



# Identifying the effectiveness and constraints of conservation interventions: A case study of the endangered lesser kestrel

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## ABSTRACT

The recognition of the rapid and ongoing biodiversity loss has been leading to increasing conservation efforts. To maximise conservation success it is important to evaluate when interventions are likely to be effective. In Portugal, previous research identified that lack of suitable nest-sites was limiting the populations of the endangered lesser kestrel (*Falco naumanni*). Consequently, a massive provisioning of artificial nest-sites and the implementation of a medium term monitoring scheme was established. Our study showed that artificial nest-site provisioning is an effective measure in mitigating the lack of traditional sites. The lesser kestrel population increased from 155–158 pairs in 1996 to 527–552 in 2007, with 52% breeding in artificial nests. We investigate the factors affecting colony growth and found that colony growth was positively affected by the provisioning of artificial nests but negatively affected by predation rate and human disturbance. Between 2003 and 2007, mean colony growth was estimated at  $6.46 \pm 1.86$  pairs for colonies where artificial nests were provided and  $-0.69 \pm 0.5$  pairs in colonies without nest-site provisioning. Moreover, predation rate was significantly lower in artificial nests than in natural ones and, although the number of competitor pairs in lesser kestrel colonies increased, the proportion of nests occupied by competitor species decreased. High risk of collapse and restoration of rural abandoned farm-houses may jeopardize the future of the lesser kestrel in Portugal. Nest-site provisioning and the establishment of a protection status for buildings holding colonies are likely the most effective means to guarantee the long-term survival of this species in the area.

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## 1. Introduction

Dramatic changes to global ecosystems originated by human activities are having worldwide massive impacts on biodiversity leading to increasing conservation efforts to prevent these impacts (Millennium Ecosystem Assessment, 2005; Rodrigues, 2006).

It is sensible to examine the effectiveness of the possible conservation actions and determine which are the most cost-effective before conservation takes place (Sutherland et al., 2004a; Pullin et al., 2004). However, the effectiveness of interventions are often not assessed or reported so that it is difficult to assess the most sensible strategy for future projects (Salafsky and Margoluis, 1999; Salafsky et al., 2002; Sutherland et al., 2004a,b; Ausden, 2007). For those reported, the majority look at the overall success

of interventions, include few sites or have short-term monitoring (e.g. Côté and Sutherland, 1997; Webb and Shine, 2000; Fox et al., 2005; Ausden and Bateson, 2005; Perkins et al., 2008). Few have analysed the species' response to management for an entire population or studied possible interactions between implemented measures and other external factors (although see Jones et al., 1995; Innes et al., 1999; Elliot et al., 2001). By considering a range of sites and monitoring the impact it is possible to tease apart the effectiveness and constraints of conservation interventions and select or adapt the most appropriate management practices.

In this paper, we evaluate the effectiveness of nest-site provisioning and the influence of potential breeding constraints on the Portuguese lesser kestrel population. Based on data collected across the whole Portuguese distribution range, we first investigate the effect of nest-site provisioning and potential remaining breeding constraints on population growth at different temporal scales by comparing the results of short and medium term monitoring. Secondly, we analyse the interacting effects of nest-site provisioning and other potential breeding constraints on population dynamics to assess the independent and shared effects of each variable.

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Our focus on the lesser kestrel is consequence of the identification of rapid declines in Western European populations leading to its classification as a globally threatened species (Birdlife International, 2004). The reasons for population decline are not fully resolved with both past and present threats varying between countries and regions (see Biber, 1990; González and Merino, 1990; Tucker and Heath, 1994). Large-scale land transformation (through urbanization and modification of traditional agricultural practices such as land abandonment, afforestation, irrigation or intensive cultivation), negative effect of pesticides in prey populations, loss of nest-sites (often related with restoration, demolition or collapse of old buildings), presence of competitors, predation and human disturbance (such as poaching and bird shooting) are generally considered as the major causes of decline (Peet and Gallo-Orsi, 2000).

As in other European countries (Bijleveld, 1974), at the beginning of the twentieth century, the lesser kestrel was a very common species in Portugal with over 700 pairs breeding in small towns and villages in the south of the country (Araújo, 1990). However, by the end of the twentieth century most of the known colonies were extinct and after the first national survey, in 1996, the Portuguese lesser kestrel breeding population was estimated to be between 155 and 158 breeding pairs (Rocha et al., 2002) and disappeared from most of its range.

The first conservation efforts in Portugal started in 1994 involving nest-site provisioning and by 2001 approximately 200 artificial nests had been provided in the three largest colonies (C. Cruz and P. Rocha, pers. comm.).

Nonetheless, large-scale surveys during 2001 and 2002 showed that 85% of sites lacked suitable nesting cavities and suggested that the Portuguese population was limited by both the number of suitable cavities in existing colonies and by insufficient buildings with suitable characteristics for the establishment of new colonies (Franco et al., 2005). Franco et al. (2005) recommended the provisioning of artificial nest-sites in existing colonies and in unoccupied buildings that were surrounded by suitable habitat.

Between 2002 and 2006 a European LIFE-Nature Project “Re-establishment of the Lesser Kestrel *Falco naumanni* in Portugal” (LIFE2002/NAT/P8481) aimed to recover the Portuguese lesser kestrel population and several interventions were carried out. One of the main aims of the LIFE project was to increase the nest-site availability and improve the quality of breeding sites in response to the recommendations of previous research (Franco et al., 2005). There was virtually no information on the influence of other presumably important constraints, such as predation or interspecific competition.

Hence, the main goals of this study are: (1) to assess the effectiveness of nest-site provisioning on growth rates in lesser kestrel colonies and global population trend, (2) to identify remaining breeding constraints in order to propose new management actions and (3) to discuss future scenarios for lesser kestrel conservation based on nest-site availability.

## 2. Methods

### 2.1. Study area

The study was carried out between 2003 and 2007 and encompasses the entire Portuguese lesser kestrel breeding range, located mainly in the south of Portugal. Presently, the Castro Verde Special Protection Area (SPA) – with 85 000 ha – harbours almost 80% of the total Portuguese lesser kestrel population. The remaining population is spread across several SPAs – Évora (8%), Vale do Guadiana (5%), Cuba (2%), Vila Fernando (2%) and S. Vicente (1%) and only 4% is located outside protected or designated areas (Fig. 1).

With the exception of the Vale do Guadiana urban colony and a small colony installed under piles of stones in the Vila Fernando SPA, lesser kestrel colonies predominantly occupy old rural buildings and artificial nesting structures. The majority of rural buildings used as colonies are abandoned, few are still inhabited and some are used to store farm machines or used as livestock and shepherd shelters. The nests are mainly located in cavities in walls or in the roof, under the tiles. Most of the colonies are easily accessed.

During the study period, colony size ranged from 1 to 83 breeding pairs with most colonies holding between 1 and 5 pairs, whilst most birds breed in medium and large colonies exceeding 6 pairs. The habitat composition around the colonies varied between areas. The Castro Verde and Vila Fernando SPAs have low-intensity farming systems where there is a dry cereal-fallow rotation scheme; typically 1–2 years of cereal cultivation is followed by 2–4 years of fallow, which is used for grazing by cattle and/or sheep. Other areas are characterized by Holm Oak *Quercus ilex* open forest and pastures grazed by cattle (Évora SPA and S. Vicente), agricultural abandonment and afforestation (Vale do Guadiana SPA) or intensive crop production with irrigation (Cuba SPA).

### 2.2. Conservation actions to improve nesting habitat

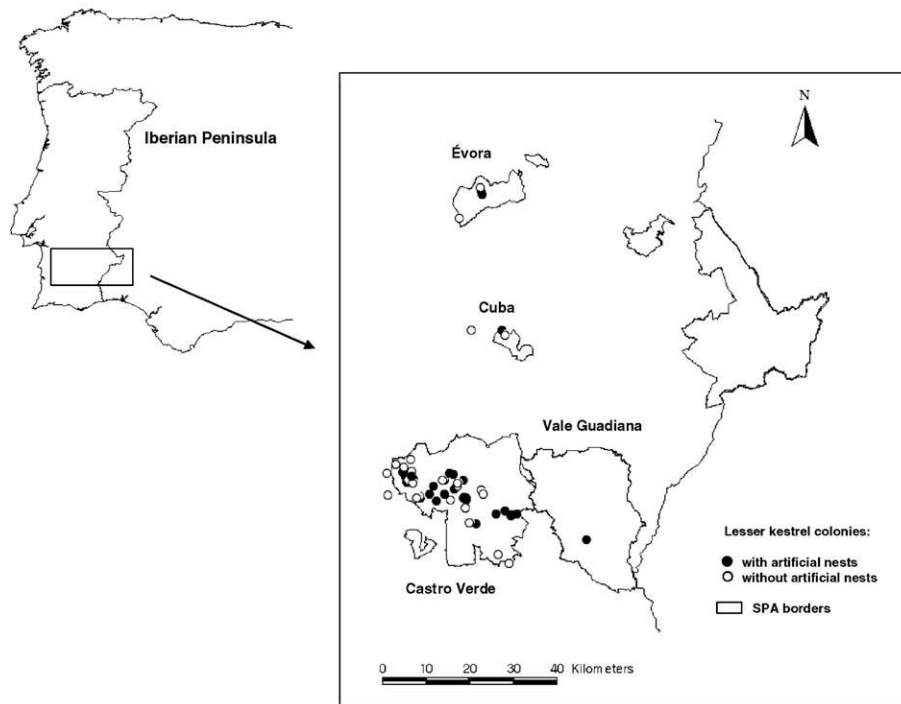
A major effort to provide suitable nest-sites started in 2002 with the Lesser Kestrel LIFE-Project (managed by League for the Protection of Nature – LPN – a national non-governmental organisation), which provided a further 865 breeding sites in 4 years, mainly in the Castro Verde and Guadiana SPAs (Fig. 1). The artificial nest-sites were provided in a range of different structures: eight new breeding walls were built and nest-site availability increased on 27 buildings (including some unoccupied sites) by provisioning of new cavities and artificial nests such as wooden nest-boxes or clay pots.

### 2.3. Population census

National surveys were conducted in 1996 and 2001 (Rocha et al., 2002), 2003, 2004, 2005, 2006 and 2007. Between 2003 and 2006 all known Portuguese colonies were surveyed on the scope of the lesser kestrel LIFE-Project. All potential nest-sites were inspected during the breeding season to effectively determine colony size. Every year new colonies were searched throughout field prospecting in potential suitable areas and both local people and field naturalists were consulted.

### 2.4. Factors affecting changes in colony size

We evaluated the most important breeding constraints described as threats in the lesser kestrel European Action Plan (Peet and Gallo-Orsi, 2000): nest-site availability, predation, interspecific competition and human persecution and disturbance. Foraging habitat around monitored colonies did not suffer significant changes through the study period (in part because agri-environmental schemes are being applied in the Castro Verde SPA that holds most population) and was not included in the analysis (authors' unpublished data). Between 2003 and 2006 most colonies were monitored on a weekly basis throughout the breeding season to ensure an effective calculation of all breeding parameters and potential constraints. In 2007, 13 colonies (representing 70% of the entire population) were monitored every week, for the remaining colonies the number of visits varied in order to ensure accurate assessment of nest-sites occupation rate and colony size. The number of monitored colonies each year varied between 42 and 53. Each year the number of new nests provided, either in existing colonies or unoccupied sites, was recorded and both natural and arti-



**Fig. 1.** Spatial distribution of lesser kestrel colonies in the study area. Black and white dots represent colonies with and without nest provisioning. The Castro Verde SPA harbours 80% of the total Portuguese population, while Évora, Vale do Guadiana and Cuba SPAs sustain 8%, 5% and 2%. The remaining population is spread within small colonies located in adjacent areas.

ficial nests were monitored to assess occupation rate by both lesser kestrels and other species and to calculate breeding parameters. All nests were mapped to obtain colony size, defined as the number of pairs that laid eggs. To compare the proportion of lesser kestrel colonies in which the availability of breeding sites could be considered a limiting factor to the colony growth, we assumed that a colony with at least five unused suitable nest-sites, either in cavities or under tiles, was not limited by lack of breeding sites. Predation rate was defined as the ratio of predated clutches or broods by the total number of clutches. The number of pairs of competitor species and the proportion of suitable nests occupied by each species were recorded in each colony and year whenever possible. Potential competitor species included the kestrel *Falco tinnunculus*, barn owl *Tyto alba*, little owl *Athene noctua*, roller *Coracias garrulus*, jackdaw *Corvus monedula* and feral pigeon *Columba livia*. Human disturbance can be caused by the presence of shepherds, inhabitants, farming activities (such as machine storage, keeping livestock, vaccination and shearing) or acts of vandalism and was assessed for each colony and year. Disturbance intensity levels were categorized as low, medium or high. Low level was defined as when no use or only sporadic use of buildings was detected. More intense use (inhabited buildings and regular presence of shepherds) and poaching activity involving less than 40% of the colony were classified in the medium level category. High levels included intensive use of buildings involving visible disturbance on incubating birds or chick feeding deliveries, building works leading to loss of more than 50% of nest-sites and poaching or acts of vandalism in over 40% of the nests.

## 2.5. Statistical analyses

Changes in colony size were defined as  $r = \ln(N_t + 1) - \ln(N_{t-1} + 1)$  (Serrano et al., 2004), including both increasing and decreasing colonies and even colonies that went extinct. Since different variables could have short or medium term influence on

population growth, changes in colony size were determined using two different approaches. In the first approach – within-year colony approach –  $N_t$  and  $N_{t-1}$  represented the number of breeding pairs at a colony in year  $t$  and  $t - 1$  while in the second approach – all-period colony approach –  $N_t$  and  $N_{t-1}$  represented the number of breeding pairs in the last and first year of monitoring, respectively (for most colonies  $N_t = 2007$  and  $N_{t-1} = 2003$ ). Our samples include data from 133 colony-years for the first approach and 56 colonies for second approach.

We examined the relationship between changes in colony size and possible predictors of this variation using a generalized linear model (GLM) for the all-period colony approach. For the within-year colony approach we used a generalized linear mixed model (GLMM), which allows us to account for non-independence in data set (Littell et al., 1996); colony site and year were fitted as random factors. For both models we assumed a Gaussian error distribution and an identity link function. Explanatory variables for each approach are described in Table 1. Analysis of correlations among predictors was used to detect redundant variables and avoid inaccurate estimation of coefficients. We used Akaike's Information Criterion (AIC) to compare the fit of a candidate set of models using the methods described by Burnham and Anderson (2002). In both data sets the ratio between the number of observations and parameters ( $n/k$ ) was below 40, so we calculated the bias-adjusted AIC (AICc) for the performed analysis. For each model we calculated the Akaike weight ( $w_i$ ), which is the probability that model  $i$  would be selected as the best-fitting model if the data were collected again under identical circumstances (Burnham and Anderson, 2002). The fit of the model was assessed using model deviance, representing the percentage of deviance explained by the model.

We use a variance partitioning approach (Borcard et al., 1992) to determine the independent and joint effects of predation, nest-site provision and human disturbance on the observed changes in colony size for the all-period approach. The total deviance obtained in the generalized linear model for these three predictors was par-

**Table 1**  
Potential explanatory predictors used to assess changes in colony size in the Portuguese lesser kestrel population.

Variable	Description	
	Within-year colony approach	All-period colony approach
Nest provisioning	Number of nests provided between years $t - 1$ and $t$ (two consecutive years)	Number of nests provided between the first and the last monitoring years (for most colonies $t - 1 = 2007$ and $t = 2003$ )
Predation	Predation rate in year $t - 1$	Mean predation rate in the considered monitoring period
Competition	Proportion of potential nest-sites occupied by competitor species in year $t$	Mean proportion of potential nest-sites occupied by competitor species in the considered monitoring period
Human disturbance	Human disturbance level (1 = low, 2 = medium and 3 = high) in year $t - 1$	Human disturbance level (1 = low, 2 = medium and 3 = high) in the considered monitoring period

tioned into eight independent components: pure effects of: (a) predation, (b) nest-site provisioning and (c) human disturbance; and combined variation due to the joint effects of (d) predation and nest-site provisioning, (e) predation and human disturbance, (f) nest-site provisioning and human disturbance and (g) all three explanatory variables; and finally (h) unexplained variation (see Heikkinen et al., 2004 and Ferreira et al., 2007 for methods).

All analyses were performed with R (R Development Core Team, 2008) and all values are given with standard errors.

### 3. Results

#### 3.1. Lesser kestrel demography

The Portuguese lesser kestrel population markedly increased during the last decade; in 2007 the national survey result was 527–552 breeding pairs, up from 155 to 158 just over a decade earlier (Fig. 2). In 1996, 82% of the lesser kestrel population was confined to three colonies, while in 2007 the same proportion of the whole population was distributed by 15 colonies. The number of colonies increased from 10 in 1996 (P. Rocha, pers. comm.) to a maximum of 53 in 2006; the breeding range showed a comparable expansion.

#### 3.2. Factors affecting changes in colony size

Predation rate and human disturbance are most important variables for explaining changes in colony size between two consecutive years (within-year colony approach) while mean predation rate and number of nests provided were important predictors when considering a longer period (all-period colony approach;

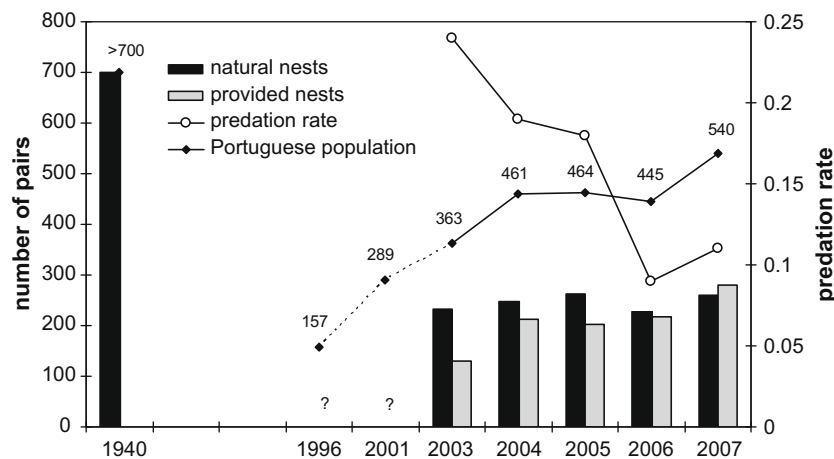
Table 2). Our top two and four most predictive models for the within-year and all-period colony approaches had an  $\Delta AICc$  under 7, suggesting that these models approximated a 95% confidence set on the best model (Burnham and Anderson, 2002).

Predation rate negatively affected colony dynamics, as determined by either approach. Selection probabilities for predation rate and mean predation rate were very high ( $\Sigma wi > 0.99$ ) and both predictors were included in all tested models, indicating strong support (see Table 2).

The number of nests provided was positively and significantly associated with changes in colony size in the all-period colony approach (Fig. 3), entering the best models with high selection probabilities ( $\Sigma wi > 0.99$ , Table 2). However, when comparing changes in colony size for shorter periods (within-year colony approach), this predictor showed a very low probability of selection ( $\Sigma wi = 0.007$ , Table 2), indicating weak support for models including it. Mean colony growth (difference between the number of breeding pairs in 2007 and 2003) in colonies without nest-site provision was  $-0.69 \pm 0.5$  ( $n = 26$ ) compared to  $6.46 \pm 1.86$  ( $n = 28$ ) where artificial nest-sites were provided (Fig. 4).

Human disturbance is a good predictor for colony size change across consecutive years (within-year colony approach), showing high selection probabilities ( $\Sigma wi > 0.99$ , Table 2) and significant impacts on colony growth where high levels of disturbance were detected (Fig. 3). This was not the case for the all-period colony approach, although there was a relatively high probability of selection ( $\Sigma wi = 0.93$ ), the estimate of the coefficient predictor showed a large standard error ( $-0.25 \pm 0.2$ ) and this variable was selected in only two of the four best models (Table 2).

Interspecific competition had a low predictor capability in explaining changes in colony size using either the within-year or all-period colony approach, showing both low selection probabili-



**Fig. 2.** Evolution of lesser kestrel Portuguese population and number of pairs occupying artificial and natural nests. Presented values show the mean between maximum and minimum surveyed pairs. For comparison, the 1940s estimate is presented. There is no information on the total number of lesser kestrels breeding in artificial and natural nests in 1996 and 2001. Annual mean predation rate is shown for the period 2003–2007.

**Table 2**

Top models for the effect of predation, nest-site provisioning, interspecific competition and human disturbance on short term (within-year colony approach) and medium term (all-period colony approach) changes in lesser kestrel colony size. Colony site and year were fitted as random factors in the first approach. Models are ranked according to the Akaike Information Criterion corrected for small samples (AICc). The  $\Delta AICc$  indicates AICc differences between a particular model and the best-fitting model. Akaike weights ( $w_i$ ) indicate the contribution of each model to the average of all candidate models. Coefficients (and SE) are showed for variables included in a particular model while blank spaces represent the exclusion of variables.  $\Sigma w_i$  for each predictor variable shows the sums of Akaike weights for all possible models in which the predictor variable was included.  $\Sigma w_i$  reflects the relative importance of each variable (the larger the  $\Sigma w_i$  the more important a variable  $j$  is, relative to other variables). Dev is the total amount of deviance explained by each model.

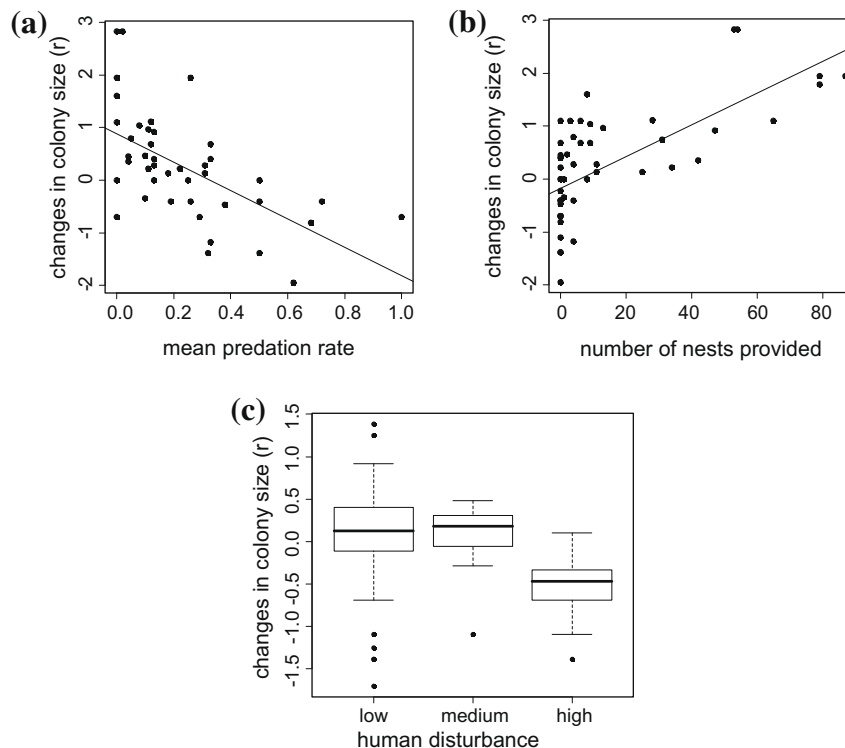
Model	Variable				AICc	$\Delta AICc$	$w_i$	Dev
	Predation	Nests provisioning	Interspecific competition	Human disturbance				
<i>Within-year colony approach</i>								
1	-1.25 (0.15)		0.37 (0.24)	-0.19 (0.06)	130.77	0.00	0.593	0.493
2	-1.16 (0.13)			-0.21 (0.06)	131.57	0.8	0.398	0.480
3	-1.25 (0.15)	0.005 (0.004)	0.39 (0.24)	-0.20 (0.06)	140.47	9.7	0.0465	0.459
$\Sigma w_i$	>0.99	0.0076	0.598	>0.99				
<i>All-period colony approach</i>								
1	-2.20 (0.49)	0.02 (0.005)	-	-0.25 (0.20)	84.214	0.00	0.481	0.752
2	-2.32 (0.51)	0.02 (0.005)	0.69 (0.74)	-2.42 (0.21)	84.348	0.134	0.450	0.758
3	-1.87 (0.48)	0.03 (0.005)	-	-	89.331	5.117	0.037	0.717
4	-1.98 (0.50)	0.03 (0.005)	0.60 (0.75)	-	89.628	5.414	0.032	0.723
5	-3.07 (0.56)	-	-	-0.47 (0.25)	101.98	17.76	0.000	0.612
$\Sigma w_i$	>0.99	>0.99	0.48184	0.9307				

ties ( $\Sigma w_i < 0.60$ ) and high estimation standard errors (Table 2). The number of pairs of competitor species in lesser kestrel colonies increased from 55 to 94 pairs between 2003 and 2007, but given the provision of hundreds of artificial nests, the proportion of nests occupied by competitors declined from 0.20 to 0.10 in the same period.

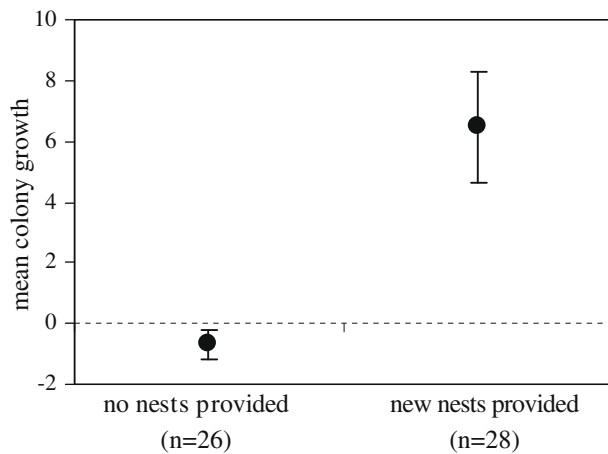
For the all-period approach, the amount of variance captured in the model with lowest AICc values was 75.2% (Table 2). The decomposition of the variation showed that the largest fractions of the variability in the changes in colony size were related to

the joint effect of predation and nest-site provisioning (27.7%). However, the pure effect of these two explanatory variables was also considerable (19.5% and 14%, respectively) while pure effects of human disturbance and joint effects including this variable were not important (Fig. 5).

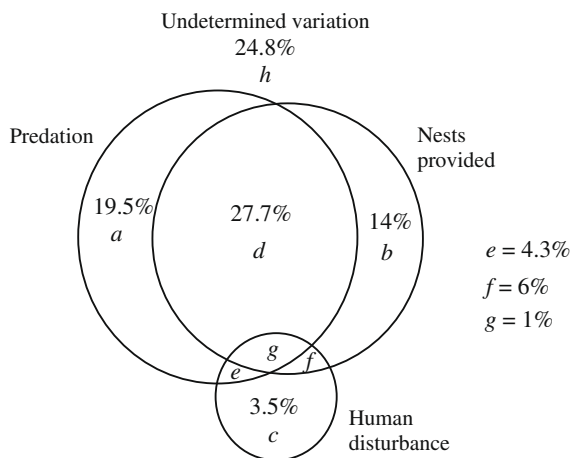
Mean predation rate was significantly lower in artificial nests ( $0.11 \pm 0.08$ ,  $n = 900$ ) than in natural ones ( $0.18 \pm 0.008$ ,  $n = 913$ ;  $\chi^2 = 33.7$ ,  $p < 0.001$ ). However, high levels of predation rate were detected in nests under tiles ( $0.25 \pm 0.009$ ,  $n = 434$ ) and in uncommon nest-sites (such as stork nests, 1st floor of old buildings, win-



**Fig. 3.** Effect of predation rate, nest-site provisioning and human disturbance on changes in lesser kestrel colony size ( $r$ ) using the all-period (a and b) and the within-year (c) colony approaches.



**Fig. 4.** Comparison of mean colony growth (number of breeding pairs) between 2003 and 2007 in the lesser kestrel Portuguese colonies provided or not with artificial nest-sites.



**Fig. 5.** Independent and joint contributions of the predictor variables for the observed changes in colony size, as estimated by variation partitioning. *a*, *b* and *c* are unique effects of predation, nest provision and human disturbance, respectively, while *d*, *e*, *f* and *g* are fractions indicating their shared effects; *h* represents the unexplained variation.

dows or on the ground,  $0.14 \pm 0.012$ ,  $n = 75$ ), while in natural cavities in walls the predation rate was lower and similar to that obtained in artificial nests ( $0.10 \pm 0.003$ ,  $n = 404$ ). Annual predation rate varied between 0.23 in 2003 and 0.06 in 2007, decreasing during the study period as the proportion of the breeding population using artificial nest-sites increased (Fig. 2).

### 3.3. Nest-site availability and occupation rates

Despite the massive provisioning of alternative new nest-sites (more than 1000 between 1994 and 2007, Table 3), the number of lesser kestrel pairs breeding in natural sites remained relatively constant between 2003 and 2007 (Fig. 2). The number of artificial nest-sites occupied by lesser kestrels increased over time, particularly since 2003 when several existing colonies and unoccupied sites were provided with new artificial nests in a major conservation effort (Fig. 2, Table 3). In 2007, the proportion of the total Portuguese lesser kestrel population breeding in artificial nests reached 52% ( $n = 279$  breeding pairs in artificial nests; Table 3). Moreover, the proportion of colonies considered to be limited by nest-site availability decreased from 81% in 2003 to 52% in 2007, from a sample of 43 and 42 visited colonies, respectively.

## 4. Discussion

### 4.1. Factors affecting changes in colony size

In the absence of human impacts, most bird populations are naturally limited by relatively few variables, of which availability of food and safe nest-sites, predation, competition and disease are among the most important (Lack, 1966; Newton, 1998; Sutherland et al., 2004b). This study suggests that changes in lesser kestrel colony size in Portugal are affected by nest predation, nest-site availability and human disturbance.

Our results show a strong negative effect of predation pressure on predicting changes in colony size in either short (two consecutive years) or medium term (2–5 years) periods. Nest predation is a powerful selective force on the reproductive strategies of birds and can potentially affect life-history traits (Martin, 1995). Like in the French and Spanish populations, where the effect of predation was analysed, predation was found to be the main breeding constraint (P. Pilard, pers. comm.; Serrano et al., 2004), which might result in low values of productivity that can negatively influence population growth (Hiraldo et al., 1996). Furthermore, Serrano et al. (2004) found that nest failure due to predation increased the probability of dispersal and that some colonies can experience massive adult dispersal events associated with total breeding failure caused by predation. During the study period, five colonies were documented as going extinct immediately after suffering massive predation events of both clutches or chicks and adults. Nest predation rate was not correlated with colony size, unlike what was found by Serrano et al. (2005).

Franco et al. (2005) showed that as in France and Greece, but contrary to studies in Spain and Turkey, nest-site availability is a limiting factor for the Portuguese lesser kestrel populations. Our results for the overall study period strongly support the previous study showing, on average, a positive increment in colony size where new nest-sites were provided, contrasting with a negative trend in colonies without nest provisioning. Nonetheless, the num-

**Table 3**  
Artificial nest-sites provisioning and occupation rate by the Portuguese lesser kestrel population.

Year	Number of sites with artificial nests (cumulative)	Total number of nests provided (cumulative)	Number of nests monitored	Number (and%) of artificial nests occupied	Proportion of population in artificial nests
1996	3	130	68	22 (32%)	0.14
2001	3	207	105	59 (56%)	0.20
2003	15	369	369	131 (36%)	0.36
2004	20	474	474	212 (45%)	0.46
2005	28	518	518	202 (39%)	0.44
2006	34	737	737	217 (29%)	0.49
2007	37	1072	854	279 (33%)	0.52

ber of nests provided in a given year was not a good predictor of the observed changes in colony size between that year and the following one. Relatively low occupation rates of artificial nests by lesser kestrels during the provisioning year but higher values for the consecutive years had been previously observed (Pomarol, 1996; Bux et al., 2008) and can explain the more likely medium term effect of these actions on population growth.

The intensity and frequency of human actions can have different impacts in lesser kestrel populations. Poaching of eggs and chicks or bird shooting is described in several countries as an important threat locally (Biber, 1990; González and Merino, 1990; Liven-Schulman et al., 2004), as well as the disturbance caused by shepherds and tourists or the renovation of historic buildings (Biber, 1990). Our results suggest that actions included in the high level of human disturbance (see methods) have a significant negative impact on lesser kestrel population growth in the following year. Nonetheless, the impact of human disturbance was not clear when considering the overall period, indicating that lesser kestrel populations can recover from some negative impacts if the disturbance source is removed or reduced. During the present study 34 nests were poached in 2003, while in 2006 an isolated act of vandalism in a different colony destroyed 17 nests by shooting both chicks and incubating adults. After the 2006 event, the population of the affected colony significantly decreased in the following year but started recovering subsequently. Building works lead to the extinction of two small colonies due to nest-site elimination while in another two extinction was prevented by artificial nest provisioning. The impact of shepherds and farmers' building occupancy is difficult to quantify and might have indirect consequences on lesser kestrel breeding success by reducing nest attendance by parents, increasing risk of predation and decreasing food delivery rates.

Site-specific competition over cavities can be severe by reducing nest-site availability causing lesser kestrels to move to nests of lower quality and consequently causing an increase in nest predation. Common kestrels, barn owls and jackdaws usually arrive earlier than lesser kestrels to the breeding sites (authors unpublished data) allowing these species to choose the best available nests. By contrast, rollers arrive from wintering grounds later than lesser kestrels but their aggressive behaviour often drives out recently established pairs or incubating ones by egg removal. Nonetheless, our results do not support competition by nest-sites as a significant predictor of changes in colony size. Forero et al. (1996) showed that in 674 colonies in Spain competitor species did not limited nest-site availability or lesser kestrel breeding success since most colonies had a surplus of unoccupied cavities. This seems to be the case in our study area, due to artificial nest provisioning.

#### 4.2. Effectiveness and constraints of nest-site provisioning

Use of artificial nests has been recommended to increase populations of many species exposed to a shortage of natural nest-sites (e.g. Newton, 1994; Smith et al., 2005; Kurniandaru, 2008) and has been reported to be an effective management tool for both common and american kestrels (Hamerstrom et al., 1973; Village, 1983; Fargallo et al., 2001). Despite several efforts to install artificial nest structures for the lesser kestrel in several countries, the reestablishment of this species has had only limited success (Pomarol, 1996; Rinat, 2008, P. Pilard, pers. comm.). In Portugal, from 1994 to 2007, more than 1000 artificial nests were provided in existing lesser kestrel colonies and unoccupied sites (farmhouses, breeding towers and walls) leading to a spectacular increase in the breeding population size. The number of colonies increased as did the breeding range, showing a more spread distribution. By 2007, 279 pairs (52% of the whole population) bred in

artificial nest-sites and the number of provided nests could easily harbour the entire Portuguese lesser kestrel population (even accounting for competitor species). Moreover, artificial nests showed a lower rate of predation when compared to natural ones. The joint effect of predation and nest provisioning in explaining changes in colony size (see the variance partitioning approach results) suggest that the observed increase in the Portuguese population could have benefited from the decline of nest predation and the resulting increased breeding success.

Despite the observed effectiveness of nest-site provisioning, future increases in lesser kestrel breeding populations may be constrained due to human disturbance and short-life and high demand maintenance of artificial nests. Nest-boxes, clay pots and breeding towers and walls make both artificial nests and colonies more visible and might lead to an increase in poaching. Longevity of nest-boxes (representing 14% of total nests provided) is proved to be short and cavities opened in adobe walls in abandoned rural buildings (as well as nest-boxes and clay pots fixed to these walls) are dependent on continued building maintenance. Within the 5-year study period several wooden nest-boxes (and some clay pots) had to be replaced due to poor condition and some of the nests located in walls of rural buildings were only prevented from collapsing due to building works that were funded by the EU-LIFE Project. The average area of collapsed roof reached 30% in the monitored colonies and in 2007 the risk of collapse evaluated in structures holding nests (after wall consolidation in six colonies) was considered high in 35% of the colonies. Breeding walls and towers, with number of cavities varying between 26 and 87 and representing around 60% of the nests provided, almost certainly have larger longevity but little is known about their carrying capacity.

#### 4.3. Future scenarios for lesser kestrel conservation and management implications

The lesser kestrel was naturally a cliff-nesting species, which has taken the opportunity of occupying new areas with suitable feeding habitats using old buildings in small towns and villages as nesting sites (typically churches, cathedrals or castles, Franco et al., 2005). Loss of nest-sites, often related with restoration, demolition or collapsing of old buildings, has been suggested as being of critical importance in several regions (González and Merino, 1990; Tucker and Heath, 1994; Prugnolle et al., 2003; Sigismondi et al., 2003; Liven-Schulman et al., 2004) but not in others (Forero et al., 1996; Parr et al., 1995, 2000). In Portugal, the species almost completely disappeared from urban areas by the end of last century, presumably due to restoration of historic buildings and poaching activities (Araújo, 1990). The 1996 and 2001 national surveys (Rocha et al., 2002) suggest the recent colonization of rural abandoned farmhouses by the species, breeding in cavities on the adobe walls (created by the wind and rain and lack of maintenance) and under roof Arabic tiles. However, in such colonies, nest-site shortage is currently a major threat due to the high risk of building collapsing or restoration (Tella et al., 1993; Franco et al., 2005). Recently built houses tend to be brick-built and roofed with Lusitanian tiles and are less likely to provide nest-sites to lesser kestrels even after abandonment. Henceforth, the Portuguese lesser kestrel population seems to mostly depend on artificial nest-sites to guarantee its survival in areas where suitable foraging habitat is still present (Fig. 6). In the future, in Portugal and in other European regions and countries, the lesser kestrel is likely to become highly associated with artificial breeding sites and strongly dependent on availability of conservation funds for their maintenance. In some cases, alternative low cost and simple interventions proved to be effective in providing new breeding sites for lesser kestrels, as demonstrated by some conservation projects developed in urban areas in Western Spain (Serrano and Delgado,

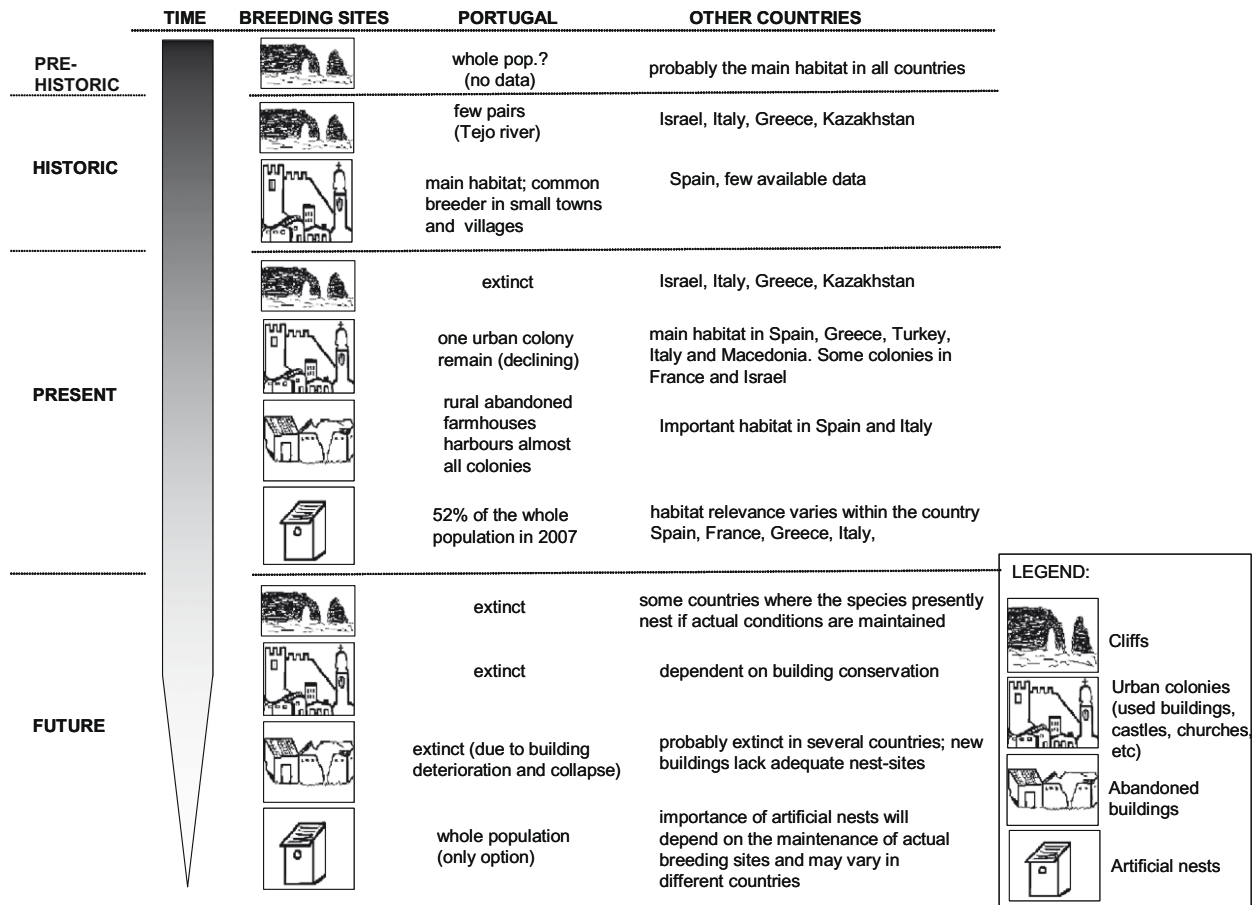


Fig. 6. Evolution of lesser kestrel breeding sites and future scenario.

2004). Therefore, it is highly recommended to evaluate the trade-offs between costs, longevity, location, breeding success and carrying capacity of different artificial nest-types in order to guarantee the long-term viability of the species on the most likely future scenario of severe lack of breeding sites. Meanwhile, replacement of unsuitable nests, building maintenance (to prevent collapse and quality of nest cavities) and provisioning of nest-sites to compensate eventual losses of old ones is crucial to ensure that the current population size is maintained. Both the location and type of nest-sites can be chosen to minimize the impacts of predation and interspecific competition. Reducing nest entrances to 6.5 cm can avoid most competitor species and placement of the artificial nests in high locations further from top walls might reduce mammal predation (Negro and Hiraldo, 1993; Pomarol, 1996; Serrano and Delgado, 2004). To overcome building deterioration and prevent colony extinction, a protection status should be defined for buildings harboring lesser kestrel pairs. Building owners could be subsidized to protect and maintain these buildings. The European Agricultural Fund for Rural Development (EAFRD) could support such schemes through the Rural Development Programme (RDP) as it currently happens in the Castro Verde SPA, where the provision of new structures for the lesser kestrel is possible through the application of non-profit investments of the agri-environmental schemes. In new constructions surrounded by adequate foraging habitat areas, a simple solution would be to subsidize the use of adequate artificial nest-sites (Pomarol, 1996). Reduce human disturbance might be achieved by raising public awareness and reinforcing colony vigilance, following previous actions undertaken during the LIFE-Project.

We should stress that the positive results obtained with the provisioning of nest-sites are only possible in locations where suitable foraging habitat is available. In the Castro Verde SPA (which harbours 80% of the Portuguese population) there is a particularly good conservation context where the implementation of conservation actions coincide with the existence of an agri-environmental measure “Castro Verde Zonal Plan” that aims to maintain favourable feeding habitat for a range of steppe bird species, including the lesser kestrel (Catry et al., 2007; Moreira et al., 2007). The lesser kestrel population response to nest-site provisioning can be very different in sites with low quality foraging habitat areas as demonstrated by a case study in the last Portuguese urban colony, where the provisioning of a huge number of artificial nests did not prevent population decline (from 81 to 25 pairs between 1995 and 2007) due to continued habitat loss (authors unpublished data; P. Rocha, pers. comm.).

#### 4.4. Concluding remarks

Without knowledge of the limiting factors of population sizes, the management of any bird population is likely to be unpredictable (Perrins et al., 1991). Although good evidence for some actions does exist, conservation actions are often poorly evaluated and are based on anecdote, personal experience and traditional practices (Pullin et al., 2004). Thus, monitoring and evaluating of effectiveness should be an integral part of all conservation projects (Sutherland et al., 2004a). In the Portuguese lesser kestrel population, an evidence-based threat was described recently (Franco et al., 2005), identifying the lack of suitable nest-sites as the main limita-



tion for population size. The massive provisioning of artificial nest-sites in areas with suitable foraging habitat on the scope of a LIFE-Project and the implementation of a medium term monitoring scheme to measure conservation project outcome revealed nest-site provisioning as a powerful and effective measure by mitigating the lack and dependence of traditional breeding sites and by reducing predation rate and interspecific competition, enhancing breeding success and clearly increasing population size.

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