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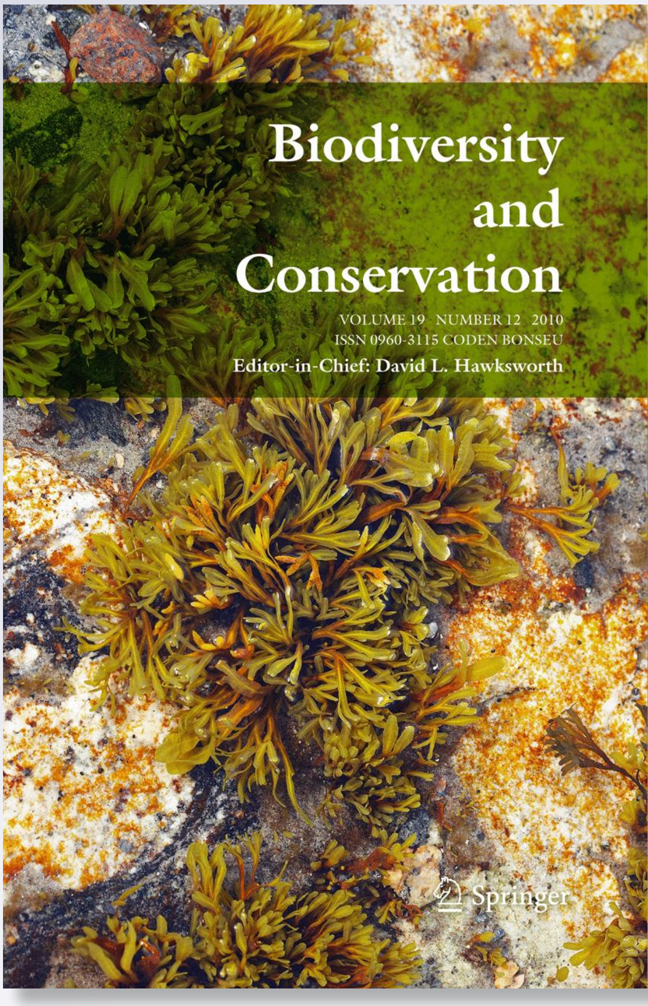

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ORIGINAL PAPER

Unraveling the importance of rice fields for waterbird populations in Europe

Gregorio M. Toral · Jordi Figuerola

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Abstract Rice fields are an alternative habitat for waterbirds and provide food and shelter for many avian species, but there is a lack of information about how the use of rice fields translates into population level effects. The aim of this study was to test the relationship between the use of rice fields by European waterbirds and trends in their populations. We tested this relationship during the autumn migration season and during the breeding season. Based on counts conducted over the last 23 years in natural marshes and areas of rice fields in Doñana (SW Spain), an index of rice field use was constructed for 76 bird species, which was then compared to these species' European population trends obtained from the literature. A positive relationship was found between waterbird population trends and the use of rice fields during autumn migration season. Our study suggests that changes in the Common Agriculture Policy in Europe leading to reductions in areas of rice cultivation may have important effects on waterbirds. The restoration of former marsh areas and the maintenance of rice cultivation would seem to be more environmentally friendly approaches than the use of these areas to grow alternative crops or solar farms.

Keywords Agriculture · Doñana · Migration · Shorebird · Wetland

Introduction

Intense habitat transformation linked to human activity has molded the composition and abundance of avian communities throughout the world (Murphy 2003; Lemoine et al. 2007) and agricultural intensification has been associated with serious declines in the populations of many farmland birds over recent decades in Europe (Donald et al. 2001, 2006; Wretenberg et al. 2007). There are also many studies about the effects of agriculture

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on waterbird populations. Duncan et al. (1999) showed a negative effect of agriculture intensification on wintering ducks populations. Long et al. (2007) concluded that an increase in the area of agricultural land could be associated with decreasing populations in Anseriformes. However, some crops could act as an alternative or 'buffer' habitat for some waterbird species that feed or breed in agricultural areas (Sánchez-Guzmán et al. 2007) and there are some studies reporting positive effects of agriculture on certain species of waterbirds (e.g., Gauthier et al. 2005; Fasola et al. 2010).

Wetlands are one of the most productive ecosystems on Earth. Nevertheless, they have been submitted to intensive transformation and drainage and they are today in decline throughout the world (Czech and Parsons 2002). It is estimated that over 50% of the world's wetlands have been lost since 1900. Over the last few centuries the natural wetlands of the Mediterranean region have been reduced in area by 80–90% due to pressure from human population growth and the conversion of wetlands into agricultural and urbanized areas (Finlayson et al. 1992). In southern Europe and North Africa large areas of pristine wetlands have been transformed into rice fields, a crop that covers 581,978 ha in Europe (Ferrero and Nguyen 2004).

Previous work suggests that rice fields may be an important habitat for waterbirds throughout the world and in some areas may in fact be the primary foraging habitat available to them (Czech and Parsons 2002). Several studies have shown the importance of rice fields as a wintering site for waterbirds in different locations around the world, such as California (Elphick and Oring 1998; Elphick and Oring 2003) or Cuba (Acosta et al. 1996) in North America; Portugal (Lourenço and Piersma 2008) or Spain (Rendón et al. 2008) in Europe; or Japan (Maeda 2005) in Asia. Furthermore, rice fields are used by a variety of waterbirds as breeding sites (Fasola and Ruiz 1996), although to a lesser extent than as foraging sites (Czech and Parsons 2002). Despite all the information about the importance of this crop for waterbirds, the possibility that the use of rice fields actually translates into population level effects has received little attention. Since rice fields differ in habitat structure, water table depth, and disturbance levels from natural marshes, and given that these factors are known to affect habitat selection by waterbirds (Bolduc and Afton 2004; Canepuccia et al. 2007), it is likely that not all species will use this alternative habitat with the same intensity.

Hundreds of thousands of birds use the area of Doñana (SW Spain), which includes marshes and rice fields, in the course of a year. The Doñana marshes are the most important wintering site for migrating waterbirds in the Mediterranean (Rendón et al. 2008) and one of the main migratory stopovers for waterbirds using the East Atlantic flyway. In this paper we test the hypothesis that the species that use rice fields most intensively will benefit at the population level from the presence of this alternative habitat. We test this hypothesis by analyzing the relationship between rice field use and population trends in Europe for 76 species of waterbirds present in natural marshes and/or rice crops in southern Spain.

Methods

In Spain, rice fields cover 118,000 (FAOSTAT 2004) and the largest such area in Spain (36,000 ha) is situated near the marshes of the Doñana National Park, a 55,000 ha wildlife reserve north of the Guadalquivir estuary in Andalucia (SW Spain). Of the 180,000 ha of fresh and brackish marshes present in 1900, 36,000 ha were transformed into rice fields between 1926 and 1997 (García-Novo and Martín-Cabrera 2005; Rendón et al. 2008). Additionally, other types of transformation have reduced the area of natural marshes to

30,000 ha at present (Enggass 1968; García-Novo and Martín-Cabrera 2005) and changes in the marshes' hydrological structure have dramatically altered the flood patterns of the area. Due to summer droughts and the unpredictability of rainfall in Mediterranean climate zones, the periods of maximum flood levels in rice fields and natural marshes do not overlap in time, thereby ensuring that rice fields can act as an alternative habitat for waterbirds in the area.

Bird's counts and population indices

We used bird counts conducted over the last 23 years (1980–2003) in the Doñana National Park and surrounding area that are part of the long-term monitoring program run in the area (http://www-rbd.ebd.csic.es/Seguimiento/seguimiento.htm). We analyzed terrestrial surveys from three sectors of rice fields (2,756 ha) and seven sectors of marsh (3,192 ha) since the highest number of surveys exist for these ten sectors. An index of rice field use in relation to natural marsh use was calculated for each species based on the proportion of positive counts (counts in which at least one bird of a particular species was detected) in rice fields in relation to the number of positive counts in both habitats (natural marshes and rice fields). We didn't base the index of rice field use on abundance data to avoid the bias produced by big flocks of waterbirds. We used Eq. 1 to calculate the rice-field use index for each species and month based on its presence/absence.

$$\text{Rice-field use index} = \text{MPR}/(\text{MPR} + \text{MPM}). \tag{1}$$

MPR (Mean Presence in Rice fields) = number of positive counts in rice fields/total number of counts in rice fields.

MPM (Mean Presence in Marshes) = number of positive counts in marshes/total number of counts in marshes.

Indices were only calculated for species with at least five positive counts in the area (76 species). We calculated two separate seasonal-use indices (breeding and autumn migration) adjusted to crop and bird phenology. We calculated seasonal indices as the mean value of the months included in the season. The breeding season index was calculated using data from April to July, a period that largely coincides with rice seeding and growth. The autumn migration season index was calculated with data from October to January, months including autumn migration and the wintering period that coincide with crop ripening, soil tilling, and the shallow flooding of fields, which dry out by the end of December–January.

We define population as a 'distinct assemblage of individuals which does not experience significant emigration or immigration' (Delany and Scott 2006). European population trends for waterbirds were obtained from 'Waterbird Population Estimates' (Delany and Scott 2006), where trends are expressed as one of the following categories: increasing, stable, decreasing, fluctuating and extinct. Those categories were scored for the analyses as positive (2), no trend (1), or negative (0), and the resulting dependent variable was treated as an ordinal variable in the analyses. We assigned no trend value (1) to *Marmaronetta angustirostris*, the only species with a fluctuating population trend for Europe. In addition to rice field use we also estimated mean migration distance as degrees of latitude between the mean breeding and mean wintering ranges (see distribution maps in Cramp 1977–1985).

Statistical methods

The relationship between population trends in Europe (as a dependent variable) and the rice-field use index (as an independent variable) was tested using Generalized Linear

Mixed Models (GLMMs). We considered the possible lack of independence of our samples, since species from the same family share a number of morphological and life history features and therefore could have similar preferences in their habitat selection for feeding and/or breeding. To avoid this possible bias we made an exploratory analysis, using a nested GLM to examine how trends in European bird populations vary between different taxonomic levels (order, family and genera). Most of the variance in population trends was unrelated to taxonomy (82%). Family and genera explained 12 and 6%, respectively, of the variance; no variance was explained by order. Furthermore, we used a nested GLM to examine the variation in the use of rice fields between different taxonomic levels (order, family, and genera).

The GLMMs were fit using the GLIMMIX procedure in SAS 9.2. The population trend in Europe was modelled by specifying a multinomial error distribution and a cumulative logit link function, with the explanatory variables coded as fixed effects and family and genera nested within family as random effects (order was excluded as random effect based on the results of the exploratory analysis). Because the taxonomy was incorporated in the model with a hierarchical structure (i.e., genera nested within families), the model helps to correct for the phylogenetic effects described between these taxonomic categories.

Two different sets of models were fitted to the data, one for each of the time periods used to calculate the rice-field use index. The explanatory variables in the initial models included rice-field use index, migration distance (and its quadratic term), as well as the two-way interaction with the rice-field use index. We included migration distance as an explanatory variable and also included its quadratic term to explore the possible differences in population trends between short, intermediate, and long distance migrants because previous studies have found Afro-Palearctic migrant birds to have negative population trends over the last few decades in comparison to short-distance migrants or resident birds (Sanderson et al. 2006). We also added the interaction of rice-field use index and migration distance since this habitat is very important as a feeding site and could have a different value for waterbird species depending on their requirements of food, which could be related to the distance they have to cover during migration. We followed a backwards regression-model selection procedure, and the factor contributing least to the model was removed at each step before the model was refitted. Variables were retained in the model until all the interactions including the variable had been excluded from the model; a lower probability limit of 0.10 was used to retain a factor in the model. Only factors with $P < 0.05$ were interpreted as statistically significant. We used this method of model selection instead of Akaike Information Criterion (AIC) because we have random effects in our models. Although the range of application of AIC can be expanded to random effect, this extension is in an early stage of development (Burnham and Anderson 2002). We intended to include also breeding latitude as an explanatory variable in our analyses. However it was strongly correlated with migration distance ($r^2 = 0.41$; $F = 48.2$; $DF = 1,70$; $P < 0.001$), and the inclusion of both variables in the analyses may produce spurious correlations. For these reasons we confirmed in separate analyses (not presented) that the relationships found were in fact with migration distance and were not significant when using breeding latitude instead of migration distance.

Results

Although the autumn migration period and breeding season indices were positively correlated, the relationship was not strong ($r^2 = 0.29$; $F = 27.4$; $DF = 1,69$; $P < 0.001$),

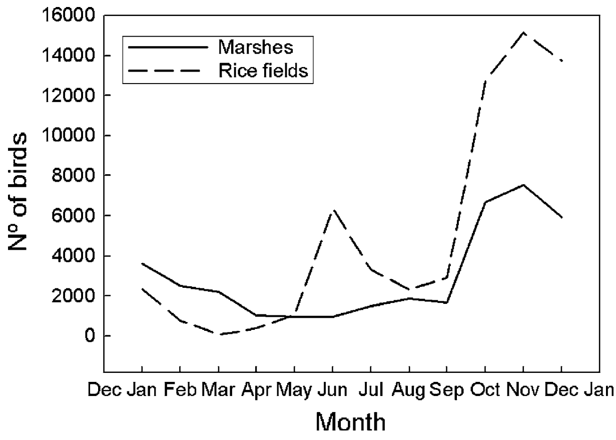

Fig. 1 Variation in the number of waterbirds that use the rice fields and marshes in Doñana during the year. Note that the numbers refer only to the areas included in our study and not to the complete surface area of marshes and rice fields present in Doñana

suggesting that some differences occur in species' habitat preferences between autumn and spring. Bird abundance in rice fields in comparison to natural marshes was higher during the autumn migration season than in spring (Fig. 1).

There was important interspecific variability in the rice-field use index (see Table 1) that was not explained by taxonomy, with values ranging between 0 (e.g., *Aythya nyroca*) and 1 (e.g., *Sterna nilotica*). Variance explained at the order level varied between 20 and 24% depending on the time period analyzed. At the family level, the values varied between 0 and 21%. No variance was explained at the genera level.

The final model for the autumn migration season retained three variables: use index, migration distance and its quadratic term (Table 2). According to this model, population trends in Europe were positively related to the autumn rice-field use index, and had a quadratic relationship with migration distance, with more negative population trends for species migrating over medium distances than for long distance and resident species. In the case of the breeding season, the final model was very similar and retained four variables (Table 2). The relationship of population trends with migration distance was similar to what we found during the autumn. Rice-field use index during the breeding season tended to be positively related to population trends ($P = 0.08$) and more strongly in resident than for species migrating over longer distances ($P = 0.06$) (Table 2).

Discussion

We found important interspecific differences in the frequency of use of rice fields as opposed to natural marshes in Doñana, which were related to population trends in waterbird populations in Europe. This suggests that the alternative habitats provided by rice fields during the autumn migration period favor the populations of certain species. We also found this relation during the breeding season although it didn't reach significance, suggesting that waterbirds benefit from using rice fields mainly as a feeding habitat during the autumn migration period.

Table 1 Values for the rice-field use index for the species analyzed in the two different time periods taken into account

Specie	Migration season index	Breeding season index	Order	Family
Aythya nyroca	0.00	0.00	Anseriforms	Anatidae
Oxyura leucocephala	0.00	0.00	Anseriforms	Anatidae
Aythya ferina	0.01	0.00	Anseriforms	Anatidae
Netta rufina	0.00	0.00	Anseriforms	Anatidae
Aythya fuligula	0.03	0.00	Anseriforms	Anatidae
Tadorna tadorna	0.03	0.00	Anseriforms	Anatidae
Anas crecca	0.10	0.00	Anseriforms	Anatidae
Anas strepera	0.10	0.00	Anseriforms	Anatidae
Anas penelope	0.19	0.00	Anseriforms	Anatidae
Anas clypeata	0.14	0.03	Anseriforms	Anatidae
Anas platyrhynchos	0.14	0.04	Anseriforms	Anatidae
Anas acuta	0.33	0.00	Anseriforms	Anatidae
Marmaronetta angustirostris	0.34	0.03	Anseriforms	Anatidae
Anas querquedula	0.19	0.00	Anseriforms	Anatidae
Anser anser	0.50	0.00	Anseriforms	Anatidae
Egretta alba	0.00	0.00	Ciconiiforms	Ardeidae
Nycticorax nycticorax	0.00	0.00	Ciconiiforms	Ardeidae
Ixobrychus minutus	–	0.18	Ciconiiforms	Ardeidae
Ardea cinerea	0.60	0.14	Ciconiiforms	Ardeidae
Ardeola ralloides	0.93	0.13	Ciconiiforms	Ardeidae
Ardea purpurea	0.99	0.14	Ciconiiforms	Ardeidae
Bubulcus ibis	0.94	0.08	Ciconiiforms	Ardeidae
Egretta garzetta	0.78	0.21	Ciconiiforms	Ardeidae
Burhinus oedicnemus	0.50	0.00	Ciconiiforms	Burhinidae
Recurvirostra avosetta	0.17	0.11	Ciconiiforms	Charadriidae
Charadrius dubius	0.20	0.00	Ciconiiforms	Charadriidae
Himantopus himantopus	0.47	0.14	Ciconiiforms	Charadriidae
Pluvialis squatarola	0.48	0.21	Ciconiiforms	Charadriidae
Vanellus vanellus	0.59	0.08	Ciconiiforms	Charadriidae
Charadrius alexandrinus	0.44	0.33	Ciconiiforms	Charadriidae
Charadrius hiaticula	0.67	0.43	Ciconiiforms	Charadriidae
Pluvialis apricaria	0.64	0.00	Ciconiiforms	Charadriidae
Ciconia ciconia	0.81	0.53	Ciconiiforms	Ciconiidae
Ciconia nigra	0.97	0.00	Ciconiiforms	Ciconiidae
Glareola prantincola	–	0.42	Ciconiiforms	Glareolidae
Larus genei	–	0.00	Ciconiiforms	Laridae
Larus minutus	0.12	0.00	Ciconiiforms	Laridae
Sterna albifrons	0.00	0.13	Ciconiiforms	Laridae
Larus fuscus	0.65	0.00	Ciconiiforms	Laridae
Larus ridibundus	0.56	0.13	Ciconiiforms	Laridae
Chlidonias niger	0.51	0.21	Ciconiiforms	Laridae

Table 1 continued

Specie	Migration season index	Breeding season index	Order	Family
Larus cachinnans	0.79	0.08	Ciconiiforms	Laridae
Sterna nilotica	1.00	0.39	Ciconiiforms	Laridae
Chlidonias hybridus	0.94	0.37	Ciconiiforms	Laridae
Phalacrocorax carbo	0.24	0.00	Ciconiiforms	Phalacrocoracidae
Phoenicopterus ruber	0.17	0.00	Ciconiiforms	Phoenicopteridae
Platalea leucorodia	0.40	0.09	Ciconiiforms	Phoenicopteridae
Podiceps cristatus	0.00	0.00	Ciconiiforms	Podicipedidae
Podiceps nigricollis	0.00	0.00	Ciconiiforms	Podicipedidae
Tachybaptus ruficollis	0.02	0.00	Ciconiiforms	Podicipedidae
Arenaria interpres	0.00	0.00	Ciconiiforms	Scolopacidae
Calidris alba	0.00	0.00	Ciconiiforms	Scolopacidae
Numenius phaeopus	–	0.00	Ciconiiforms	Scolopacidae
Limosa lapponica	0.33	0.00	Ciconiiforms	Scolopacidae
Tringa hypoleucos	0.47	0.00	Ciconiiforms	Scolopacidae
Tringa erythropus	0.52	0.00	Ciconiiforms	Scolopacidae
Numenius arquata	0.35	0.00	Ciconiiforms	Scolopacidae
Calidris ferruginea	1.00	0.12	Ciconiiforms	Scolopacidae
Calidris canutus	0.33	0.42	Ciconiiforms	Scolopacidae
Limosa limosa	0.44	0.16	Ciconiiforms	Scolopacidae
Tringa totanus	0.36	0.25	Ciconiiforms	Scolopacidae
Calidris alpina	0.47	0.12	Ciconiiforms	Scolopacidae
Calidris minuta	0.61	0.00	Ciconiiforms	Scolopacidae
Philomachus pugnax	0.64	0.38	Ciconiiforms	Scolopacidae
Tringa nebularia	0.69	0.17	Ciconiiforms	Scolopacidae
Gallinago gallinago	0.74	0.00	Ciconiiforms	Scolopacidae
Tringa ochropus	0.88	0.12	Ciconiiforms	Scolopacidae
Tringa glareola	0.97	0.41	Ciconiiforms	Scolopacidae
Lymnocryptes minimus	1.00	–	Ciconiiforms	Scolopacidae
Plegadis falcinellus	0.98	0.09	Ciconiiforms	Threskiornithidae
Grus grus	0.45	0.00	Gruiforms	Gruidae
Rallus aquaticus	0.00	–	Gruiforms	Rallidae
Fulica atra	0.11	0.03	Gruiforms	Rallidae
Fulica cristata	0.16	0.00	Gruiforms	Rallidae
Gallinula chloropus	0.27	0.00	Gruiforms	Rallidae
Porphyrio porphyrio	0.43	0.10	Gruiforms	Rallidae

Our results support the hypothesis that the creation of rice fields after the Second World War in the Mediterranean Region helped increase the populations of breeding and migrating waterbirds (Czech and Parsons 2002). Previous work suggests that increases in the number of little egrets in Italy were mainly driven by an increasing availability of rice fields (Fasola et al. 2010). Sánchez-Guzmán et al. (2007) recorded population sizes of international importance (>1% of the biogeographical population using the Eastern Atlantic Flyway) for

Table 2 Relationship between European population trends and the variables considered in the analysis

Factor	Migration period			Breeding period		
	Estimate	F1,27	*P*	Estimate	F1,28	*P*
Use index	2.0306	5.85	**0.023**	7.1779	3.2	0.085
Migration distance	−0.1423	7.52	**0.011**	−0.1153	5.93	**0.022**
Migration distance × migration distance	0.0018	5.06	**0.033**	0.001894	5.01	**0.033**
Use index × migration distance				−0.2516	3.74	0.063

Significant values are in bold. Estimates correspond to the regression parameters of each factor included in the final model obtained by backwards regression

several waterbird species in the rice fields of Extremadura in continental southwest Spain, and suggest that the creation of these rice fields could be modifying the wintering and/or feeding sites of some of the waterbirds using this flyway. Ackerman et al. (2006) found that the increase in rice cultivated area in California's Central Valley allowed the wintering Pacific Greater White-fronted Geese (*Anser albifrons frontalis*) population to concentrate their habitat use, thus reducing the population range and roost-to-feed distances between decades.

Our results suggest that the positive effect of rice fields on waterbird populations could be operating at large scales for many species across Europe, and may be a global pattern.

We analyzed the autumn migration period separately to avoid taking into account the months in which rice fields are not available as habitat for waterbirds. As well, previous studies have found that rice fields are particularly attractive to waterbirds during autumn and early winter in the Mediterranean region, when invertebrate biomass levels peak and temporary wetlands are usually dry (González-Solís et al. 1996). During this period, this habitat is of international importance as a stopover site in the western Mediterranean (Finlayson et al. 1992). In the Doñana rice fields the peak in the number of birds using these fields occurs in autumn (Fig. 1).

Previous work found Afro-Palearctic migrant birds to have negative population trends over the last few decades in comparison to short-distance migrants or resident birds (Sanderson et al. 2006). Our results show that the relationship between population trends and migration distance is quadratic, with some species with extreme migration distances (more than fifty degrees of latitude between their mean breeding latitude and mean wintering latitude) having more positive population trends than those with medium values. The question of why extreme long-distant migrating species have more positive trends merits further study, but it is possible that they benefit from having a very large winter range (although the relationship between extreme long-distant migration and large winter range should also be explored). This would allow them to cope with the alterations occurring in some wintering areas, including changes in rainfall patterns or variations in primary productivity in the Sahel region, the latter is a factor which has been linked with declines and population fluctuations in a number of European migrants that wintered there during the drought of the 1980s (Den Held 1981; Kanyamibwa et al. 1990).

Shultz et al. (2005) suggest that the British farmland birds whose populations have suffered most under agricultural intensification are those with the most specialized resource and habitat use and least cognitive abilities. In this sense, benefits from the exploitation of rice fields could be due to a coincidence with the characteristics of the natural habitats exploited by these species, but could also be due to a high plasticity in habitat selection.

In this case, an alternative explanation for the positive relationship between rice field use and population trends would be that the most plastic species are better at dealing with human-transformed environments.

Although we can't demonstrate that there is a causal relation between the use of rice fields and European population trends, our approach identifies potential impacts of changes on rice field management on waterbirds that should be taken into account by policy makers and future research projects. The relevance of rice fields as an alternative habitat for waterbirds in Europe should not be underestimated since the loss of natural wetlands means that these artificial habitats now represent an important proportion of the total habitat area suitable for waterbirds in the region. The surface area of rice cultivated in southern Europe (Italy, Spain, Greece, and Portugal) represents 30.7% of suitable habitat for waterbirds. In Spain, this percentage has now risen to 49.5% (Table 3).

Understanding how rice field management affects birds is important to the development of sustainable agricultural systems that combine economically viable farming and bird conservation. In fact, previous studies have shown that there are agricultural benefits derived from having waterbirds in rice fields, since they improve straw decomposition (Bird et al. 2000) or weed control (Van Groenigen et al. 2003). However, changes in the Common Agriculture Policy may reduce the surface of rice fields in southern Spain and in the rest of Europe. The 2003 reform of the Common Agriculture Policy introduced a number of modifications such as the withdrawal of support for farm production, which has meant a reduction in the grants received by rice farmers, who are now changing to alternative crops with the concomitant loss of habitat for waterbirds. In light of our study, the awarding of grants by the EU to ensure the maintenance of the surface area of rice cultivated, together with the implementation of ecological agriculture or the transformation of rice fields into natural marshlands, would seem a better option. Furthermore, well-designed environmental agricultural schemes in southern Europe may also increase the winter survival of bird populations breeding further north (Wretenberg et al. 2007).

It is important to note that we are not advocating the transformation of natural marshland into rice fields: however, managers and policy makers should be aware that the transformation of rice fields into other types of croplands (for example, cotton) or into solar farms will have an important negative impact on wildlife conservation in Europe.

Climate change involves potentially negative effects on biodiversity. It is important that the development of alternative sustainable energy production be favoured, since the impact of climate change need to be mitigated through low carbon energy production. However, the indiscriminate siting of wind or solar farms without any detailed assessment of their environmental impact or alternatives may have important negative impacts on wildlife. Solar farms are usually situated on former agriculture land because a flat surface is necessary. Nowadays, the environmental damage caused by the implementation of solar farms is not considered to be relevant in Andalucia (Plan Andaluz de Sostenibilidad Energética

Table 3 Area of natural marshes and rice fields in southern European countries, taken from the Pan-European Wetland Inventory (2004) and FAOSTAT (2004) (http://www.wetlands.org/RSIS/WKBASE/)

Country	Marshes (ha)	Rice fields (ha)	% Area of rice fields
Spain	120,537	118,000	49.5
Portugal	130,943	25,198	16.1
Italy	450,563	218,676	32.7
Greece	166,794	22,413	11.8
Total	868,837	384,287	30.7

PASENER 2007-2013). However, bearing in mind the results presented here, the negative effect that the placing of solar farms on former rice fields would have on Doñana waterbird communities must be taken into account. Spain now has the third-largest solar capacity in the world, behind only the United States and Germany (Abend 2008) and current solar-energy projects in the Doñana area will transform about 1,000 ha of rice fields: this transformation of rice fields into solar farms may represent an important and silent secondary loss of wetlands in southern Europe.

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