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# Spatial analysis of lanner falcon habitat preferences: Implications for agro-ecosystems management at landscape scale and raptor conservation

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ABSTRACT

Sicily hosts the largest European population of the endangered lanner falcon, a poorly known species which needs conservation planning based on habitat preferences. A distribution model on 10 × 10 km cells of Sicily was described using Generalized Linear Models and variation partitioning methods. This modelling approach extracted explanatory factors, pure and joint effects of greatest influence from subsets of variables controlled for multi-collinearity and spatial autocorrelation. Analytical cartography used the environmental favourability function to assess habitat preferences, and the insecurity index estimated the degree to which lanner falcon occupancy is represented in the Natura2000 networks of Sicily. The lanner population is not randomly distributed across the geographical space as the significant latitudinal effect revealed. The most parsimonious explanatory model suggested traditional agro-ecosystems (i.e. arable lowlands and grasslands, with rugged terrains and cliffs) as the best predictors of lanner occupancy, and gave strong support to the negative effects of land abandonment and intensification (i.e. increase of heterogeneous areas and shrubby vegetation). The variation partitioning method suggested how an alteration of traditional agro-ecosystems might enhance interference competition with the peregrine falcon and limit lanner falcon occupancy. Most of the lanner falcon favourable habitats fall outside the Natura2000 networks, thus the main challenge for its conservation is represented by agri-environmental measures to be taken within the Common Agricultural Policy of the European Union. Conservation of traditional agro-ecosystems devoted to top-predators, like the lanner falcon, requires single environmental management agreements for multiple farm units, deployed at landscape scale on a network of favourable areas.



## 1. Introduction

Complex gradients of anthropogenic disturbances and historical changes of land uses have created over millennia, the agro-sylvo-pastoral landscape mosaics (=agro-ecosystems) of the Mediterranean basin (Blondel and Aronson, 1999). Actually, these human-generated open landscapes contain more specialised bird communities than forests (Clavero and Brotons, 2010), and the high species diversity and endemism of the Mediterranean basin is documented as a global biodiversity hotspot (Myers et al., 2000).

Biodiversity is one of the three priority levels for the European Union (EU), whose agricultural policies should have been adapted to halt the rate of biodiversity loss by 2010 and beyond (European Commission, 2006). Nevertheless in the last decades, expansion of the EU and its common market continued driving agricultural intensification; and the EU Common Agricultural Policy (CAP) is influencing the management of nearly half of terrestrial area of Europe, so causing vast landscape-scale changes (Pe'er et al., 2014). According to Balmford et al. (2009), intensification of farming practices in flat and coastal areas and abandonment of less productive and marginal lands, represent the main threats of agriculture on wildlife. These two opposite trends are rapidly changing friendly-to-wildlife farming systems (Brotons et al., 2004; Brambilla et al., 2008), and they will be even more enhanced, as forecasted by a range of future land-use change scenarios in the EU countries (Rounsevell et al., 2006). Changes in Mediterranean agro-ecosystems are affecting bird communities (Fonderflick et al., 2010; Sirami et al., 2008) and wildlife diversity (e.g. dung beetles, Zamora et al., 2007). Therefore, the widespread decline in European wildlife linked to agro-ecosystems currently presents a major conservation challenge (Butler et al., 2010; Green et al., 2005; Pain and Pienkowski, 1997), and understanding what

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specific land uses cause the most serious effects on wildlife and how they might evolve is required to estimate anthropogenic impacts on biodiversity of the Mediterranean basin (Donald et al., 2001; Foster et al., 2003).

The recognized broad influence of the CAP on the EU biodiversity has promoted the Rural Development Regulation (Pillar 2 of the CAP), trying to promote the maintenance of agro-ecosystems through measures designed to encourage farmers to protect and enhance habitat quality on their farmlands (Pe'er et al., 2014). Agri-environment schemes (AES) provide for payments to farmers in return for a service that is the maintenance of agricultural practices allowing the conservation of threatened species (De la Concha, 2005; European Commission, 2005). AES were introduced into EU law in the 1980s, and although designed primarily as a production control measure, they rapidly became the most important support to biodiversity in agro-ecosystems across the whole Europe (Whittingham, 2007). Depending on the species and landscape studied, AES were successful for some species and neutral for others (Batáry et al., 2011; Broyer et al., 2014; Reino et al., 2010), or even had negative effects (6% of cases reviewed in Kleijn and Sutherland, 2003). Nonetheless, Kleijn and Sutherland (2003) found a positive response for biodiversity in the 54% of cases reviewed across Europe, as well as many recent studies on plant and animal diversity did (e.g. Hiron et al., 2013; Kovács-Hostyánszki and Báldi, 2012; Pywell et al., 2012). Despite their patchy success (Sutherland, 2004) and debates on their effectiveness (Whittingham, 2011), AES still provide the major tool to support conservation actions in agro-ecosystems (Stoate et al., 2009).

As main legislation for wildlife conservation, beside the institution of National and Local Nature Parks and Reserves, the EU has coordinated the implementation of a conservation network at a large spatial scale, namely the Natura 2000 (N2000). This protection network is based on the Birds (79/409/EEC, then amended in 2009/147/EC) and Habitats Directive of the European Union (92/43/EEC, consolidated in 2007), which focuses on the preservation of the favourable conservation status of threatened habitats, animal and plant species (as listed in the Annexes of both Directives). In many EU countries, AES implementation forms a substantial part of nature protection relative to farmed landscapes within the N2000 networks (European Commission, 2005).

Species distribution models (SDM, Guisan and Thuiller, 2005) are increasingly being used to address a wide range of questions in ecology, conservation and environmental sciences (Elith and Leathwick, 2009). In conservation biology, one major goal of regional-scale modelling is to search for anthropogenic drivers (e.g. land use change), abiotic factors (e.g. topography, climate), biotic interactions (e.g. competition), as well as historical and contingent factors that shape species distributions; with the aim to assess the impact of environmental changes and then support management plans for species recovery (Guisan and Thuiller, 2005; Rodríguez et al., 2007). Species distribution models commonly follow a correlative approach to combine species occurrence data with environmental conditions where a species is known to be present or absent, and then to build a representation of a species' ecological affinities (Guisan and Zimmermann, 2000; Franklin, 2009). Model predictions based on this approach have made a considerable contribution to identification of species-environment relationships (Bustamante and Seoane, 2004; Di Vittorio et al., 2012; Lane et al., 2001) and conservation strategies (López-López et al., 2007a,b; Poirazidis et al., 2004) for threatened avian species in Mediterranean area.

Within this context, the lanner falcon (*Falco biarmicus*), which is distributed across Africa, the Middle East and South-eastern Europe (Ferguson-Lee and Christie, 2001), is an ideal candidate for testing the effects of potential land use changes on wildlife and, if necessary, identifying conservation actions for threatened species in Mediterranean agro-ecosystems. The European subspecies of lanner falcon (*F. b. feldeggii*) is a medium-sized top predator, which inhabits Mediterranean steppe-like habitats, where it preys upon a variety of vertebrates, including diurnal and nocturnal raptors and carnivores (Massa et al., 1991). It is included in Annex I of the 2009/147/EC Bird Directive and is classified as vulnerable (Birdlife International, 2004), due to its small population and dispersal range. The largest European population of *F. b. feldeggii*, is found in Sicily (AA.VV., 2008; Sarà, 2008), but its range extends to continental Italy (Andreotti et al., 2008). In spite of its rarity and unfavourable conservation status, very little is known about the ecology and habitat requirements of this species (Andreotti and Leonardi, 2007).

The landscape perspective, involving the analysis of large territories, has recently been targeted as the best approach towards conservation (Pressey and Bottrill, 2009; Sanderson et al., 2002). Understanding how and where the lanner falcon occurs in a landscape that is becoming increasingly degraded and fragmented by anthropogenic pressure is a necessary prerequisite for conservation planning that aims to mitigate the population decline in its core Mediterranean range. Therefore, the first purpose of this study was to model the distribution of the lanner falcon at the landscape scale, to categorise the environmental features that best predict its habitat preferences.

As an Annex-I species, the lanner falcon would benefit from Special Protected Areas (SPAs) implemented on behalf of the Birds Directive. The Insecurity index can be used to assess the degree to which any target species is represented in an existing system of protected areas (Díaz-Gómez et al., 2013). Therefore, the second purpose of this study was to quantify how much of the regional N2000 network envelops the species' habitat preferences to further implement conservation actions.

The aims in more detail were: (i) to check whether there is a spatial structure in lanner falcon occupancy; (ii) to identify the landscape factors that influence its occupancy in Sicily; (iii) to assess whether the current regional N2000 network is adequate to preserve the population; (iv) to highlight conservation actions required to viably maintain, inside and outside the N2000 networks, the largest European population of lanner falcons.

## 2. Materials and methods

### 2.1. Study area

Sicily, the largest Mediterranean island, was selected as a study area that is representative of the lanner falcon range. It extends over an area of 25,832 $km^2$ and is one of the most populated regions of Italy (193 inhabitants per $km^2$). Almost 24.4% of the territory is mountainous, 61.4% is composed of highlands, and 14.2% of the surface is lowland. Forests and Mediterranean vegetation, of which almost 6–8% burns every year, cover 8.4% of the surface area (APAT, 2005). There is considerable habitat heterogeneity in hilly and flat inland areas, where cultivation zones (especially arable land, fodder, vineyards and olive orchards) alternate with forest patches of non-native species (*Pinus* spp. and *Eucalyptus* spp.), natural evergreen woodlands (*Quercus* spp.), Mediterranean xeric grasslands and shrub vegetation.

### 2.2. Census and the measurement of variables at the landscape scale

The database of lanner falcon occupancy (i.e. presence/absence) was obtained from the Atlas of Sicily (AA.VV., 2008) and from specific field surveys in the breeding territories (Andreotti and Leonardi, 2007; Di Vittorio, 2007). Together with collaborators