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Benefits of the European Agri-Environment Schemes for Wintering Lapwings: A Case Study from Rice Fields in the Mediterranean Region

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Abstract.—Mediterranean European rice fields provide important habitats for migrating waterbirds. In winter, one waterbird species that particularly benefits from rice fields is the Northern Lapwing (*Vanellus vanellus*), a species threatened in Europe. To assess the effect of agri-environmental measures on rice field selection and use by wintering lapwings, bird counts were conducted in northeastern Spain during two consecutive winters (2005-2006 and 2006-2007). Information on two mandatory post-harvest management prescriptions of the agri-environment schemes was collected, namely winter flooding (percent ground surface covered by water) and whether fields were rolled or not. The number of lapwings in rolled fields was significantly higher compared to non-rolled fields. For instance, an average rolled field with 50% water cover (percentage at which lapwing abundance more or less peaked) would host an estimated 12.03 ± 0.52 SE lapwings versus 0.18 ± 0.58 in a non-rolled field. While the maximum abundance of lapwings in rolled fields was found at an intermediate percentage of water cover (about 25 to 75%), the number of lapwings increased steadily with water cover in non-rolled fields. Rice post-harvest practices derived from the agri-environment schemes are beneficial for biodiversity, promoting the conservation of suitable habitats for waterbirds. *Received 27 April 2019, accepted 5 December 2019.*

Key words.—Agri-environmental measures, lapwing, Mediterranean, post-harvest management, rice, waterbirds.

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It is estimated that natural wetlands have been reduced by 80-90% in the Mediterranean region (Finlayson *et al.* 1992), and approximately 23% of the remaining wetlands are artificial (e.g., rice fields, salt pans; Perennou *et al.* 2012). Rice fields, which are among the most important artificial habitats, account for 15% of the world's wetlands (Lawler 2001). Within the European Union, rice cultivation in the Mediterranean currently covers about 445,000 ha, with Italy and Spain making up nearly 80% of the overall production (53% and 25%, respectively; FAOSTAT 2016). Several studies have demonstrated that Mediterranean European rice fields constitute an important habitat for migrating waterbirds, both during the breeding and wintering periods (e.g., Sánchez-Guzmán *et al.* 2007; Longoni 2010; Masero *et al.* 2011; Pernollet *et al.* 2015a).

Especially in countries with a long tradition of rice farming, rice fields may represent a significant proportion of suitable habitat for waterbirds, to the point of being considered as surrogates of natural wetlands (e.g., Fasola and Ruiz 1996; Toral and Figuerola 2010). However, the suitability of rice fields for waterbirds largely depends on the type of farming practices implemented (Elphick *et al.* 2010; Longoni 2010; Pernollet *et al.* 2015b; Niang *et al.* 2016). As an example, during the post-harvest period, straw management activities may involve cutting the straw into small pieces and rolling the field to mix the stubble and incorporate it into the soil (Elphick and Oring 1998; Elphick *et* *al.* 2010). This process is usually combined with flooding, which increases decomposition (Elphick *et al.* 2010).

Agri-environment schemes (AES) were introduced in the European Union in the early 1990s as a response to concerns over biodiversity loss (Kleijn and Sutherland 2003; Concepción *et al.* 2008; Scheper *et al.* 2013; Batáry *et al.* 2015). In these schemes, farmers are paid to undertake environmentally friendly practices, therefore promoting sustainable agriculture (Donald and Evans 2006; Kleijn *et al.* 2006; Ernoul *et al.* 2014; Science for Environment Policy 2017). Although these schemes were mainly conceived as a response to declining biodiversity in farmland ecosystems, the real benefits for biodiversity and the cost-effectiveness of AES have been extensively discussed (Kleijn and Sutherland 2003; Whittingham 2007, 2011; Ansell *et al.* 2016).

One of the wintering waterbirds that is frequently observed in rice fields in Mediterranean wetlands is the Northern Lapwing (*Vanellus vanellus*; hereafter "lapwing") (Longoni 2010), a species classified as Near Threatened on the Global Red List (BirdLife International 2018) and as Vulnerable on the European Red List of Birds (BirdLife International 2015). The European lapwing population has been declining since the 1980s most likely due to agricultural intensification on its breeding grounds (Newton 2004; Sheldon *et al.* 2004; Robinson *et al.* 2014; Souchay and Schaub 2016).

The objective of this study was to assess the effect of agri-environmental measures on rice field selection and use by wintering lapwings in the Baix Ter wetlands. To date, the rice field avifauna has not been extensively monitored in this region, and therefore the lapwing occurrence in rice fields is not properly documented. We study the extent to which rolling after flooding (a straw management method consisting of rolling the field to mix the stubble into the soil) and winter flooding (where no straw management is applied), two of the primary mandatory agri-environmental measures that farmers implement (Reig-Martínez and Estruch 2006; Picazo-Tadeo *et al.* 2009), influence the abundance of lapwings. Our hypothesis is that AES enhance lapwing abundances in rice fields during the post-harvest period and are therefore beneficial for lapwings and other wader species due to the presence of arthropods and earthworms, which are key for their wintering diet (Gillings and Sutherland 2007).

Methods

Study Area

This study was carried out in the Baix Ter wetlands of northeastern Spain (42° 00′ 18″ N, 3° 11′ 04″ E; Fig. 1A), of which rice fields currently cover about 600 ha. Given that the area is part of the Natura 2000 network (Quintana *et al.* 2009), management prescriptions of AES are mandatory for farmers (OECD 2017). After the harvest, in September-October, straw is left standing in the fields. Following the AES prescriptions, farmers flood the fields for four months (Fig. 1B). During this time, stubble is mixed with standing water in a process called rolling after flooding (Fig. 1C). The maintenance of flooded fields during winter forms a dynamic landscape where the percent ground surface covered by water differs in each of the crops. Straw management options (e.g., rolling after flooding; Elphick and Oring 1998) are similar for both organic and conventional farms, but our analysis only included conventional farms.

Lapwing Counts and Rice Field Management

During the winters 2005-2006 and 2006-2007, from the beginning of December to mid-March, we counted the number of lapwings present on 40 rice fields covering an area of 96.5 ha (ranging from 0.34 to 7.97 ha; $\bar{x}$ area ± SE = 2.41 ± 1.65). Surveys were conducted from a vehicle on a road alongside the fields at low speed to avoid flushing the birds and to cover the maximum number possible of rice fields in the Baix Ter. Two persons were responsible for counting all the birds in each of the fields. Birds that left from or landed on a field during a survey were counted, but birds flying overhead were not. Counters only recorded the number of lapwings, which was the main bird species encountered in the fields. Although lapwing numbers only marginally change throughout the day, surveys were always made four hours after sunrise to avoid any potential time bias. During the first winter, a total of 14 weekly surveys were done, but only 13 surveys were conducted in winter 2006-2007 due to bad weather conditions on the last week of December. Surveys were finalized when fields had to be plowed (around mid-March). In every visit and for each rice field included in this study, we collected information on: 1) whether the field was rolled; and 2) the percent ground surface covered by water (ranging from 0% to a value of 100% for a completely flooded field).

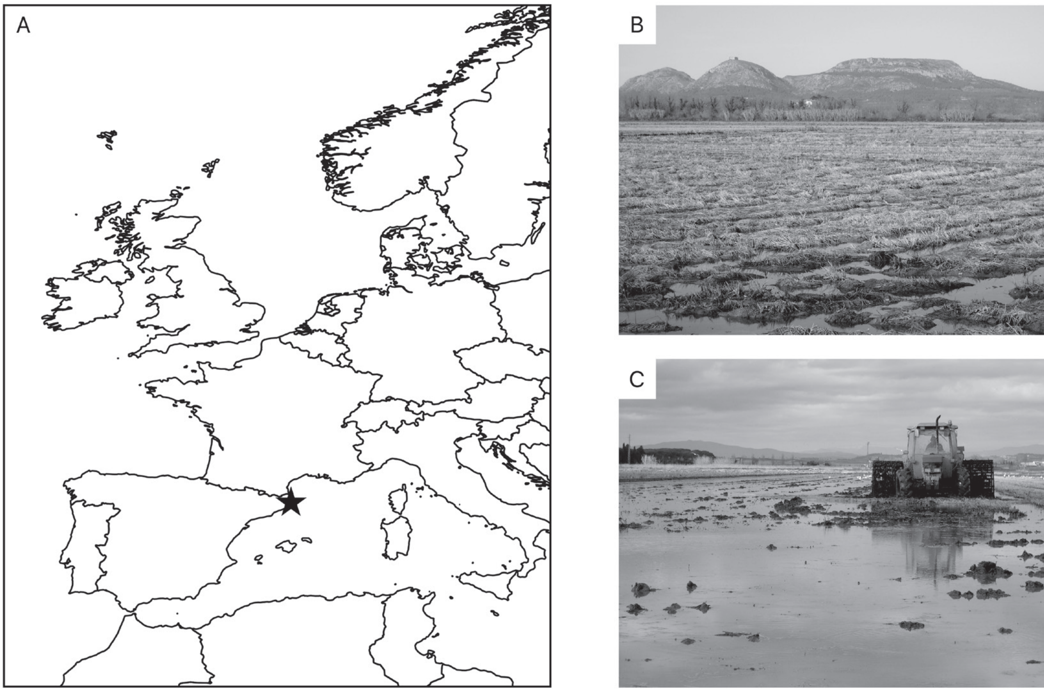

Figure 1. Location of the study area in the Baix Ter wetlands, northeastern Spain (A), where the effect of agri-environmental measures on rice field selection and use by wintering Northern Lapwings (*Vanellus vanellus*) was studied; with picture of a flooded-non-rolled rice field (B) and a rolled rice field (C).

Data Analysis

To assess lapwing site preference, we applied a generalized linear mixed model (GLMM) with a Negative binomial error distribution (given that lapwings tend to flock) and a logarithmic link-function to model the abundance of lapwings in relation to rolling and water cover. The latter variable was transformed into a second-degree polynomial ("water cover2") to acknowledge the possibility that lapwing abundance did not respond linearly to water cover. We added the interaction between water cover ("water cover2"; continuous variable) and rolling ("rolled"; defined as a factor) to investigate if the effect of water cover on lapwing numbers was conditional on the field being already rolled (Table 1). We also included in the model two random-effect intercepts: field identity accounts for random variation in the intercept among fields (i.e., we assume that there were other differences between rice fields than the ones we could account for in our model), whereas number of weeks since the first of December takes into account the fact that lapwing numbers can also vary due to the species phenology, or also because rice fields are much drier towards the end of the winter. Finally, the area of the fields was transformed into log of area (i.e., used as an offset variable) to scale the expected number of lapwings to the hectares counted by the observers, since one would presume that the number of lapwings is proportional to the size of the field. We evaluated five different model combinations to identify the one that best described lapwing abundance (Table 1). For that, we performed our model selection based on Akaike Information Criterion (AIC_c) due to low sample sizes, and considered that models in which the difference in AIC_c compared to the best model was < 2 had substantial support (Burnham and Anderson 2002). We used Likelihood-ratio tests to evaluate the inclusion of fixed effects in the most parsimonious model (Pinheiro and Bates 2000). Analyses were carried out using the package lme4 in R software v3.5.0 (Bates *et al.* 2015; R Core Team 2019).

RESULTS

The average water cover in a field was about 28% during the first winter and 32% in winter 2006-2007 (Fig. 2). On average, non-rolled fields had higher water cover than rolled fields, 38% and 26% respectively (Wilcoxon rank-sum test: $W = 172103$, $P < 0.001$). The total lapwing numbers followed a characteristic pattern in both years, with two peaks corresponding to southwards movements in January, and another peak for the northward migration during the second week of February (Fig. 3A). During De-

Table 1. Results from the five candidate models explaining Northern Lapwing (*Vanellus vanellus*) abundance evaluated based on their AIC_c (small-sample-size corrected version of Akaike Information Criterion) values: *K* is the number of explanatory variables, Δ_i the AIC_c differences compared to the most parsimonious model, and LL the model log-likelihood. All models included the random intercepts of field identity ("field") and number of weeks since the first of December ("no week"). The most parsimonious model is in bold.

Model	K	Δ_i	LL
count ~ water cover2 * rolled + (1|field) + (1|no week)	**9**	**0.00**	**-1986.83**
count ~ water cover2 + rolled + (1|field) + (1|no week)	7	41.00	-2009.36
count ~ rolled + (1|field) + (1|no week)	5	69.99	-2025.88
count ~ water cover2 + (1|field) + (1|no week)	6	129.56	-2054.65
count ~ (1|field) + (1|no week)	4	171.59	-2077.69

cember and January, the number of rolled rice fields was variable, and the proportion of rolled fields gradually increased until all the fields were rolled by mid-February (Fig. 3B).

The results from the Likelihood-ratio tests revealed that there was one model supported over the others in terms of parsimony (difference in AIC_c between the best and the second-best model $\Delta_i > 41$, $\chi^2_2 = 45.1$, $P < 0.001$; Table 1). The best model included as fixed effects the interaction between the second-degree polynomial of water cover and rolling (Table 1). The two random effects (field identity and number of weeks since the first of December) were included in the model with estimated variance of 2.631 ± 1.622 SD and 2.072 ± 1.439, respectively (Table 2).

The number of lapwings that rolled fields could host was manifold higher than in non-rolled fields (Table 2; Fig. 4). For instance, an average rolled field with 50% water cover (percentage at which lapwing abundance more or less peaked) would host an estimated 12.03 ± 0.52 SE lapwings versus 0.18 ± 0.58 win a non-rolled field. While in rolled fields the maximum abundance of lapwings was found at an intermediate percentage of water cover (approximately from 25 to 75%), in non-rolled fields the number of lapwings increased steadily with water cover (Fig. 4). According to our data, water cover was between 25 and 75% in less than 50% of the times the rice fields were counted (41% in winter 2005-2006 and 37% in winter 2006-2007).

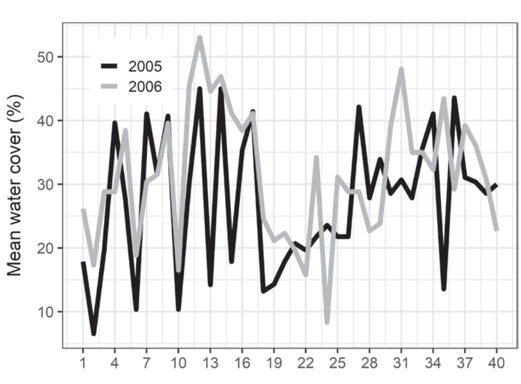

Figure 2. Mean percent ground surface covered by water in each of the study rice fields (*n*=40) in the Baix Ter wetlands, northeastern Spain, during two consecutive winters: 2005-2006 and 2006-2007.

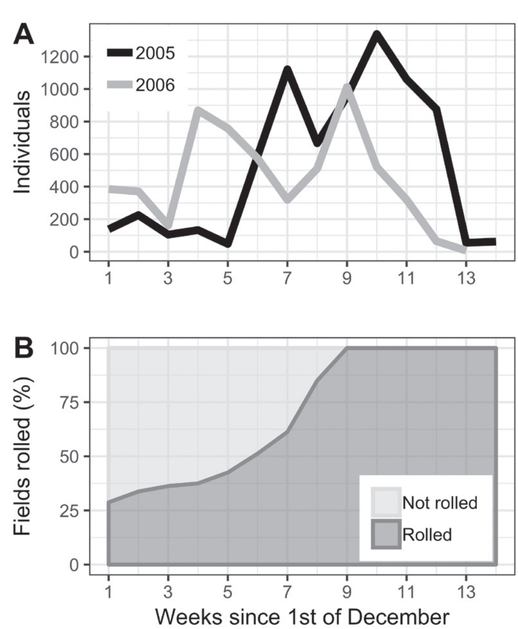

Figure 3. Total counts of Northern Lapwings (*Vanellus vanellus*) in the rice fields of Baix Ter wetlands, northeastern Spain, during the two winter seasons 2005-2006 and 2006-2007 (A); and proportion of rolled and non-rolled fields averaged over the two winters (B).

Table 2. Coefficients of the top negative binomial GLMM (Generalized Linear Mixed Model) predicting the number of Northern Lapwings (*Vanellus vanellus*) in rice fields. Negative binomial dispersion parameter: 0.201.

	Estimate	SE	*Z*-value	*P*-value
Intercept	**-2.597**	**0.578**	-4.496	< 0.001
Water cover	**25.792**	**8.120**	3.176	0.001
(Water cover)^2	10.117	7.374	1.372	0.170
Rolled[a]	**3.108**	**0.394**	7.880	< 0.001
Water cover:Rolled	-14.664	9.295	-1.578	0.115
(Water cover)^2:Rolled	**-38.960**	**8.341**	-4.671	<0.001

[a]Reference level is "Non-rolled"

DISCUSSION

Our results showed that the agri-environmental measures of flooding and rolling rice fields during winter favor the presence of lapwings. A correct management of these agricultural habitats promotes waterbird conservation (Elphick and Oring 2003; Lourenço and Piersma 2009; Longoni 2010; Pernollet *et al.* 2015b). Contrary to other traditional management methods used in the study area during the 1980s (e.g., high use of chemicals or stubble burning), which are widely recognized as being detrimental to waterbirds (Longoni 2010), flooding of rice fields has been demonstrated to increase the numbers of several bird species (Elphick and Oring 1998, 2003; Pernollet *et al.* 2015a). This tech-

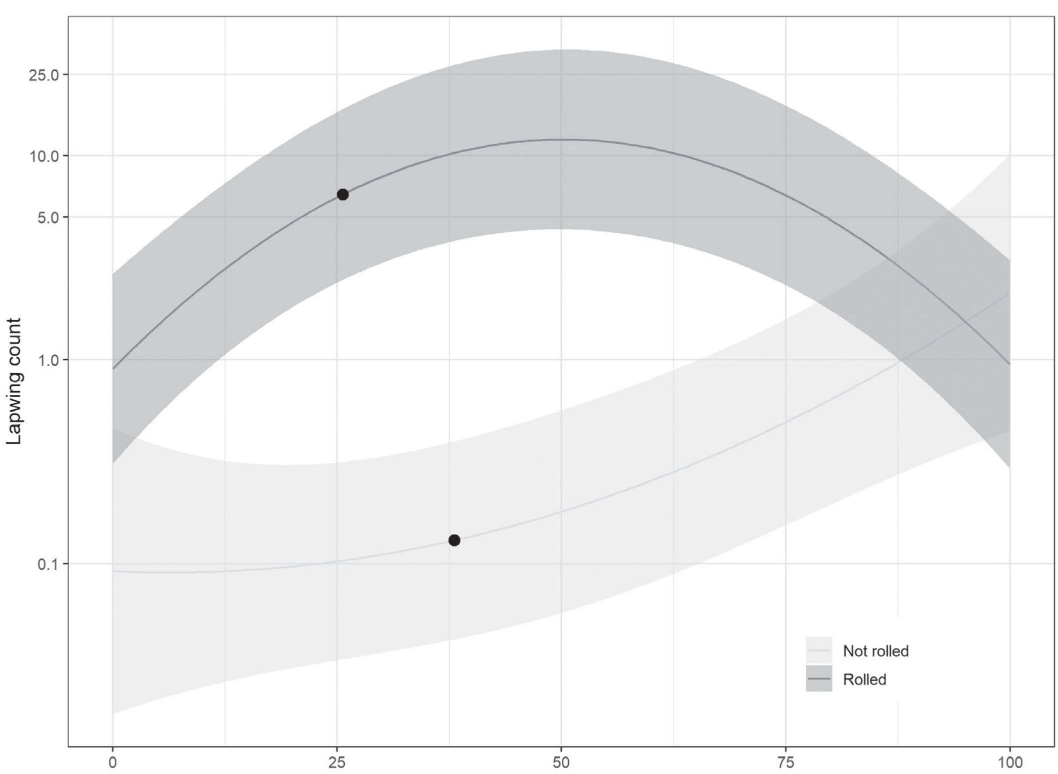

Figure 4. Estimated number of Northern Lapwings (*Vanellus vanellus*) in the Baix Ter wetlands, northeastern Spain, for an average rice field depending on water cover and whether the field is rolled or not. Shaded areas represent 95% confidence intervals. Black dots correspond to the average water cover for non-rolled and rolled rice fields.

nique, which started to be implemented in the 1990s in the Baix Ter wetlands, improves rice stubble decomposition, mainly because waterbirds tear the stubble into pieces, therefore improving its contact with soil (Bird *et al.* 2000; van Groenigen *et al.* 2003; Brogi *et al.* 2015). The increase in decomposition also makes nitrogen more available the following spring (van Diepen *et al.* 2004). The presence of high waterbird densities also benefits farmers because waterbird foraging activity on stubble decomposition may help to reduce the abundance of pest species (Green and Elmberg 2014). Although flooding may be beneficial to farmers, this practice can be costly if it consumes a lot of water. In this sense, focusing on optimal flooding levels could possibly minimize this concern (Elphick *et al.* 2010). Similar to the results found by Eadie *et al.* (2008), in many cases the percentage of water cover estimated in rice fields was above or below the range at which lapwing abundance was found to be at its highest, indicating that the same (or maybe more) conservation benefits could have been obtained using less water (Elphick *et al.* 2010).

Despite that higher densities of lapwings were observed on wintering flooded rice fields in Portugal (Lourenço and Piersma 2009), several studies have demonstrated that the practice of rolling after flooding can increase the richness of waterbird communities, especially when it comes to short-legged shorebirds (Elphick and Oring 1998, 2003; Sánchez-Guzmán *et al.* 2007; Lourenço and Piersma 2009). A potential explanation for this association is most likely better access to the foraging substrate when stubble is mixed (Lourenço and Piersma 2009). Some long-legged wading species can sometimes favor rolled rather than only flooded rice fields (standing stubble), such as the case of Black-tailed Godwits (*Limosa limosa*) (Lourenço and Piersma 2008; Santiago-Quesada *et al.* 2014). This suggests that other measures than flooding alone can also provide suitable habitat for waterbirds, while at the same time increasing invertebrate production (Lawler and Dritz 2005; Longoni 2010), possibly benefitting other insectivorous species. In fact, the results of the present case study indicate that when rice fields have been rolled after flooding, the density of lapwings is higher than in non-rolled fields. High water cover is an essential factor in non-rolled fields, whereas for rolled fields, an intermediate percentage of water cover is preferable. Some studies carried out on USA rice fields have pointed out how water depth influenced whether a species was present at a site (Elphick and Oring 1998, 2003). However, the relationship between bird abundance and water cover has been investigated in other types of wetlands different than rice fields (e.g., Baschuk *et al.* 2012; Vanausdall and Dinsmore 2019). This is one of the few studies that assesses the interaction between two different AES measures (here flooding and rolling) and identifies the optimal ranges of water cover where species abundance is found at its highest depending on whether rice fields are rolled or not.

Farmers are encouraged to roll their fields and maintain a water cover not too high to obtain both agronomic benefits and ecosystem services for waterbirds, while at the same time promoting the conservation of their habitats (Pernollet *et al.* 2015a; Niang *et al.* 2016). However, because not all waterbird species react positively to rolled rice fields, a combination of rolled and non-rolled fields would be ideal, with plowing spread across the winter to guarantee the availability of standing stubble fields throughout the period (Lourenço and Piersma 2009; Strum *et al.* 2013). Also, keeping water on fields for longer periods increases the number of invertebrates which favors pre-breeding and migrant shorebirds in early spring (Krapu and Reinecke 1992; Elphick *et al.* 2010). This research study reaffirms the importance of rice post-harvest management practices as an essential tool for the conservation of waterbirds. The management prescriptions of AES increase the suitability of these habitats for most waterbird species.

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