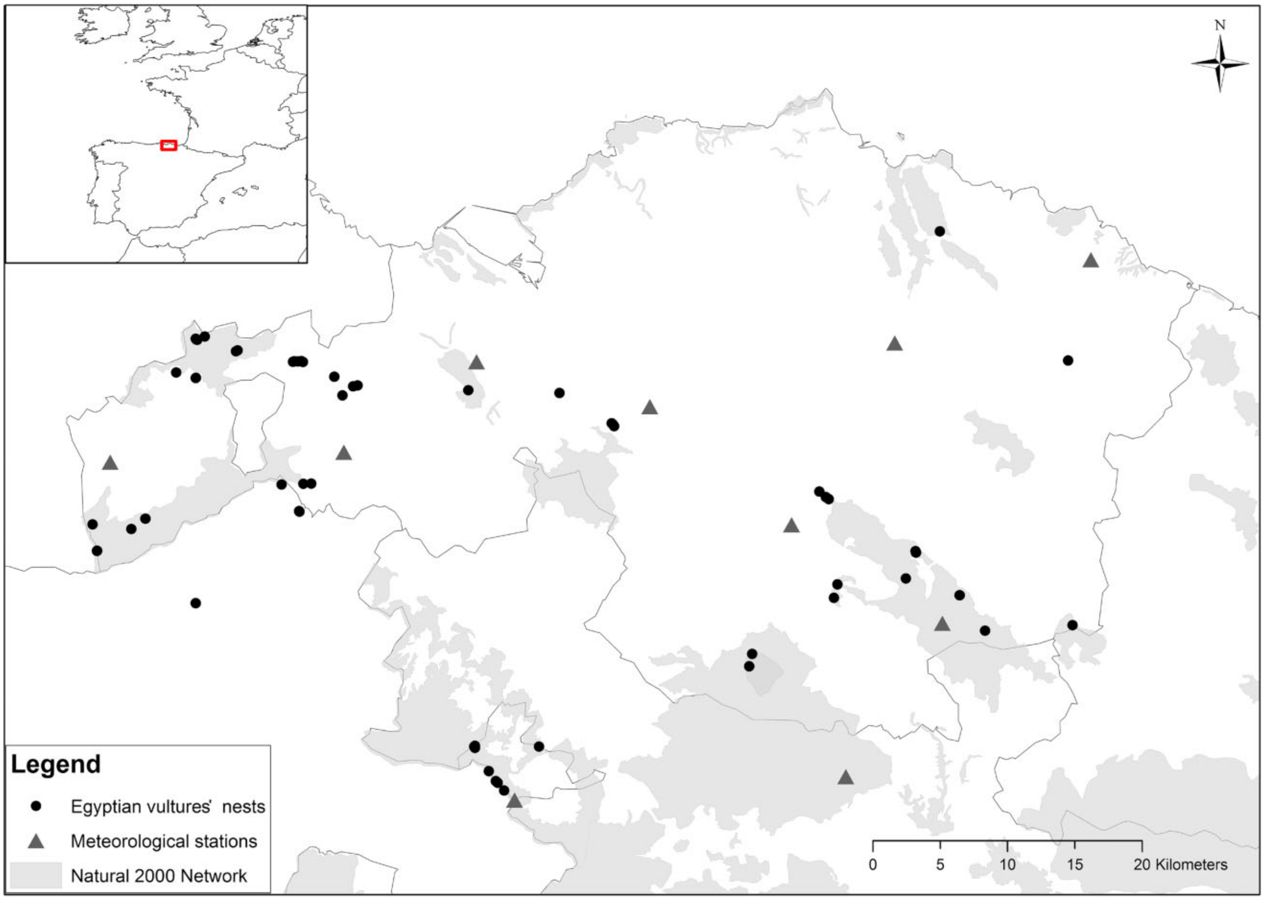

Figure 1 Distribution of Egyptian vulture nests (black dots), meteorological stations (triangles) and protected areas included in the Natura 2000 Network within the study area (Biscay), northern Spain, from 2000 to 2012. The inset map shows the geographic location of the study area in Western Europe.

The influence of weather variables on the Egyptian vultures' breeding performance was calculated for three periods: (1) incubation, spanning April to May; (2) first month of the nestlings, June; (3) second month of the nestlings, July. The first flights occurred at the end of July and the first weeks of August. August was excluded from this particular analysis in order to avoid including variables, which would only include some days of the nestling period. We considered weather variables for the full breeding period (March to August) for the analysis of inter-annual weather variations.

Weather data were gathered from 12 meteorological stations (Euskalmet, agencia Vasca de Meteorología, 2013) spread over the study area. Thereby, we obtained data on precipitation (mm) on a daily basis and the number of rainy days per month. Firstly, we considered precipitation from March to August at the 12 stations during the 2001–2012 period in order to detect differences in the variance between stations and years (there were no data for the first year, 2000). Following this, in order to analyse the effect of weather conditions on the Egyptian vulture's productivity, we tested rainfall variation among areas, months and years. To this end, we selected those stations that were located closest to the nests (nine stations situated on average 5.9 ± 3.0 km from the nests, Fig. 1) and were placed at similar altitude as the nests (Student's t-test for paired samples, considering distances from the nests to the closest station, $t = -1.022$, d.f. $= 47$, $P = 0.312$). Thereby, we reduced possible biases due to differences in rainfall because of the altitude of the station.

Disturbance variables, including type and duration, were measured in the field following Zuberogoitia *et al.* (2008), including those which occurred within a 600-m radius around the annually occupied nests. Human activities observed in the vicinity of the nests that could potentially cause disturbance included forestry activities, opening of new forest tracks and new quarries, cars, motorcycles and tractors passing or parking in the vicinity of the nest, people climbing the nesting cliff or their vicinity, hikers, mountain bikers and birdwatchers, shepherds with their livestock and fire. According to duration and frequency, disturbances were divided into: (1) low-level specific/unusual disturbance (i.e. when disturbances were occasionally detected; for example people developing sport activities or forestry and

Table 1 Variables describing nest-site characteristics, weather conditions and potential sources of disturbance around Egyptian vulture territories

Subset	Variable	Description	Statistical notes
Nest-site variables (NEST)			
	ELE	Elevation: altitude of the nest (m a.s.l.)	Covariate factor
	TYPE	Typology of the nest. Categorical variable with nest on ledge (0); sheltered ledge (1); cavity (2); cave (3)	Fixed factor
	EXP	Compass orientation of the nest. Categorical variable summarized in four categories according to the driest and warmest exposition to the prevailing wet winds: south, south-west (1); south-east, east (2); north-east, north (3); west, north-west (4).	Fixed factor
	HEIG	Height of the nesting cliff (m.)	Covariate factor
	LENG	Length of the nesting cliff (m.)	Covariate factor
Weather variables (WEATHER)			
	RAIN	Rainfall recorded during the incubation period (mm; rainfall in April and May)	Covariate factor
	RANE	Rainfall during the first month of the nestlings (mm; rainfall in June).	Covariate factor
	RAFL	Rainfall during the second month of the nestlings (mm; rainfall in July)	Covariate factor
	DAYIN	Number of rainy days during the incubation period	Covariate factor
	DAYNE	Number of rainy days during the first month of the nestlings	Covariate factor
	DAYFL	Number of rainy days during the second month of the nestlings	Covariate factor
Disturbance factors (DISTURB)			
	DIST	Human disturbance within a radius of 600 m around the nest. Categorical variable which indicates no disturbance events (0); specific low-level disturbance (1); specific high-level disturbance (2); chronic high-level disturbance (3).	Fixed factor
	NEST	Random factor included to control for non-independence of data collected within the same breeding site	Random factor (1–5)
	TER	Random factor included to control for non-independence of data collected within the same territory	Random factor (1–22)

farming works within the radius for periods of several hours); (2) one-off high-level disturbance (i.e. when disturbance duration extended during periods of several hours; e.g. multitudinous races during one whole day, large vehicles or machines working over periods of several hours); (3) chronic and high-level disturbance (i.e. when disturbance causes were detected almost every day or the effect was permanent; e.g. forestry activities, works related to the construction of new infrastructures and actions, which produced direct disturbance during the entire activity period). It is remarkable that high-level disturbances sometimes produce temporal or permanent habitat changes (e.g. opening of new roads, trails and paths close to nests, or clear-cuts, which eliminate protection patches of vegetation around the nests), and consequently, they can potentially generate disturbances of types one and two as well as habitat alterations in the future.

Management measures to mitigate the effect of human disturbances

Once we detected a potential problem with the Egyptian vulture's breeding performance because of human disturbance (Zuberogoitia *et al.*, 2008), we began to work hand in hand with environmental authorities in order to implement conservation measures aimed at reducing the disturbance from 2010 onwards. We firstly developed management strategies for some of the nests deeply affected by chronic disturbances. Simultaneously, environmental authorities promulgated mandatory regulations to limit outdoor recreational activities, mainly climbing in cliff-raptor nesting areas. Moreover, information panels were placed and guard surveillance reinforced in sensitive areas. This strategy was extended to the whole study area in 2011 and 2012, as well as to other activities such as forestry, industry and construction works for highways, roads and railways, which could generate disturbance. In particular, management regulations included: (1) prohibition of developing activities that caused habitat modification (i.e. forest clear-cuts and loggings, general construction work on roads, power lines and buildings) within a 1-km radius around breeding sites during the nesting period (from March to mid-September); (2) restriction of climbing on nesting cliffs and those neighbouring cliffs situated within the 600-m radius; (3) displacement of pedestrian, cycling and motorbike races out of the restricted radius during the nesting period.

Data analysis

Variations in weather conditions among months, years and stations were analysed by one and two-way analyses of variance (ANOVAs). Between-year effects of rainfall (i.e. precipitation and number of rainy days for each period) on the percentage of breeding success were analysed with non-parametric Spearman correlations. The preference for particular nest orientation was computed by means of the Rayleigh test of uniformity (Past Software 2.1; Hammer, 2011).

We built generalized linear mixed models fitted with the Laplace approximation (Bolker *et al.*, 2009) and using productivity as the dependent variable under a Poisson distribution, that is 0 (breeding failure), 1 or 2 (number of fledged young). Predictor variables were *a priori* clustered into three subsets: (1) nest-site variables (elevation, typology and orientation of the nest, and height and length of the nesting cliff); (2) weather variables (precipitation and number of rainy days in each period); (3) disturbance factors (human related disturbance). We entered 'territory' and 'nest' as random factors (the second nested within the first; Table 1) to account for the lack of independence of data because of the re-use of the same nest in different years. None of the variables were highly intercorrelated (Spearman rank correlation $r < 0.5$). The analyses were performed using the R software (R 2.15.1; R Development Computing, 2008), using generalized linear mixed models (GLMMs; GLIMMIX) as implemented in the lme4 package (Bates, Maechler & Bolker, 2012); this package allows fitting models using the Laplace approximation, particularly recommended when mean values of the response variable are below 5 (Bolker *et al.*, 2009). Firstly, we run different GLMMs to find the best structure of the fixed effects (i.e. nest-site characteristics, rainfall and human disturbance) on productivity. Secondly, we built biologically meaningful models (seven models) combining the three variable sets to create competing hypotheses depicting different interactions of variable sets, and evaluated them using an information-theoretic approach for model selection by means of Akaike's information criterion corrected for small samples (AIC*c*, Burnham & Anderson, 2002). To ascertain the relative contribution of each variable set in the averaged combined models, we calculated their Akaike weight (Burnham & Anderson, 2002). The variables with the highest weight (Σw_i) were of higher relative importance. We calculated the probability of overdispersion for each model and none of them was overdispersed. Mean values are reported with (±) their SD. Statistical significance was set at $P < 0.05$.

Results

Breeding performance and nest-site characteristics

We monitored a total of 191 breeding attempts in 22 Egyptian vulture territories. Of these, 121 nestlings fledged successfully during the study period (2000–2012) (Fig. 2). We recorded an average of 8.8 ± 4.2 breeding attempts per territory during the study period. Only an average of 41.7% ± 31.4% (range 0–92.3%) of the breeding attempts per territory were successful.

Egyptian vultures used on average 2.7 ± 1.4 nests (range 1–5) per territory. We detected 61 different nests located 578 ± 220 m a.s.l. (range 271–1050 m a.s.l.) in cliffs of 252 ± 407 m (range 14–2167 m) in length and 53.6 ± 68.7 m (range 5–345) in height. Birds did not show a preferred nest orientation (Rayleigh test, $r = 0.049$, $P = 0.863$), although the model for the effects of nest characteristics on productivity selected 'orientation' as a key feature of nest site (categories 1, south, south-west, $z = -2.39$; $P = 0.016$ and 3, north, north-east, $z = -2.171$; $P = 0.030$).

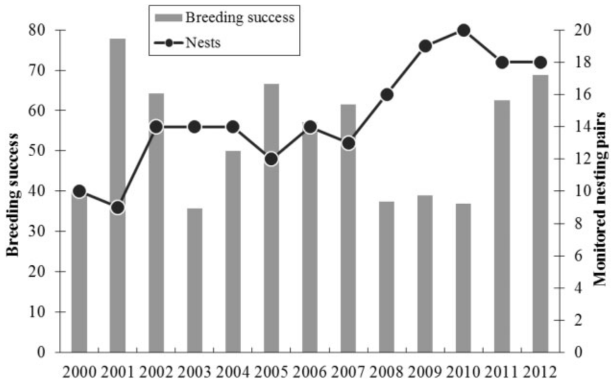

Figure 2 Breeding success (percentage of nests which fledged at least one chick per nesting pair) and number of monitored nesting pairs of Egyptian vulture in Biscay, northern Spain, from 2000 to 2012.

Effects of rainfall and human disturbance on breeding performance

Average annual total rainfall during the study period (2001–2012) in the study area was 1178 ± 232 mm (range = 580–1840) and 180 ± 18 rainy days per year (range = 136–229). Considering the overall breeding season (from the arrival in March, until the departure in August), there were significant differences in the rainfall among years (ANOVA, $F = 7.870$; $P < 0.001$), with 2007 and 2008 being the rainiest years. There were also differences among months (ANOVA, $F = 27.827$; $P < 0.001$), with April and May being the rainiest months and July the driest month, and among stations (ANOVA, $F = 2.372$; $P < 0.001$). There were significant inter-annual variations in the monthly rainfall (two-way ANOVA, $F = 35.077$; $P < 0.001$), and the highest variability was detected in spring (March, April and May). There were no significant differences among years in the rainfall collected at each station (two-way ANOVA, $F = 0.244$; $P = 1.000$).

The annual percentage of breeding success of the Egyptian vulture population was negatively and significantly correlated with the rainfall (Spearman correlation, $r = -0.629$, $P = 0.028$) and the number of rainy days in June ($r = -0.654$, $P = 0.021$). There were no significant correlations among the annual percentage of breeding success, rainfall and number of rainy days during the incubation ($P > 0.05$) nor during the second month of nestlings (July, $P > 0.05$). The model in which productivity was considered, however, did not extract any weather variable. Regarding the effect of human disturbance, the model showed a significant negative effect of specific high-level disturbance on productivity ($z = -4.066$; $P < 0.001$).

Model ranking and model selection

We considered seven competitive model sets, a global model, including all variables (i.e. full-factorial model), and the others combining the three sets of variables (i.e. nest,

Table 2 Results of the model selection procedure for the Egyptian vulture's productivity in relation to disturbance, nest-site characteristics and weather variables

Ranking	Model		K	AIC*c*	ΔAIC_c	AIC*c* w_i
1	DISTURB	111	6	113.71	0.00	0.738
2	WEATHER + DISTURB	113	8	116.15	2.43	0.219
3	NEST + DISTURB	116	15	119.72	6.01	0.037
4	NEST + WEATHER + DISTURB	118	17	123.24	9.52	0.006
5	WEATHER	160	5	158.75	45.03	0.000
6	NEST	162	12	161.75	48.03	0.000
7	NEST + WEATHER	161	14	163.72	50.00	0.000

Models were ranked according to AIC*c* values and Akaike weights (AIC*c* w_i); K, number of parameters in the model; DISTURB, disturbance factors; NEST, nest-site variables; WEATHER, weather variables.

weather and disturbance) (Table 2). AIC*c* scores indicated that the 'disturbance model' was the best model and 'disturbance + weather' model ($\Delta AICc = 2.43$) and 'disturbance + nest' model ($\Delta AICc = 6.01$) were also reasonable (Table 2).

Effects of management actions to reduce consequences of human disturbances

The breeding success was 0.87 ± 0.42 considering the overall non- and low-level disturbance nests ($n = 91$ cases) up till 2010. During the study period, we detected cases of high-level disturbance (levels 2 and 3 in Table 1) in 59 nests of 17 territories, which only produced three fledglings (breeding success = 0.05). Eight of these nests also suffered high-level disturbances in 2010 (when we started to develop management actions), five in 2011 and two in 2012. Measures aimed at reducing disturbance were successful, as the breeding success was 0.83 ± 0.43 in the 43 cases, which were free from disturbance after 2010 (considering altogether those nests free from disturbance and those nests in which actions were highly developed in order to avoid disturbance). In fact, the breeding success of non- or low-level disturbance nests prior to 2010 was not significantly different to that of the nests, which were managed to avoid disturbances after 2010 (Mann–Whitney test, $U = 97$, $P = 0.753$). The effectiveness of the management actions was higher in those territories that suffered specific/sporadic high-level disturbance, than in those territories with chronic high-level disturbance (Fig. 3).

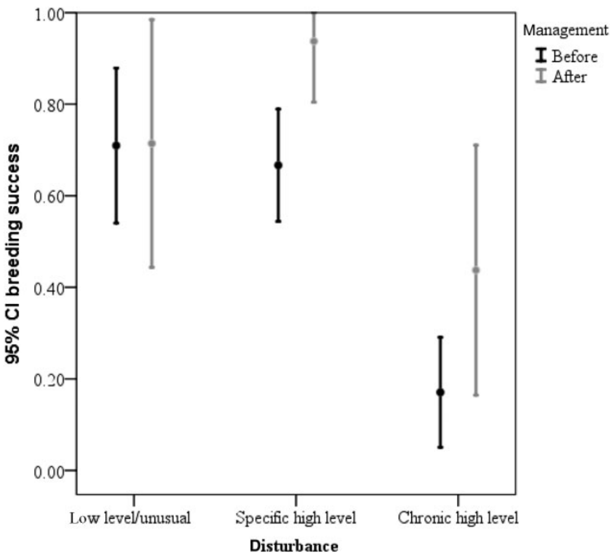

Figure 3 Breeding success (percentage of nests which fledged at least one chick per nesting pair) of each Egyptian vulture territory, before (2000–2009) and after (2010–2012) the management actions in Biscay, northern Spain, considering three levels of disturbance: (1) chronic high-level; (2) specific high-level; (3), low-level/unusual disturbance. Abbreviations: CI, confidence interval.

Discussion

In our study area, located on the border of the Egyptian vulture's distribution range, precipitation showed high inter-annual variability. We have shown that rainfall (precipitation and number of rainy days) during June, when Egyptian vultures are immersed in the chick-rearing period, was negatively correlated with breeding success. During this breeding phase, nestlings do not thermoregulate; therefore, rain increases the risk of hypothermia (Elkins, 2004). In this sense, a high amount of rain even if only on one day (e.g. 160 mm, registered on 16 June 2010) can be as negative as a number of continuous rainy days. A literature review on other raptor species suggests that rain during the chick-rearing phase prevents adults from foraging, resulting in food shortage for the young (Kostrzewa & Kostrzewa, 1990; Penteriani, 1997; Sergio, 2003; Mcdonald, Olsen & Cockburn, 2004; Lehikoinen *et al.*, 2009; Bionda & Brambilla, 2012). If this was the case, it would explain why, contrary to other studies (Liberatori & Penteriani, 2001; Sarà & Di Vittorio, 2003; García-Ripollés & López-López, 2006; Mateo-Tomás & Olea, 2009), we found no relationship between productivity and nest characteristics. This suggests that the main deleterious effect of rainfall could act through lowering foraging efficiency of adults, which can also be affected by disturbance. However, it should be emphasized that other variables such as territory's quality and birds' experience could be masking the effect of nest characteristics on breeding performance.

The effect of adverse weather conditions may have major consequences in the northernmost part of the species' distribution area, as seems to occur with other raptor species (Lehikoinen *et al.*, 2009). Paradoxically, the Egyptian vulture is a long-lived species, which shows strong resilience to inter-annual changes (Grande *et al.*, 2009), and actually the northernmost Spanish population is one of the few which is currently increasing (Del Moral, 2009).

Conservation strategies in a changing world

Some of the possible scenarios of climate change in Europe forecast an increase in rainfall during spring (IPCC, 2012). This may negatively affect the productivity of Egyptian vultures in the future. We cannot avoid this effect using the current conservation and management tools. However, according to Mawdsley *et al.* (2009), one strategy to reduce the pressure from climate change on a certain species would be to reduce or remove other non-climatic stressors in order to maximize the potential of wildlife to develop responses to climate change. Hence, strategies aimed at reducing the effects of human disturbances on the Egyptian vulture may be fundamental to compensate for the potential negative effects of climate change.

While some authors suggest that the Egyptian vulture is tolerant to human activities (Ceballos & Donázar, 1989), our study (Zuberogoitia *et al.*, 2008) suggests that human disturbance constitutes a key factor conditioning the Egyptian vulture's breeding performance. This is particularly important in areas of high human population density. The combined effects of weather conditions and nest characteristics (e.g. exposure and/or sheltering, Ceballos & Donázar, 1988) may be stronger if disturbance appears during key phases of breeding (e.g. risk of hypothermia during incubation or when nestlings are still very young). This problem has even been detected in protected areas. In fact, the Network of Protected Areas attracts ecotourism and outdoor recreational activities related to an interest in some key wildlife species (e.g. the Egyptian vulture), to which these activities are causing damage (Krüger, 2005; Cardoni *et al.*, 2008). Consequently, conservation actions are needed to reduce their impact on species, even though these measures are not always welcomed by the users of these natural resources.

Conclusions

We have found that it is possible to develop management plans to avoid the effects of human disturbance on the endangered Egyptian vulture, and remarkably, the study population reacted rapidly, increasing productivity. However, other threats related to human activities such as poisoning still remain unsolved and are causing a decrease in adult populations in southern Europe (Cortés-Avizanda *et al.*, 2009; Grande *et al.*, 2009; García-Ripollés & López-López, 2011).

Our results also show that management actions aimed at reducing or removing human disturbance are of paramount importance in order to assure the conservation of this endangered species. These measures should be taken, particularly in those protected areas likely to attract ecotourism and in zones that could potentially be affected by new infrastructure, forestry or simply urban development. Moreover, these measures should be considered in order to reduce the likely adverse effects of the forecasted increase of episodes of heavy rainfall on Egyptian vultures' breeding output.

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