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Habitat- and density-dependent demography of a colonial raptor in Mediterranean agro-ecosystems

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ABSTRACT

Agricultural intensification is considered the major cause of decline in farmland bird populations, especially in the Mediterranean region. Food shortage increased by the interaction between agricultural intensification and density-dependent mechanisms could influence the population dynamics of colonial birds. We used demographic data on lesser kestrels (*Falco naumanni*), a key species of Mediterranean pseudo-steppes, to understand the importance of land-use changes and density-dependent mechanisms in the light of its fluctuating conservation status in the Western Palearctic. Our analysis indicated an important influence of land uses (artichokes, arable and grassland fields) and colony size on kestrel survival rates. The strong habitat effect revealed the unsuitability of intensive arable lands with respect to extensive grasslands for lesser kestrels. Notably, artichokes, a winter-intensive crop, proved to be a high-quality habitat as they were associated with survival values equal to those of grassland. This is likely due to prey availability and reveals that non-traditional crops may provide suitable habitats for lesser kestrels. Information theory gave strong support to the negative influence of colony size on fecundity, albeit a small one, for its positive effect on survival probability. The estimated population growth rate was negative for all three habitats, indicating a decline over time and urging conservation actions in all of the areas studied. This decline was much higher in colonies surrounded by arable fields. In sensitivity analyses, λ indicated that adult survival was the parameter with the greatest effect on population growth, followed by survival of fledglings and fecundity. Our study showed how the costs and benefits of group living interact with agricultural intensification to drive species demography. In addition, we integrated significant information on one of the largest lesser kestrel populations to fine tune the most effective conservation strategy to prevent the collapse of the species in a relevant part of its range.

1. Introduction

The polarization of agriculture, with the intensification of farming practices in flat and coastal areas and the abandonment of less productive and marginal lands, is causing great landscape changes on a global scale (Donald et al., 2001; Baldi et al., 2013; Pe'er et al., 2014). This polarization is promoting wildlife-unfriendly farming systems (Brambilla et al., 2008), with a consequent loss of biodiversity in Europe, especially in regard to farmland birds (Butler et al., 2010; Sokos et al., 2013; Berg et al., 2015). Common Agricultural Policy (CAP) through the agri-environmental schemes (AES) provides the major mechanisms to support conservation actions in agro-ecosystems and faces the challenges of the expansion of the EU common market (Stoate et al., 2009; Sokos et al., 2013). Even if the EU recognizes biodiversity as a priority and modifies agricultural policies to stop and reverse the biodiversity loss (European Commission, 2006), agricultural intensification is still an ongoing process. The reformed CAP for 2014-20 provided new environmental prescriptions such as organic farming and protection of traditional rural landscape, which have been argued to be too weak to benefit biodiversity (Pe'er et al., 2014).

Dramatic modifications occurred in Mediterranean pseudo-steppes, a global biodiversity hotspot (Myers et al., 2000), such as the reduction in fallow land and field margins, removal of semi-natural patches, increase in irrigated lands, and abuse of biocides, all of which seem to contribute to the decline of farmland birds and other wildlife (Sirami et al., 2008; Gonzalez-Estebanez et al., 2011; Sokos et al., 2013; Chiatante et al., 2014).

It has been suggested that avian species breeding in pseudo-steppes and aggregating in breeding colonies would suffer the most from the current intensification of farming practices (Lane et al., 2001; Catry et al., 2012). The causal link between the decline of such avian species and agricultural changes has been proposed to operate via density-dependent mechanisms, where colony size plays a crucial role (Rodrıguez et al., 2006). In many cases, spatial arrangement between food and nest-site availability determines the number of breeders within colonies, i.e. colony size (Rodrıguez et al., 2006). Moreover, food

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depletion due to intraspecific competition, a density-dependent mechanism, regulates colony size and, ultimately, the population growth rate (Lewis et al., 2001; Forero et al., 2002). It is thus likely that agricultural intensification would exacerbate density-dependent effects, so we might expect large colonies, characterized by higher food demand and increased levels of agonistic interactions (Serrano and Tella, 2007), to be more vulnerable to food depletion when placed in fast changing agro-ecosystems. In other words, the relationship between agricultural changes and colony size may have serious implications, still poorly known, for the understanding of population dynamics in colonial birds living in a pseudo-steppe habitat.

Here, we investigate how different agricultural habitats and colony sizes may drive the demography of the colonial lesser kestrel *Falco naumanni*, breeding in a pseudo-steppe of southern Italy. The lesser kestrel is an appropriate model for the study of species–habitat relationships because of its role as biological indicator for the monitoring of population dynamics of pseudo-steppe avian species (Bustamante, 1997). The demography of lesser kestrel populations was first investigated in Spain (Hiraldo et al., 1996) with the aim of estimating the probability of species extinction and evaluating different management actions. Monitoring lesser kestrel populations beyond the Iberian peninsula might provide further indications for preserving steppe wildlife and setting management strategies applicable not only on the local but also on the regional scale within Europe (Kolb, 2000; Sarà, 2010). The species has recently been downgraded from the 'Vulnerable' to the 'Least Concern' IUCN category (Iñigo and Barov, 2011) but population trends are highly variable across its range, including local cases of population decline (Iñigo and Barov, 2011). In reality, where management measures were applied, the lesser kestrel has improved its conservation status (Catry et al., 2012), while in areas of the Palearctic range (e.g. Italy), without effective conservation strategies, populations are fluctuating (Sarà, 2010). To allow full conservation recovery across the range, it would be necessary to identify, assess, and ultimately prevent the factors affecting the lesser kestrel's fluctuating demography, especially in rapidly human-altered environments and in the light of the six-year reporting cycle under Article 12 of the Birds Directive 2009/147/EC and the 2020 review of the European lesser kestrel Action Plan.

In this study, we aimed to i) quantify the effect of land uses on fecundity and survival probability, and its potential interaction with colony size; ii) identify which demographic component was more important in determining the population growth rate; and iii) provide conservation guidelines to improve habitat suitability for one of the largest Italian populations of lesser kestrels.

Lesser kestrels tend to forage close to the breeding colony (García et al., 2006). As a consequence, we expect a direct influence of habitat around the colonies on survival and fecundity. In particular, we expect both parameters to be higher in territories characterized by extensive agriculture with expected high food availability (García et al., 2006). Previous works have found higher survival probability in large colonies compared with medium or small ones and concluded that colony size was the causative factor (see, for example, Serrano et al., 2005). Because for a given colony size, per capita food availability would depend on the total amount of resources, we also explored the simultaneous effect of colony size, habitat type and their interaction, i.e. the relative effect of colony size according to the habitat considered.

2. Methods

2.1. Study species and data collection

The lesser kestrel is a small raptor that lives in pseudo-steppes of the Western Palearctic and spends the winter in West Africa (Iñigo and Barov, 2011). It is a facultative colonial species that usually breeds in association with jackdaws *Corvus monedula* and rock pigeons *Columba livia* (Campobello et al., 2012, 2015). From spring to summer between 2004 and 2012 (with the exception of 2008), an average of 14 ± 4 (range 8–24; $N = 28$) colonies per year were visited in an area of 474 km^2 corresponding to the Gela Plain in southern Sicily (Italy, 37° 07′ N, 14° 19′ E). The Gela Plain hosts one of the most important lesser kestrel breeding populations in Italy, with colony sizes ranging from 1 to 45 pairs (Sarà et al., 2012). Since the 1950s, the human population has shifted from the villages to the main two cities in the area, and the rural past of the Gela Plain is characterized by several farmhouses and rural buildings, partially destroyed or abandoned, that currently host 84% of the lesser kestrel colonies occurring in the area (the remaining 16% nesting in cliffs; Sarà, 2010). We defined a breeding colony as a man-made building with at least one pair of kestrels performing some reproductive behavior at the site (i.e. a male delivering prey to a female, copulation or inspection of nest chambers) (Di Maggio et al., 2013; 2014). Visits to the colonies were conducted periodically, at the time of site occupation and egg-laying (April–May), incubation and hatching (May–June), and fledging (June–July). During these visits, we captured breeding adults in accessible nests, recorded reproductive parameters, and ringed nestlings using metal and darvic rings with unique alphanumeric codes. We carefully inspected colony buildings looking for dead birds, and checked their sex, age, and whenever possible, causes of death. During the same periods, 2 to 4 experienced observers conducted resighting sessions of one hour per colony with 20×60 spotting scopes to check lesser kestrels marked in previous years. Every year, the same observers conducted two to three resighting sessions per month in three roosts (one on a pine-tree, two on electric pylons) where most of the population gathered at night. Birds at the roosts were neither breeding juveniles of the past year nor breeding adults. Double records of the same birds, in the roost and at the colony, proved that many breeders spent the night outside of their colony. Adults were also observed there after having failed to reproduce (M. Sarà, unpublished results). We recorded the sampling effort as the number of days spent in the field per year, and used this covariate as a predictor of resighting probability. Since our data encompass both physical recaptures and resighting of individuals, we addressed them with the general term of 'encounters' (Serrano et al., 2005).

2.2. Habitat types

The Gela Plain, due to limited precipitation (350 mm/yr), is composed of a mosaic of pseudo-steppes dominated by artichoke fields (*Cynara* spp.), in rotation with wheat (*Triticum* spp.) and leguminous cultivations (80.9%, Triolo et al., 2011). The rest of the area contains pastures and xeric vegetation, predominantly graminaceous plants and Mediterranean shrubs (*Stipa capensis* and *Hyparrhenia hirta*; 10.7%) and small artificial Eucalyptus and pine stands (3.7%; Sarà et al., 2012). Previous landscape analysis revealed a strong decrease in Mediterranean shrublands and grasslands from 1867 to 2000, replaced by arable lands, vineyards and greenhouses (Russo et al., 2009). Historically, the cultivation of cotton was predominant in the area until the latter half of the past century when it was gradually replaced by artichokes in the 1960s–80s. Today, agricultural intensification is increasingly changing the core area of the Gela Plain with irrigated crops implanted after the artichoke harvest. Nonetheless, the Gela Plain includes a Special Protection Area (SPA, ITA050001) and a Site of Community Importance (SCI, ITA050011) and constitutes an Important Bird Area (IBA 166; Gariboldi et al., 2000). A Principal Component Analysis (PCA) was used to summarize the essential land-use characteristics within an area of radius 1 km around each colony (Bonal and Aparicio, 2008; online Appendix A1). Results indicated that the habitat surrounding the colonies was characterized by one of the three main habitat types (arable, artichoke or grassland (Table A1 and Fig. A1) and thus we assigned each colony to one of these habitats for survival and demographic modeling (Soliveres et al., 2011; Fig. A2). PCA was calculated using STATISTICA 8.0 (www.statsoft.com).