# Is the historical war against wildlife over in southern Europe?

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## Abstract

Most southern European regions have experienced a rapid economical change during the last decades, moving from a historical economy based on agriculture to a society based on industry and technology. We test here whether causes of admission of birds admitted to a large southern European rehabilitation centre, during a 14-year period (1994–2007), reflect these socio-economical changes. Specifically, we estimated the trends in the number of birds admitted to the centre by shooting (S) over the number of birds admitted due to impacts caused by infrastructures (I), for the 10 most commonly admitted species with complete time series available. Species were grouped in three groups following ecological traits: raptors (diurnal and nocturnal) and aquatic birds. Trends were estimated by means of the slope of a linear regression of the log-transformed S/I ratio over time, which provided the finite population growth rate ($\lambda$) and its 95% confidence intervals. We used the ratio to prevent possible biases caused by changes in wild population densities over the years. We conclude that the overall trend in the S/I ratio, as well as the trends for all three bird groups considered, were negative, and indicated a $c$. 10% annual reduction in the number of birds admitted by shooting in relation to those admitted by infrastructure-related injuries. Causal relationships were analysed by means of Poisson regressions on absolute numbers. Importantly we show that despite the direct historical war against wildlife seems to be coming to an end in southern Europe, impact to wildlife continues in an indirect way, as collateral damages caused by our post-industrial way of life. So the overall scenario is most likely not one of improved conservation status in southern Europe, but rather one of shifting ways of impacting wildlife in parallel with socio-economic changes.

## Introduction

The historical relationship of humans with nature has not been a smooth and straightforward one. During Palaeolithic times our kind had to fight with nature for survival, and seemingly Palaeolithic hunter-gathers even led many large vertebrate faunas to extinction often, but not always, following global climate changes (Schule, 1993; Schuster & Schüle, 2000; Flannery, 2001; Roberts, 2007). The consequences of this fight with nature became especially relevant from Neolithic times on, after the invention of large-scale agriculture and livestock domestication, with increased human population size, and an increased capacity of habitat modification by humans. For example many dwarf island faunas, relict of the Pleistocene megafauna, were extirpated across the Mediterranean with the arrival of Neolithic man (Blondel & Aronson, 1999; Blondel, 2007; Alcover, 2008). This way of life based on agriculture and livestock growing has endured basically unchanged for millennia since very

recent times, up to the advent of the modern industrial and technological revolution. In modern times our relationship with nature has changed dramatically, with humans concentrated mostly in large cities, and hence far from the natural world (Miller, 2005; Decker, Kerkhoff & Moses, 2007). This change in socio-economical patterns of our society should affect the way we impact our environment and its associated animal populations (e.g. Ditchkoff, Saalfeld & Gibson, 2006) and, at the same time, such changes should affect historical evolutionary pressures on fauna and flora.

Here we specifically hypothesize that the quick socio-economical changes experienced by southern European countries during the last decades should be reflected by changing patterns in the causes of admission of animals to rehabilitation centres. We predict that there should be a trend from a majority of animals affected by shooting (a typical consequence of a rural society based on agriculture) to a majority of animals affected by impacts related to the construction of infrastructures, such as roads, highways,

power lines, railways or wind power generators. Particularly, we have chosen birds as a study model because birds are known to reflect well habitat changes, especially waterbirds, seabirds and raptors (Morrison, 1986; Bost & Le Maho, 1993; Kushlan, 1993; Rodríguez-Estrella, Donázar & Hiraldo, 1998).

As our study model we have chosen a Spanish southern European region of $23\,255\,\text{km}^2$ characterized by a pronounced and rapid change from a rural structure to an economy largely supported by industry and tourism during the last decades, to a large extent owing to the incorporation of the region to the economical framework of the EU by the mid-1980s of the last century. Human population grew by *c.* 900 000 inhabitants in our model region during 1991–2007 (+23.4%), mainly concentrated in a few large coastal cities. The number of licences for motor vehicles increased by 86% from 1994 to 2004, a total of 9000 km of new roads were constructed during 1990–2004 (increasing the chances of animal road casualties), and the rate of power consumption increased by 68% during the period 1993–2004 (http://www.ine.es), in parallel with an increase of power-related infrastructures, leading to increased chances of animal collision and electrocution. For example, the accumulated wind power in Spain has multiplied six times during the last decade, with 13 800 MW installed in 2007. This profound and fast change has probably caused a substantial detachment of industrialized humans from nature, and hence of the perception of wildlife as a problem (Miller, 2005; Roe, 2008).

## Methods

We studied the number of birds admitted annually to the main rehabilitation centre in the study region, both by shooting ('S' hereafter) and impacts associated to infrastructures ('I' hereafter), during a 14-year period (1994–2007). We tested whether the trend of the ratio between S and I increased or decreased during that period. We worked initially with the S/I ratio, instead of with absolute numbers, as a strategy to prevent (1) a possible bias introduced by the fact that the populations of some of the species considered in the study, but not all, are reinforced during the winter by incoming wintering birds and (2) the bias introduced by unknown increasing/decreasing population trends of the study species in the wild. The probabilities of receiving in the centre a bird that has been shot or poisoned compared with a bird that has been injured by an infrastructure are most likely unequal because more effort is devoted to surveying infrastructures than the countryside, especially private land. However, we assume that this bias has been constant throughout the study period, and hence that unequal probabilities of both events are not a caveat for our analyses.

We analysed the database of the 'La Granja de El Saler' rehabilitation centre (*c.* 3000 animals admitted in 2007, including all taxa), which is administrated by the environmental agency of the regional government (i.e. Generalitat Valenciana) since the beginning of the 1990s. This centre is one the most relevant ones at a national scale, and collects a large part of the animals injured in the study region, owing to the availability of a large number of people (i.e. wardens, police and technicians) involved during the collection stage.

The most commonly admitted bird species (a total of 23) were selected initially, but 13 of them were subsequently discarded because time series were not complete. We were not sure whether lack of information in a particular year meant missing information or truly reflected absence of admissions that particular year; if lack of information was due to missing data the trends detected could be seriously biased (precautionary principle). Hence we finally worked with the 10 most commonly admitted bird species with complete time series for the study period, divided by us in three taxonomical groups, attending to common ecological characteristics: diurnal birds of prey (common buzzard *Buteo buteo*, Eurasian sparrowhawk *Accipiter nisus* and common kestrel *Falco tinnunculus*), nocturnal raptors (little owl *Athene noctua*, barn owl *Tyto alba* and eagle owl *Bubo bubo*) and aquatic birds (grey heron *Ardea cinerea*, cattle egret *Bubulcus ibis*, yellow-legged gull *Larus michahellis* and black-headed gull *Larus ridibundus*), all of them either protected by law or without any true value for hunters, but nevertheless historically affected in this region by hunters with low levels of environmental awareness. The group of species selected has the advantage of providing information on different main habitat types. We analysed a total of 1050 admissions; *c.* 55% were diurnal raptors, 25% nocturnal raptors and 20% aquatic birds.

To prevent a possible inflation of data on birds admitted by impacts due to infrastructures, owing to the fact that admissions by shooting are more likely to occur during the hunting season (October–January), we only considered birds admitted by both causes during those months.

### Statistical treatment of data

Average trends were studied by means of the finite growth rate ($\lambda$) of the ratio of birds admitted annually to the centre by shooting over those admitted by injured caused by infrastructures. $\lambda$ was estimated using simple linear regression analysis of the ratio with time, using the logarithm as a link function, to obtain the slope of the model and its 95% confidence interval (95% CI), so that the back-transformed exponentials of the slope and its CI corresponded to the population growth rate ($\lambda$) and its 95% CI (see Oro & Martínez-Abraín, 2006) which were used to test the null hypothesis of stability ($\lambda = 1$) in the trend of the S/I ratio, so that a CI containing the value 1 implies a statistically non-significant result (Reichardt & Gollob, 1997). Values of $\lambda$ higher and lower than 1 indicate increasing and decreasing trends of the ratio, respectively.

In order to explore the causal relationship between the number of birds shoot (dependent variable) and the number of hunting licences issues and time (correcting by the number of birds admitted with injuries caused by infrastructure) we tested simultaneously several hypotheses by means of Generalized Linear Models with Poisson error (Table 2),

using software R (http://www.r-project.org/). Models were selected by means of information theoretical criteria duly corrected both for small sample size and overdispersion (Anderson, 2008). The magnitude of the effects (effect size) was evaluated by means of the slopes of the regressions and its standard errors or 95% CIs.
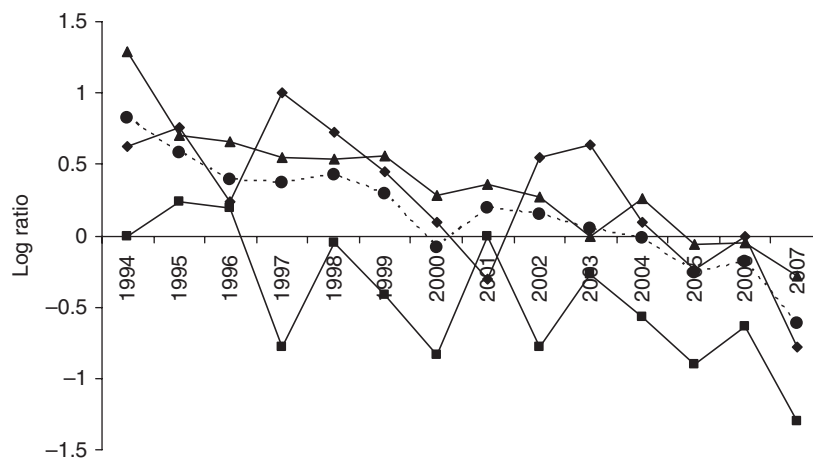
## Results

Interestingly all three taxonomic groups considered showed a similar trend, both in direction and magnitude (Table 1 and Fig. 1). Our log-transformed linear model showed a great degree of fit to data ($r^2 = 0.87$; $r^2_{adj} = 0.86$), suggesting exponential decrease of the actual curves. The overall trend in the S/I ratio, as well as those of the three bird groups considered, were negative, statistically significant (indicating a departure from population stability), and had a low uncertainty associated (narrow 95% CIs). Estimated finite population growth rates indicated a $c$. 10% mean annual reduction in the number of birds admitted by shooting in relation to those admitted by infrastructure-related injuries. The most linear trend of all bird groups analysed was shown by diurnal (coefficient of variation $C_v = 1.07$) and nocturnal ($C_v = 1.10$) raptors, whereas aquatic birds showed a higher inter-annual variability ($C_v = 1.79$) (Table 1 and Fig. 1). Considering that 55% of admissions corresponded to diur-

nal raptors, and that this group showed the most clear linear trend, it turns out that the overall trend in the ratio was mainly determined by diurnal raptors.

After comparing and selecting the Poisson regression models exploring causal effects among variables we found that the hypothesis including an additive relationship (similar slopes, different intercepts) between number of licences issued and number of birds admitted due to infrastructure-related causes had the highest support with the evidence available. This suggests that the observed decrease in the S/I ratio was most likely due both to an actual decrease in direct persecution but also to an increase in indirect damage to wildlife (Table 2). An examination of the slopes from Poisson regressions including only one of the two variables at a time indicated that the decrease in shooting pressure was due to a larger extent to an increase in the number of birds affected by infrastructures than to a decrease in hunting licences (slope $\pm$ SE: infrastructures $-0.010 \pm 0.0030$; licences: $1.78 \times 10^{-5} \pm 1.87 \times 10^{-6}$).

**Table 1** Mean growth rates of the log of the ratio between admissions due to shooting (S) and impacts caused by infrastructures (I), of birds admitted in a major rehabilitation centre in southern Europe during a period of 14 years

| Taxonomic group | $\lambda$ ratio S/I | Lower 95% CI | Upper 95% CI |
|---|---|---|---|
| Diurnal raptors | −1.09 | −1.12 | −1.07 |
| Nocturnal raptors | −1.08 | −1.14 | −1.03 |
| Aquatic birds | −1.09 | −1.15 | −1.03 |
| Total | −1.09 | −1.11 | −1.06 |

CI, confidence interval.

**Table 2** Multiple hypothesis testing to study the causal relationships between the number of birds admitted due to shooting to a major rehabilitation centre located in southern Europe, during a 14-year period, in relation to time and number of hunting licences issued in the region during that period, controlling by the number of birds admitted to the centre due to impact caused by infrastructures

| Model | Deviance | QAIC$_c$ | $\Delta$QIC$_c$ | K | $w_i$ |
|---|---|---|---|---|---|
| t + infrastructures | 22.4 | 23.01 | 4.2 | 3 | 0.08 |
| t + licence | 29.5 | 20.34 | 1.6 | 3 | 0.29 |
| t + licence + infrastructures | 21.4 | 32.41 | 13.6 | 4 | 0.00 |
| **Licence + infrastructures** | **36.3** | **18.77** | **0** | **3** | **0.63** |

+, a linearized relationship with different intercepts but same slope. The best model of the set compared is highlighted in bold.
QAIC$_c$, Akaike's Information Criterion corrected for overdispersion and small sample size; deviance, residual deviance; K, number of estimable parameters; $w_i$, Akaike weight of each model.



**Figure 1** Evolution of the ratio of the number of birds admitted by shooting over the number of birds admitted due to impacts caused by infrastructures in a major rehabilitation centre in southern Europe, during the period 1994–2007 (in logarithmic scale for comparison). Solid dots, total number of bird species considered; solid squares, nocturnal raptors; solid triangles, diurnal raptors; solid diamonds, aquatic birds.

## Discussion

The negative trend in the S/I ratio for all bird groups considered, together with the decrease trend observed for hunting licences in the region (33% decrease between 1991 and 2000; http://www.ine.es), suggest that the large and rapid economical change of the southern European region under study has led to a decreasing trend in wildlife direct persecution. This is a remarkable finding considering that our history of wildlife persecution dates back thousands of years and that just a few decades ago there was in operation a Spanish Board of Extinction of Dangerous Predators, which used to pay rewards for the capture of raptors and carnivores preying on game. As recently as 1961 as many as 148 wolves, 10 345 foxes, 249 weasels, 43 martens, 551 wild cats, 956 genets, 13 lynxes, four otters, 184 badgers and 8553 polecats were reported to have been killed under governmental support. Regarding birds, the Spanish government paid, between 1955 and 1961, for the carcasses of 784 vultures, 1033 eagles, 20 228 other raptor types and more than 500 000 other birds (including corvids and non-identified raptors) in 10 provinces, representing 27% of the country surface area (Martínez-Abraín *et al.*, 2008*a*). Hence, we may be living a historical moment in the history of our relationships with wildlife, although this of course does not mean that we have reached an optimal situation from a conservation perspective, because some direct persecution still persists, especially in the form of poisoning in private lands (Carrete *et al.*, 2007; Margalida *et al.*, 2008). We have not detected poisoning as a serious direct threat to wildlife, but this may be an artefact due to the low diversity and abundance of scavenger birds in the study region, because poisoning is known to have had a revival in other southern European regions during the last decades (Grande *et al.*, 2008; Oro *et al.*, 2008). In addition, considering that the absolute number of birds admitted due to direct persecution was explained both by the decrease in the number of licences and the increase in birds injured by infrastructures it is likely that although the direct war against wildlife seems to be coming to an end in southern Europe, the collateral damages caused by infrastructures are counterbalancing that positive effect (see e.g. Rodríguez, Crema & Delibes, 1996; Richardson, Shore & Treweek, 1997; Taggart *et al.*, 2006; De Lucas, Janss & Ferrer, 2007; Stewart, Pullin & Coles, 2007; Tellería, 2008). This factor can become more relevant in the near future as the development of infrastructures can grow non-linearly as alternative sources of energy are promoted throughout the Southern European region. So, rather than an absolute improvement in wildlife preservation we are most likely detecting a shift in the way humans affect wildlife, in parallel with the socio-economical changes experienced in the region. Ideally, an update of this study should be done in 10 years time to track the changing way we impact wildlife. On the other hand, considering the increasing number of species habituating to massive harmless human presence (see e.g. Martínez-Abraín *et al.*, 2008*b*) the future can be as well a time in which we humans experience increasing conflicts due to a fearless relationship of wildlife with us (J. A. Donázar, pers. comm.).

## Evolutionary implications

Importantly, ancient evolutionary pressures, associated to human persecution of wildlife during millennia, are coming to an end in regions with a socio-economic history similar to the one under study, being changed by new evolutionary pressures, associated to our post-industrial way of life. For example, hunting can have a highly deterministic component, as it can be directed towards specific stages (i.e. males and oldest animals being preferred), whereas deaths caused by infrastructures have a stronger stochastic component. Hunting therefore can be considered in many instances as compensatory mortality (Nichols *et al.*, 1984), whereas casualties due to infrastructures are most likely additive sources of mortality. Nevertheless, this point is probably more relevant for big game species than for the small game species considered in our study, although hunting could also act as a deterministic selective agent removing the least healthy small game individuals. Also, the old heterogeneity between rural and urban areas regarding mortality risk (i.e. rural areas used to be the largest source of mortality) is now disappearing, because of increased concentration of people in urban areas, and also because of occupation of the population-empty rural areas by all kinds of infrastructures (i.e. roads, power lines, wind farms, solar plants and pipelines). Hence, this homogenization of the landscape also homogenizes the selective pressures experimented by rural and urban wildlife (Ditchkoff *et al.*, 2006), which in the Mediterranean coincides to a large extent with inland and coastal areas.

## Acknowledgements

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Appendix S1.** Number of birds admitted to a rehabilitation centre due to shooting in a southern European region from 1994 to 2007. Data are referred to the ten most commonly admitted species.

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