



## Terrestrial birds as indicators of agricultural-induced changes and associated loss in conservation value of Mediterranean wetlands

Francisco Robledano<sup>\*</sup>, Miguel A. Esteve, Pablo Farinós, M. Francisca Carreño, Julia Martínez-Fernández

Departamento de Ecología e Hidrología, Facultad de Biología, E-30100 Espinardo (Murcia), Spain

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### ABSTRACT

During the last decades, agricultural intensification has modified the hydrology of Mediterranean wetlands, as has occurred in the Mar Menor coastal lagoon (SE Spain). Salt-steppe dominated wetlands, characteristic of transitional areas surrounding this lagoon and rich in biodiversity values, are threatened by changes in their water regime originated by land-use changes in the watershed. Traditional dryland cultures have also been replaced by irrigated ones. We assess the direct and indirect changes induced by agriculture on a terrestrial vertebrate community (steppe birds) especially sensitive to these ecosystem changes. This is made on the basis of several surveys of terrestrial birds (excluding aerial feeders and raptors) carried out between 1984 and 2008 in a representative wetland of the lagoon's continental margin (Marina del Carmolí). The changes in this bird assemblage reflect the hydrological modifications induced by agriculture at the watershed scale, which have significant effects on the relative representation of wetland habitats. Bird metrics and indices (species abundance, taxonomic composition, conservation value) describe these community changes as the combination of early declines in some species and families, and transient or late increases in other. In the long term, the family *Alaudidae* (and particularly species like *Melanocorypha calandra*) have lost importance to the benefit of *Turdidae* and *Fringillidae*. The area of salt-steppe explains a large part of the variation in the abundance of *Alaudidae*, while most variation of *Turdidae* and *Fringillidae* respond to the area of saltmarsh. Some *Alaudidae* seem to take advantage of the intermediate stages of saltmarsh expansion (*Calandrella rufescens*), or from the marginal irrigated crops fringing the wetland (*Calandrella brachydactyla*) that could compensate the loss of original agricultural habitats. Habitat changes in the wetland have occurred in three differentiated stages, and modify the steppe bird community towards a more heterogeneous assemblage including scrubland and palustrine species. Among three indices of ornithological value, only that based on the EU Bird's Directive Annex I species was negatively affected, but since the wetland has been designated a Specially Protected Area under this regulation, this represents a management failure. There exists some chance, however, to manage peripheral cropland in favour of biodiversity. The importance of monitoring in conservation evaluation and management is also stressed, since the terrestrial bird community of this wetland has not been regularly surveyed. In fact, its evaluation against the Bird's Directive criteria was made in a period of quick departure from the original, good ecological state of the wetland.

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### 1. Introduction

The importance of wetlands is increasingly recognised as systems supporting specific and valuable biodiversity (Maltby, 1986; Gibbs, 2000), and as areas playing a key role in essential ecological functions such as the control of sediment and nutrient flows and the removal of diffuse pollution at the landscape scale (Álvarez-Rogel et al., 2006; Moreno et al., 2007). This has promoted

different protection and conservation strategies which in the context of arid regions have an especial importance due to the singularity and key role of wetlands in their landscapes. However, conventional protection and conservation strategies usually do not take into account the close dependency of wetlands on the dynamics and management outside the protected area and this may interfere with the protection and conservation goals. Land use and management practices at the watershed scale affect the wetlands in many ways and especially through processes linked to the flows of water and nutrients reaching the wetlands.

In this context, we need to determine the extent to which wetlands react to land-use changes in the watershed, and how

<sup>\*</sup> Corresponding author. Tel.: +34 868 88 43 24; fax: +34 868 88 39 63.  
E-mail address: [frobleda@um.es](mailto:frobleda@um.es) (F. Robledano).

these changes can be tracked in different ecological compartments of the wetlands. We have tried to answer these questions studying a suite of biological indicators in a complex of wetlands in an arid landscape which has suffered important long-term land-use changes: The Mar Menor lagoon and its associated wetlands (Esteve et al., 2008; Pardo et al., 2008).

Urban changes, tourist development and especially the spread of irrigated agriculture favoured by the construction of the Tagus-Segura water transfer scheme in 1979, have led to a significant increase in the water and nutrient flows reaching the lagoon-wetlands complex. In the wetlands this has caused changes which are relevant at the complex scale, due to the role of the active wetland area in the removal of nutrients from diffuse sources, and also at the scale of the wetland itself, due to the effects on biodiversity. Understanding the dynamics of change is therefore important for conserving the biodiversity of the wetlands and for the sustainable management of the Mar Menor lagoon and watershed. The identification of indicator taxa is also a relevant issue for the monitoring of wetland changes, especially if these taxa share the properties of being ecosystem health and biodiversity indicators (Caro and O'Doherty, 1999; Duelli and Obrist, 2003). In this paper we focus in terrestrial birds as proximate indicators of habitat changes caused by irrigation and water drainage.

Birds have been used as bioindicators for many reasons, including the understanding of their ecology, the clearly demonstrated links among bird communities, vegetal associations, and territory, their coverage of different levels of the ecological pyramid in every environment, their detectability allowing rapid data collection not only on presence/absence but also on abundance (Padoa-Schioppa et al., 2006). Moreover, bird taxa are appropriate indicators for monitoring changes at ecosystem scale because (i) birds occur across a broad gradient of anthropogenic disturbance, from pristine wilderness to metropolitan areas; (ii) most birds live only a few years, so changes in species composition and abundance will manifest relatively quickly after a disturbance; and (iii) systematic and extensive bird surveys are currently conducted across many countries. Finally, birds are important to a large segment of the public, so the public may better relate to concerns about changes in bird communities than to those of other less popular taxa (Browder et al., 2002). In the European context, the advantages of birds as indicators, particularly with regard to agricultural intensification, have been pointed out by Gregory et al. (2005), and more recently Everard (2008) reaffirmed the value of bird based environmental indicators against other taxa using semiobjective criteria.

Surveys of bird populations and communities have been carried out in the Mar Menor lagoon and its associated wetlands since the early 70s of the past century. Previous pioneer studies (Guirao, 1859; Zamorano Ruiz, 1932) already recognise this as a rich area in terms of ornithological diversity. Monitoring effort, however, has been quite heterogeneous and still in recent years varies greatly in space and time. Long time-series of biological data are scarce, with the exception of wintering waterbird census more recently complemented by breeding waterbird population surveys. Typically terrestrial or palustrine bird communities (e.g. steppe and reedbed passerines) have been studied much less intensively, and good long-term records are scarce or totally lacking. In this paper we focus on terrestrial bird communities, and especially on steppe passerines which have the greatest conservation value in the European context (Tucker, 1997; Birdlife International, 2004; Santos and Suárez, 2005; Burfield, 2005). Although far from the systematic record of waterbirds, steppe passerines have the second best series of data among the potential ornithological indicators of landscape and environmental change in the wetland complex. We were able to reconstruct a series of data extending from 1984 to

2008, through the compilation of several surveys undergone in the same wetland area by the own authors and other researchers (Hernández, 1995; Torralva et al., 2003; Robledano et al., 2006), and to relate these with a comparable dataset on wetland habitat variation at the wetland scale. Since this variation has a well-documented relationship with agricultural intensification in the Mar Menor watershed, this allowed us to analyse the direct and indirect effects of agriculture (changes in the crop system and induced habitat changes) on this especially sensitive vertebrate community.

## 2. Study area and methods

### 2.1. Study area

The Mar Menor lagoon is a hypersaline Mediterranean coastal lagoon located in Southeast Spain (Fig. 1). Ramsar Site since 1994, is the largest water surface of the western Mediterranean coast (135 km<sup>2</sup> surface area and a 580 hm<sup>3</sup> volume), and a remarkable biodiversity and scientific resource (EU Bird Specially Protected Area and Barcelona Convention's Specially Protected Areas of Mediterranean Importance since 2001). It is almost closed by a sand bar 22 km long with a very narrow connection with the open sea. Associated to its internal shore there are several margino-littoral wetlands, which are protected at both regional (Protected Landscapes) and international level (Ramsar and Barcelona Conventions, Natura-2000 Network) due to their natural and ecological interest. They include several natural habitats of priority and community interest according to the Habitats Directive (92/43 CEE). They are defined as coastal *crypto-wetlands* or "hidden seepages" (Vidal-Abarca et al., 2003). This paper refers to one of these wetlands, the Marina del Carmolí (Fig. 1), with a total surface area of 314 ha and located in the middle of the western side of the lagoon (latitude between 37°42'58" and 37°41'28"N; longitude between 0°50'25" and 0°51'58"W). Although most bird data were collected within the wetland itself, the objective was to analyse how the populations and assemblages of the site were influenced by agricultural change in the watershed, through its effects on the relative representation of wetland habitats.

The Mar Menor watershed is a 1200 km<sup>2</sup> plain slightly inclined towards this coastal lagoon and drained by several ephemeral watercourses (*ramblas*), which in natural regime flow towards the lagoon only after episodic storm rainfall events. Agriculture is the predominant land-use in the Mar Menor watershed. The discharge of the drainage system can be direct into the lagoon (surface outlets) or diffuse (subsurface flow through the peripheral wetlands). The spread of irrigation has caused both discharge types to increase. Direct ephemeral flows have become continuous water currents, while subsurface drainage has caused a general rise in the water table and the gradual conversion of steppe wetlands into palustrine ones. The area has a Mediterranean arid climate, with warm winters, an annual mean temperature about 17 °C, annual mean rainfall of 330 mm and a high inter-annual rainfall variation. The Carmolí wetland lies at the end of the largest sub-basin (633 km<sup>2</sup>) of the Mar Menor watershed, accounting for more than half of its total surface.

### 2.2. Habitat changes

From 1984 to 2001, temporal and spatial changes in total surface area and internal habitat composition of the main wetlands fringing the inner (continental) shore of the Mar Menor Lagoon were studied by means of remote sensing, in order to analyse their conservation implications, especially as regards the application of the Habitats Directive. All these wetlands present salt steppes, saltmarshes, reedbeds and sandy areas, although with a different

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