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Roost location and landscape attributes influencing habitat selection of migratory waterbirds in rice fields

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ABSTRACT

An analysis of habitat selection and use patterns by the near-threatened black-tailed godwit (*Limosa limosa*), a long-distance migratory waterbird, was conducted in rice fields of southern Europe during their northwards migration. A complete set of factors was assessed, including food availability, crop management, predation risk, human disturbance, habitat structure, and the presence of roosting areas. Additionally, by tracking radio-tagged godwits, the home range of this waterbird species was established while staging in the rice fields. Godwits selected as foraging grounds flooded, rolled pans that minimised their movements (average home range: 4919 ± 2226 ha) between the roosting and foraging grounds. The presence of power lines in the rice fields was the most important landscape factor affecting the location of the godwits' roosts, which were also flooded, rolled pans. The quality of rice fields as a key staging area for godwits lay in the presence not only of suitable foraging areas, but also of roosting sites. This study highlights for first time the key role of some facilities and the availability of roosting sites in determining the use of rice fields by migratory waterbirds such as godwits.

1. Introduction

Among the anthropogenic habitats used by migrating waterbirds, rice fields stand worldwide as agricultural habitat of great importance for this group of birds (see reviews by Blanco et al., 2006; Colwell, 2010; Elphick, 2010). These agricultural fields could buffer the loss of natural wetlands (e.g. Toral et al., 2012), since large numbers of waterbirds make use of them during the non-breeding season (e.g. Sánchez-Guzmán et al., 2007; Elphick, 2010; Masero et al., 2011).

During migration, habitat selection by waterbirds may be driven primarily by food availability (e.g. Van Gils et al., 2004; Lourenço et al., 2005; Piersma, 2006), with the energy and nutrient refuelling rate generally being the main determinant of the bird stopover duration (e.g. Hedenström and Alerstam, 1997; Chernetsov et al., 2004). There are, however, other factors that may also be important in their selection of a stopover area, including the presence of predators (e.g. Alerstam and Lindström, 1990; Newton, 1998), human disturbance (Rosa et al., 2006; Holm and Laursen, 2009), the carrying capacity of the area (Hutto, 1985), and even factors deriving from each given species' own innate morphological characteristics (Bairlein, 1983, 1992).

To date, studies on the use of rice fields by migratory waterbirds have focused on the effects of several of these factors, such as food density (Lourenço et al., 2010), post-harvest management practices involving the crop stubble and/or the water level in the rice pans (Elphick et al., 2010b), habitat heterogeneity (Amano et al., 2008), and specific characteristics of the rice fields including the age of the crop (Tourenq et al., 2003), as well as the size and location of the rice pan (Maeda, 2005). However, although numerous studies have highlighted the importance of landscape attributes in the spatial distribution of birds, this issue has not been tackled in habitats such as rice fields, resulting in a gap in the understanding of the use and selection of this anthropogenic habitat by birds (Elphick et al., 2010a).

In this study, the habitat selection and use patterns of black-tailed godwits (*Limosa limosa*), a long-distance migratory waterbird, was examined in rice fields of Southern Europe during northwards migration. Despite the large amount of investment and efforts to improve its main breeding areas (Jensen et al., 2008), the numbers of godwits have declined over the last 20 years (Gill et al., 2007), and this species is currently red-listed as near threatened (IUCN, 2008). Its long migrations cover thousands of kilometres between their main wintering grounds in West Africa and their breeding grounds in Western Europe (Piersma et al., 1996). The loss of suitable natural habitats appears to be one of the main threats

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(IWSG, 2003). On a landscape-scale, this study evaluated the role of food availability, predation risk, human disturbance, habitat structure, and roost location in rice fields of Southern Europe. Godwit's home range was determined by monitoring radio-tagged male and female godwits staying in the rice fields. In addition, on the pan-scale, the size, crop management regime, and water level of the rice pans were considered as potential factors influencing godwits' habitat selection and use.

2. Methods

This study was carried out in Extremadura rice fields (39°02′ N 5°56′ W), in South-West Spain. These rice fields are a key stopover site that supports >24,000 godwits (i.e. >14% of the Western European population) during the migration to the breeding grounds (Masero et al., 2009, 2011).

2.1. Habitat structure and selection

Based on information from previous studies (Sánchez-Guzmán et al., 2007; Masero et al., 2009, 2011), the whole area of the rice fields (30,361 ha) was divided into seven sectors according to the movements of godwits. During the daylight period, the godwits used different rice pans in the same sector, with virtually no movement of individuals detected between sectors except at dawn and dusk. From 2004 to 2010, regular surveys (from early January to late March) were performed through the whole study area to record the number of godwits. The type of habitat available for the godwits was characterised by choosing 20 locations randomly distributed over the seven sectors of the rice fields in accordance with their area. At the beginning and end of the 2005 migratory period, management type (standing stubble, rolled, or ploughed) and the water level (flooded, waterlogged, wet, or dry) were recorded for all pans included in two 500 m linear transect per location, as these two factors may influence the use of the pans by godwits (Lourenço and Piersma, 2008). The proportion of each habitat type present at each sampling point was calculated with the aid of a geographic information system (ArcGIS, v9.1). Using this method, a total of 150 rice pans (total surface: 244.1 ha) were characterised in the seven sectors.

In 2004 and 2005, weekly surveys of the whole study area were performed in the morning, which involved recording the UTM coordinates, the crop management regime, and the water level of every pan on which godwits were detected. The proportion of godwits observed in each type of pan was compared according to the availability of such pans (see above). Using digital cartography and the ArcGIS software package, each pan selected by godwits was characterised according to the size (i.e. surface area), and the distances from its centre-point to the nearest village/town, road, roosting site and power transmission line. Distances to roads, settlements and power lines were used as surrogate measures of human disturbance (Smit and Visser, 1993; Milsom et al., 2000). The number of raptors was also recorded, and a "case–control" design was established (Agresti, 1996) in a number of pans not selected by godwits.

2.2. Food availability

The food available for godwits in each sector was sampled during the early (15 January) and late (5 March) 2005 migratory period. 54 rice pans potentially usable by godwits over the seven sectors were randomly chosen (stratified sampling; samples weighted by sector area). A substrate sample was taken per pan, using a 10 cm diameter PVC corer. Each sample consisted of three units, and the sampling depth was the maximum permitted by the hardness of the mud, but in no case was this depth more than 12 cm, which is the maximum godwits' bill length (Cramp and Simmons, 1983). The samples were sieved through a 0.5 mm mesh and preserved in 70% ethanol until further laboratory analysis was required. To characterise each sector according to the food available for godwits, the average numbers of rice seeds and macro-invertebrates found in the sampled pans of each sector were considered.

2.3. Location of the roosts

During the North migration in 2004 and 2005, regular surveys were conducted at dusk to locate the pans selected for the establishment of their roosts, and the UTM coordinates and characteristics of the pans were recorded as described above.

2.4. Home range size

During the migratory period 2005, 24 godwits (11 males and 13 females) were tagged with radio transmitters (model TW-3, Biotrack, England), following the procedure of Warnock and Takekawa (2003). The birds were captured at night in the surroundings of the roosting area using mist nets. The weight of the transmitter (with a mean battery life of 60 days and a mean range of 2 km) always represented less than 4% of the godwits body mass. The sex of the bird was determined from a blood sample taken from the brachial vein, following the procedure of Fridolfsson and Ellegren (1999).

The positions of the radio-tagged godwits were located using mobile receivers with hand-held Yagi antennas. All frequencies in each of the seven sectors were scanned on a daily basis during the daylight period (7 AM–8 PM), changing the route between consecutive monitoring sessions. In addition, all frequencies from different strategic locations were searched on an hourly basis, which maximised the surveyed area, taking advantage of several teams searching simultaneously in different locations. In this way each radio-frequency had the same probability of being detected throughout the study area. When a frequency was located, the position of each godwit was pinpointed with the aid of a 20–60× telescope, recording the UTM coordinates of the bird. All radio-tagged godwits were also marked with colour-coded rings (see www.cr-birding.be), which facilitated their identification.

2.5. Data analysis

Data from the weekly surveys of 2004 and 2005 were used to compare the percentage and density of godwits among the seven sectors (ANOVA).

We modelled the proportion of godwits using each habitat in each sector using the estimated proportion of each habitat available in each sector. The proportion of each type of pan available for godwits in the different sectors (data obtained from transects; pooling the transect data within each sector) was compared using a two-way ANOVA, with migratory period (two levels) included in the analysis as a fixed factor. After replacing zero values with 0.01 and log-ratio transformation, compositional analysis (Aebischer et al., 1993) was used to determine whether the godwits selected certain types of pans ranking habitats in order of preference. Wilk's lambda statistic (Λ) and a multivariate analysis of variance were used to assess whether the difference between habitat use and availability differed significantly from zero ($P < 0.05$). Student's t-test was used to determine any possible effects of the quantitative variables considered by comparing the values between the pans selected by godwits and those in which they were never detected, and the correlation was studied between these variables and the maximum density of godwits found in each used rice pan. Additionally, we performed a presence/absence modelling framework by using the MaxEnt v3.3 software, and used the Receiver Operating Curve (ROC) values to assess model fitting (Phillips et al., 2006). Also, an ANOVA was performed to test for the possible effect of the factors