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# Assessing the effectiveness of a hunting moratorium on target and non-target species

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ABSTRACT

Information on the effectiveness of wildlife management actions is scarce, despite the great relevance of this type of information for maximizing conservation goals while minimizing resource expenditure. Here we assess the management effectiveness of a four-year hunting moratorium, addressed to protecting a declining waterbird game species: common coot *Fulica atra*. We also studied the indirect benefits that this management action could have had on a non-target endangered species (crested coot *Fulica cristata*), currently being reintroduced in the study region (Comunidad Valenciana, eastern Spain). We found that wintering common coots interrupted their marked negative trend coinciding with the hunting moratorium, and Before-After-Control-Impact modelling confirmed this fact. However breeding common coots continued their negative trend in numbers. We also found that crested coots increased their wintering numbers during the hunting moratorium years but not during breeding. We detected a strong and time variant cost of release on survival probability of crested coots, but annual survival probability was found to be constant and low for experienced birds, with no clear effects of the hunting moratorium on survival probability. We conclude that the moratorium had some positive effect on both species, but we suggest that lack of enforcement during a traditional hunting practice at the end of each hunting season, most likely precluded the moratorium having a long-lasting effect on the breeding numbers and probably on survival, of both species. Hence, when fully-enforced hunting moratoria are difficult to implement, we recommend the creation of hunting preserves of high habitat quality to attract coots during the winter, allowing its subsequent reproduction during the breeding season.



## 1. Introduction

The effectiveness of management actions addressed to preserving wildlife is seldom assessed, despite large money expenses may be involved (e.g. in developing compulsory mitigation measures associated to infrastructure construction), and the growing need of basing decision-making on solid scientific evidence (see e.g. Stewart et al., 2005). The biological effects of some types of European wildlife exploitation moratoria, such as those applied to trawler fishing in the Mediterranean, have been well explored (e.g. Oro et al., 1995; Arcos and Oro, 1996; Jiménez and Martínez-Vilalta, 1998; Oro et al., 2004; Laneri et al., 2010) as well as the effectiveness of temperate marine reserves worldwide (Stewart et al., 2009). However, the literature on the biological effects of bird hunting moratoria is scarce in Europe probably because of the difficulty of having proper information (i.e. mainly counts and estimates of survival probability from individually-marked animals), before, during and after the hunting moratorium. Information on adaptive management of waterfowl, including effects of hunting regulations on migratory bird populations, is more common in North America (see e.g. Nichols et al. 2007; Williams and Johnson 1995).

Here we assess the management effectiveness of a four-year (2005–2008) hunting moratorium implemented in southern Europe (i.e. Comunidad Valenciana, eastern Spain), addressed to protecting a declining game species, and the possible indirect effects on a non-target endangered species. This is interesting because the management of threatened species is typically approached by means of direct conservation measures aiming to improve demographic parameters of the target species. However, species are integrated in assemblages, and constituent parts of animal

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assemblages interact among them in complex ways so that conservation actions addressed to one species can have side effects on others. For example many gregarious bird species experience both conspecific and heterospecific attraction (Mínguez, 1994; Martínez-Abraín, 1998, 1999; Martínez-Abraín et al., 2001). However, heterospecific attraction can sometimes lead indirectly to the formation of ecological traps (see Delibes et al., 2001; Schalaepfer et al., 2002; Battin, 2004; Robertson and Hutto, 2006), when the species acting as a lure is for example a facultative predator or a game species (Dwernychuk and Boag, 1972; Abrams et al., 2012). The latter situation was identified for crested coots (*Fulica cristata*), a critically endangered waterbird species in Europe that gathers in mixed flocks during the winter with common coots (*Fulica atra*), a game species, in southern European wetlands (Martínez-Abraín et al., 2007). Owing to this, crested coots are killed accidentally when common coots are hunted, because both species are indistinguishable under hunting conditions. Hence a hunting moratorium addressed to improving the status of common coots can be an indirect procedure to help improving the current low success of the ongoing reintroduction program for crested coots in eastern Spain (Martínez-Abraín et al., 2011). Crested coots have been subjected to two reintroduction programs in Spain, the above-cited one (launched in 2000), and a second one in Andalusia, southern Spain (Varo and Amat, 2008). For the first one Tavecchia et al. (2009) found that crested coots suffered a high cost in terms of probability of survival immediately after release. This is emerging as a property of many reintroduction programs (see e.g. Oro et al., 2010; Champagnon et al., 2012). In fact immediately-released crested coots had an annual survival probability of 0.14 ± 0.03 (mean ± SE), compared to 0.20 ± 0.04 for individuals surviving in the wild more than one month after release but less than one year, and 0.66 ± 0.20 for coots surviving at least one year after release (Tavecchia et al., 2009). The cause of this high local or apparent mortality during their first year of life has not been properly identified yet, but it could be at least partially related with incidental mortality during the winter hunting season, together with low habitat quality for the species at release sites, and lack of experience in the wild (op. cit.). We explore here whether the implementation of the four-years hunting moratorium fulfils the expectancy of wildlife managers of improving the demography of common wintering and breeding common coots, as well as that of the associated crested coots, or not.

## 2. Methods

### 2.1. Effects of the moratorium on common coots

Firstly, the change over time in common coot numbers during wintering and breeding periods were modelled as a smooth non-linear function of time using generalized additive models (GAM; Hastie and Tibshirani, 1990) and the corresponding mixed models (GAMM; Wood, 2006). More specifically we used Negative Binomial GA(M)M to deal with overdispersion (Zuur et al., 2009). GAMs are useful for modelling trends because they incorporate smoothing procedures into the model fitting process, and allow a range of curves to be considered (linear trends to annual fluctuations). GAMs also allow for a statistical test of changes in direction of the index trajectory (Fewster et al., 2000), and the relationship between response and time is assumed to be smooth but not necessarily linear (O'Brien et al., 2010). For the selection of the degree of smoothing, controlled by specifying degrees of freedom, we followed Fewster et al. (2000). Temporal autocorrelation was tested on the basis of AIC, and taken into account with an auto-regressive model of order 1 (AR-1; Zuur et al., 2009).

We followed Fewster et al. (2000) and Buckland et al. (2005) to analyze direction, magnitude, and timing of changes in breeding and wintering common coot abundance. The rate of change in the number of breeding pairs or wintering birds was measured by the slope (i.e. first derivative), of the smoothed trend. Non-linear trends allow for changes in the rate of change over time. Fluctuations over time in the rate of change were measured by calculating the second derivative of the trend at each time point, and the (non-parametric) bootstrapped 95% confidence interval around the second derivative. If the second derivative is greater than zero, the curve is turning upward, while if it is less than zero, the curve is turning downward. The magnitude of the second derivative quantifies the tightness of the curvature. Values of approximately zero indicate that the model curve is roughly linear, and the population trajectory is changing at a steady rate. Years in which the second derivative is markedly different from zero are those in which something is altering that rate of population change. In conjunction with other temporally-referenced data, the timing of the change points might help to suggest causes of the change (Fewster et al., 2000). All results in this paper were obtained from 3000 bootstrap replicates. Analyses were performed using software R (R Development Core Team, 2010) with packages mgcv (Wood, 2006), nlme (Pinheiro et al.,2013), and boot (Davison and Hinkley, 1997). Data consisted on single counts performed in the month of January every year.

Secondly, to analyze the effects of the hunting moratorium on common coots we performed a BACI analysis (BA = before/after and CI = control/impact) (Underwood 1994). We modelled the number of common coots counted, on an annual basis, during the wintering and breeding seasons, in 10 wetlands of Comunidad Valenciana (Fig. 1) during the period 1990–2012 as a function of BA and CI. We controlled for time as a continuous variable to account for possible variations in the number of coots due to annual variations not related to the moratorium. Factors before-after and control-impact were introduced as dummy variables (0–1) in each case. Our design included 15 pre-moratorium years, 4 years during moratorium, and 3 years after the moratorium for wintering coots and 9, 4 and 3 years, respectively, for breeding coots. However, for our modelling we grouped the years during and after the hunting moratorium to avoid power problems. The study sites included 7 wetlands which were affected by the hunting moratorium ("treatment or impact" hereon): Cabanes, Mijares, Almenara, Moro, Albufera, Xeresa-Xeraco and Pego-Oliva, and 3 sites which were not ("control" hereon): El Hondo, Santa Pola and Galvany (Fig. 1). Hence we had information on the abundance of common coots before, during and after the moratorium for treatment and control areas. For our BACI analysis we used Generalized Linear Models with negative binomial errors and log link to deal with the large overdispersion detected when modelling our coot counts with Poisson errors, after empirically discarding the quasi-Poisson family as a good alternative (see Crawley, 2007; Zuur et al., 2009). We built multiple models, corresponding to biologically-meaningful hypotheses, and compared and selected them by means of AIC-based criteria (Burnham and Anderson 2002; Anderson 2008). If the moratorium had an effect on coot abundance we would expect to select as the most parsimonious model the one containing an interaction term between the factors BA and CI, meaning that the number of coots had changed in a different way in control and impact sites in relation to the hunting moratorium. BACI analyses were performed using R library MASS (Venables and Ripley, 2002).

### 2.2. Effects of the moratorium on crested coots

Since crested coots are not present in the control area (southern Alicante province wetlands, bottom part in Fig. 1), except for a few occasional individuals in some winters, we were not able to