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The benefits of a constructed lagoon for the conservation of Eurasian Spoonbills (*Platalea leucorodia*) in a tidal marsh

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ABSTRACT

In sites where habitat loss has been intense, or where human disturbance is high, the restoration or creation of undisturbed habitats for species of concern is fundamental for wildlife conservation. In 2009, a 11.5 ha area in the upper marsh at Urdaibai (North of Spain) was excavated, and a new, stable lagoon of brackish water built in its place. In contrast to the rest of Urdaibai, the lagoon was not tidal, and it had lower reported rates of human disturbance than the rest of Urdaibai. Our aim was to quantify the benefits of this lagoon on Eurasian Spoonbill (*Platalea leucorodia*) populations. The lagoon hosted 42% of the spoonbills deciding to stop over at Urdaibai, although only representing ca. 1% of the total marsh and 6% of the area effectively used by spoonbills. Spoonbills at the lagoon invested less time in foraging, but had higher foraging success rates than birds stopping over in other areas of Urdaibai. Most spoonbills only stopped over at Urdaibai for <24 h whilst migrating, but the longest stopover periods were detected at the lagoon. It appears the lagoon has improved the quality of Urdaibai as a stopover site for the Eurasian Spoonbill in the Bay of Biscay region. However, more work is needed to verify the suggested energetic benefits of the new lagoon in order to assess the full degree to which the newly constructed lagoon benefitted local spoonbills, and to ascertain if this kind of management could benefit the species more widely.

Introduction

In ecologically highly deteriorated areas, where habitat loss has been intense, or in areas where human disturbance is very high (Navedo & Herrera, 2012), the restoration or creation of undisturbed habitats for species of concern, is fundamental for wildlife conservation (Braun et al., 1978; Dobkin et al., 1998; Manning et al., 2011). This is especially true among habitat types with patchy distributions, such as wetlands (Weller, 1999; Murray & Hamilton, 2010). However, habitat management does not always result in positive outcomes for waterbirds. For instance, in some cases foraging rates in managed habitats are not as high as observed in natural habitats (Mander et al., 2013; Choi et al., 2014) and in other cases artificial or restored habitats are not used by the same species using natural habitats (Rogers et al., 2013; Dias et al., 2014). Therefore, the evaluation of management actions carried out to restore or maintain waterbird populations need to be made carefully to ensure they are beneficial. This is even more important for a threatened bird such as the Eurasian Spoonbill (*Platalea leucorodia*).

The Eurasian Spoonbill (hereafter, Spoonbill) is a widespread Palaearctic bird that breeds patchily from Europe to East Asia, India, the Red Sea and northern Africa. The European population (subspecies *P. l. leucorodia*) is distributed between some breeding nuclei in southwestern Iberia (Máñez & Rendón-Martos, 2009), others in the Wadden Sea and in central-western Europe, and further sites through East Europe (Tucker and Heath, 2004Tucker & Heath, 2004). The population from central-western Europe (also known as the north-Atlantic population) migrates via the eastern Atlantic coast, to spend the winter either in southwestern Iberia or in the Banc d'Arguin in Mauritania (Lok et al., 2011).

The Spoonbill is a species of concern in Europe. It is listed as SPEC 2, and its status is "Rare" (Tucker & Heath, 2004). Although increasing in size (Tucker & Heath, 2004; Lok et al., 2009), its population is patchily distributed, and is still small (<10,000 pairs) after a large decline between 1970 and 1990. Mortality mostly occurs during the non-breeding period (Lok et al., 2011), and hence the availability of adequate stopovers is important for the conservation of the species.

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Wetlands along the coast of northern Iberia constitute a target stopover region for the central-western European population (Galarza, 1986; Navedo, 2006; Garaita, 2011, 2012), with the Santoña Marshes being of chief importance (Navedo, 2006). In contrast to other nearby areas, the Santoña Marshes host more spoonbills and the birds occuring there make longer stopovers (Navedo et al., 2010a). The lower abundance of spoonbills at other wetland areas located further east, in particular Urdaibai and Txingudi (Overdijk & Navedo, 2012), may be due to their relatively small size, which makes them more vulnerable to disturbance (Garaita, 2012).

Extending 945 ha, Urdaibai is one of the main estuaries along the coast of northern Iberia (Galarza, 1984). Urdaibai is traditionally used by spoonbills to rest and gain some fuel during less-than-one-day stopovers (Garaita, 2012). The species is present during the autumn migration period (from August to mid- or the end of October) and, to a lesser extent, the spring migration period (mainly in March and April). From a spoonbill perspective, Urdaibai is thought to be used as an emergency site, where birds only (or mostly) stop over in case of adverse weather (Overdijk & Navedo, 2012). This contrasts with other nearby sites, such as Santoña, where birds could extend their stopover to several days (Navedo et al., 2010a, 2010b). The impact of human disturbance seems to be one of the capital reasons why spoonbills do not stay in Urdaibai for longer periods (Del Villar et al., 2007; Garaita, 2012). Human disturbances in the area are due to activities such as shellfishing, people walking dogs, canoeing and sightseeing (Garaita, 2012). This author observed that the decision to depart from Urdaibai was mostly directly linked to humans approaching the birds and found disturbance rates of >5 disturbances/h in the lower marsh (which reach peak values >10 disturbances/h during some weekends).

In October of 2009, a site in the upper marsh, which contained an old, deteriorated polder, colonized by an exotic saltbush (*Baccharis halimifolia*), was excavated and a new lagoon of brackish water was built (Rozas and Álvarez, 2011Rozas & Álvarez, 2011). This lagoon (hereafter, Orueta Lagoon) occupied an area of 11.5 ha and consisted of free water of less than 1-m depth, small islets and sedges (*Juncus* spp.). During heavy spring tides the Orueta Lagoon was filled with salty water but otherwise it was maintained by rain and drainage water. By the very end of 2009, the Orueta Lagoon was seen to be used by an increasing number of waterbirds. In 2010 it was practically full of water and hence was used by several waterbird species (J. Arizaga, unpubl. data).

The aim of the present article is to quantify the benefits of this lagoon on spoonbills stopping over at Urdaibai. The Orueta Lagoon constituted a site free ($\ll$1 disturbance/h) from severe human disturbance which also provided a stable layer of water, i.e. a new habitat for the Spoonbill at Urdaibai. Therefore, our prediction was that the lagoon may improve the quality of Urdaibai as a stopover site for the Spoonbill. In particular it may increase the carrying capacity of Urdaibai, thus allowing a higher number of spoonbills to stop over, and may also increase spoonbills' stopover duration. We also explored whether foraging success rate at the Orueta Lagoon varied in relation to the rest of Urdaibai.

Materials and methods

Sampling site and data collection

Sampling work was carried out at the Urdaibai estuary, in northern Iberia (Fig. 1). It is included in the Urdaibai Biosphere Reserve, declared in 1984. Thereafter, in 1993, the estuary was also declared a Ramsar site.

Spoonbills at Urdaibai were surveyed on a daily basis, from dawn to dusk, during the autumn migrations of 2002 to 2012. The migration period potentially lasted from late August to mid-October (Garaita, 2012). We only considered data from September for our analyses.

Bird counts were conducted from 2002 to 2010 at the only place known to be used by spoonbills at Urdaibai, an area of ca. 160 ha at the lower marsh and comprised of mudflats and low halophytic vegetation (Fig. 1). In 2010 spoonbills were first seen at the new Orueta Lagoon (Arizaga et al., 2013), and an additional systematic survey of this 11.5 ha lagoon was carried out since 2011.

Counts were done very accurately, as we knew exactly how many spoonbills landed at Urdaibai each day. Accurate counts allowed us to detect >99% of the spoonbills stopping over at Urdaibai (Garaita, 2012). Counts were conducted from three locations which provided sufficient elevated viewing to observe over 99% of the spoonbills at both study sites (Fig. 1). To count birds at the lower marsh the survey was carried out from two sighting points situated on road Bi-3235 (kilometers 40.5 and 41.5; Fig. 1). At the Orueta Lagoon, counts were done from an observatory. From each survey site, spoonbills were observed with a telescope ($\times$20–60) or binoculars ($\times$8). Spoonbills were detected with the same probability at the Orueta Lagoon and the rest of Urdaibai. Flocks or individual spoonbills arriving, stopping over or abandoning the area were easily observed from such points. Movements of spoonbills within Urdaibai (e.g. flocks or individual spoonbills moving from the Orueta Lagoon to the lower marsh and *vice-versa*) were also easily detected. Most spoonbills stopping over at Urdaibai stayed in the area for less than 24 h, and the majority were observed arriving in Urdaibai during the day and departing before dusk. Accordingly, the sum of spoonbills seen in each study month was used to assess the size of the population stopping over at Urdaibai. If on one day we observed a flock of eight spoonbills and the next day we still observed eight spoonbills in the area, we considered that these eight birds were the same as the day before. The frequent presence of colour-ringed spoonbills in many flocks helped us to know that this approach was likely acceptable in most cases. Our method assumes that arrival/departure of spoonbills at night is rare and hence had a minor impact on our estimate of population size at Urdaibai in September. Deviation from this assumption leads to an underestimation of population size (Frederiksen et al., 2001), which should affect both study sites to the same degree.

We also surveyed the spoonbills' activity patterns (Garaita, 2012). Individual bird activity was surveyed every 15 min, and we noted whether birds were foraging, sleeping/preening, flying or "other". We also recorded tide height as high, intermediate (increasing or decreasing) or low when the activity was surveyed. Activity patterns were recorded at the Orueta Lagoon from 2011, whereas the rest of Urdaibai was surveyed from 2002. We only considered data from 2011 and 2012 to compare activity patterns between the Orueta Lagoon and the rest of Urdaibai.

Foraging rate was used here as a proxy of food availability, assuming that a higher foraging rate (e.g. item swallowed/minute) is possible when a site provides more food (Delingat & Dierschke, 2000). To estimate foraging rate, we observed individual foraging spoonbills over 1-min periods and counted the number of items taken during that time. This survey was carried out by choosing specific spoonbills randomly throughout September. This survey was carried out at the Orueta Lagoon only in 2012, and in the rest of Urdaibai from 2002.

Data analyses

We used a *t*-test to see whether the foraging rate in the Orueta Lagoon was different from the rest of Urdaibai both in 2012 (a two-sample *t*-test) and in the Orueta Lagoon in 2012 compared to the mean foraging rate at the rest of Urdiabai for the period 2002–2012 (a one-sample *t*-test).

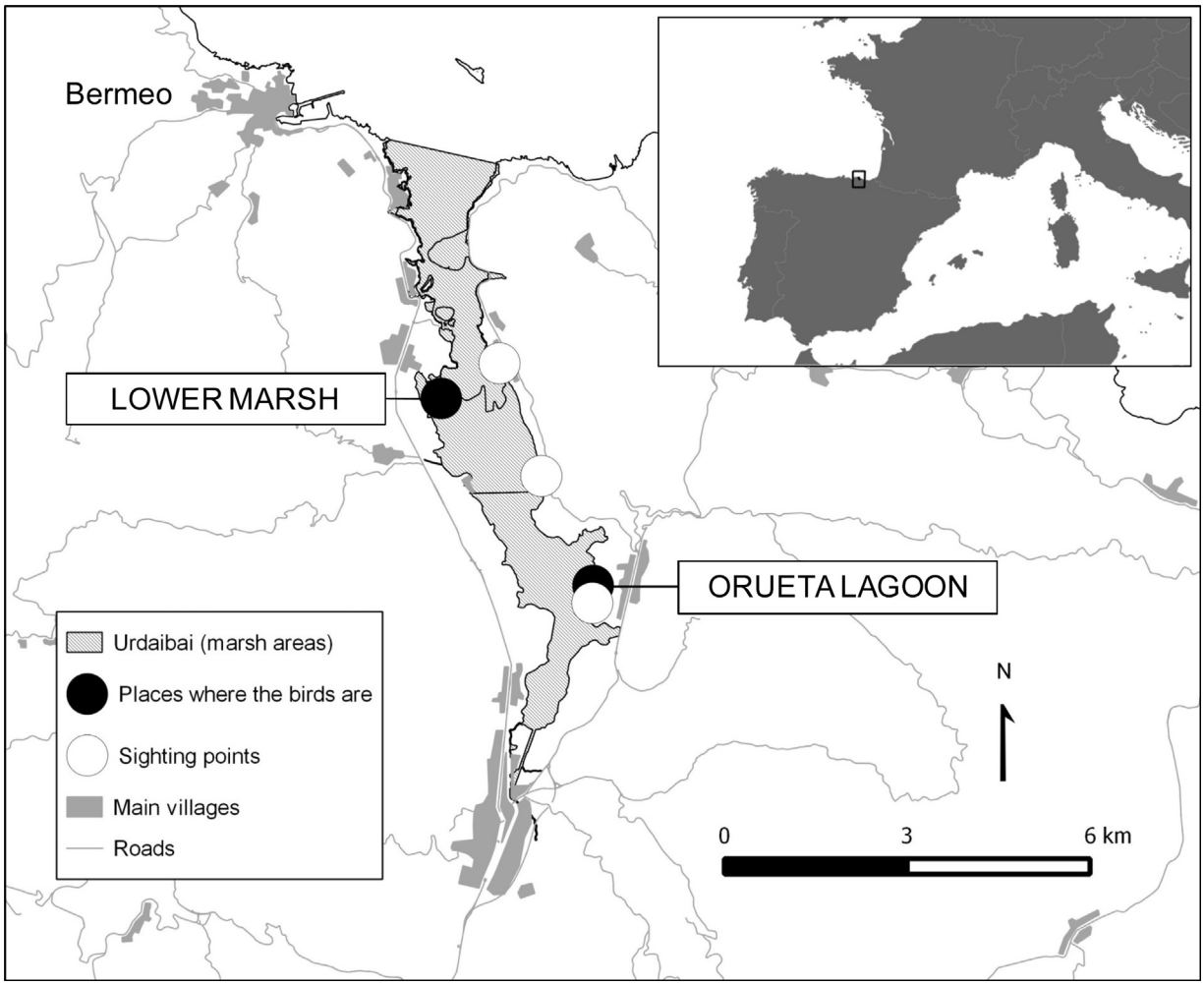

Fig. 1. The Urdaibai marsh areas, study sites, and sighting points used to survey Eurasian Spoonbills stopping over at Urdaibai (North of Spain).

Using data from 2011 and 2012, to test whether spoonbills preferably used the Orueta Lagoon and/or the rest of Urdaibai, we ran a chi-square test on the number of spoonbills observed, with year (column: 2011, 2012) × site (rows: Orueta Lagoon, rest of Urdaibai, both). The identification of spoonbills using both sites was carried out just by observing that particular flocks or individual birds moved between sites. When the absolute standardized difference between observed and expected values is higher than 3, the difference can be considered significant (Agresti, 2002). Additionally, we divided bird numbers by the area of each site (i.e. calculated an annual average bird density) and tested with a one-sample *t* test whether the density at the Orueta Lagoon in 2011 and 2012 varied in relation to the mean for the rest of Urdaibai for the period 2002–2012.

Stopover duration was assessed using data from birds observed to be colour-ringed. The stopover duration was calculated as the time (number of days) elapsed between the first and last days when a bird was seen (Navedo et al., 2010a). Stopover duration did not fit to a normal distribution. Therefore, in order to test if it varied between the studied sites, we conducted a non-parametric *U* test. We also ran a chi-square test in order to test if the proportion of spoonbills stopping over one or >1 days differed between the two studied sites. We used for this analysis the data collected from 2002 to 2012.

To test if the activity pattern differed between the Orueta Lagoon and the rest of Urdaibai, we only considered data from 2011 and 2012, since these were the years when spoonbills were found both at the Orueta Lagoon and in the rest of Urdaibai. We conducted 428 surveys overall (Orueta Lagoon: 236; Rest of Urdaibai: 192). We first ran a chi-square test for each site with type of activity (foraging, sleeping/preening, flying) × type of tide (high, intermediate and low). Activities included in the "others" category were not considered here since few birds were found in this category (Orueta Lagoon: 0.01%; Rest of Urdaibai: 0.62%). Standardized residual values from this test were used to identify significant biases from a distribution assuming the same time invested to each type of activity independently of tide. Standardized residual values >3 indicate significant differences (Agresti, 2002).

We tested if the spoonbill population stopping over at Urdaibai (1) remained stable over time, or (2) showed an increasing tendency (we considered here a linear growth rate), in parallel with the tendency observed for the breeding grounds in Europe, mostly in the Netherlands (van Turnhout et al., 2010). To test this we used TRIM software, considering two alternative models: no time effect and linear tendency. The small sample sizes-corrected Akaike values (AICc) were used to rank the fit of the models to our data and to select the models that best fitted to data (Burnham & Anderson, 1998). In particular, the model which had the lowest AICc was considered to be the one that best fitted to data. Models with an AICc difference <2 were considered to fit the data equally well (Burnham & Anderson, 1998).

We used SPSS software for the analyses.

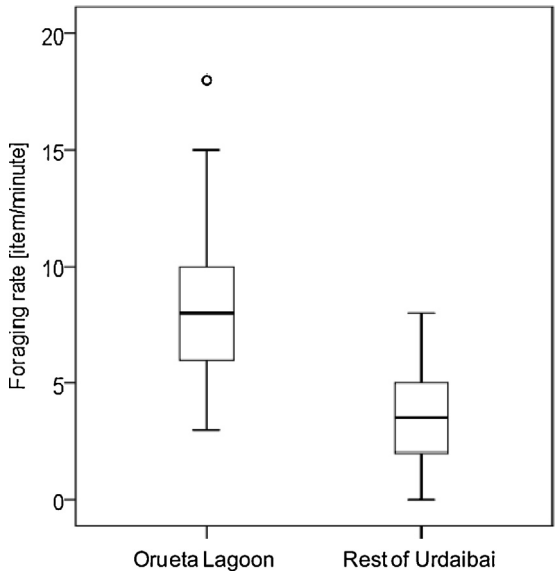

Fig. 2. Foraging success rate of spoonbills stopping over at the Orueta Lagoon and the lower marsh at Urdaibai, during the autumn migration period of 2012.

Results

Foraging rate

The foraging rate at the Orueta Lagoon was higher (mean ± SD: 8.7 ± 3.6 item/min, $n = 48$) than at the rest of Urdaibai (3.8 ± 2.4 item/min, $n = 14$; $t_{60} = 4.736$, $P < 0.001$; Fig. 2) in 2012. This rate was also higher than the rate observed at the rest of Urdaibai for the period 2002–2012 (5.6± 0.4 item/min, $t_{10} = 7.073$, $P < 0.001$).

Site use

Overall, most spoonbills used only one of the sites and relatively few used both when stopping over at Urdaibai (Orueta Lagoon: 41.8%, Rest of Urdaibai: 51.4%, Both: 6.8%). Regarding the use of the Orueta Lagoon and the rest of Urdaibai, more birds used the rest of Urdabai ($\chi^2 = 18.425$, $df = 1$, $P < 0.001$). However, we detected significant differences in this use between 2011 and 2012 ($\chi^2 = 45.684$, $df = 2$, $P < 0.001$). In particular, we detected a proportionally higher than expected number of spoonbills using both sites in 2012, as well as less birds than expected at the Orueta Lagoon in 2012 (Table 1). In relation to the area existing at each site, however, more spoonbills used the Orueta Lagoon in 2011 (51.9 spoonbills/ha; $t = 108.051$, $P < 0.001$) or 2012 (15.9 spoonbills/ha, $t = 28.326$, $P < 0.0001$) than the rest of Urdaibai for the period 2002–2012 (mean ± SE: 3.1 ± 0.5 spoonbills/ha).

Stopover duration

Overall, the stopover duration was found to range from one to 14 days, with most spoonbills (87.0%, $n = 234$) making one-day stopovers at Urdaibai. We did not find site-associated significant differences in the stopover duration ($U = 7977.0$, $P = 0.359$). Overall, spoonbills stayed at Urdaibai less than 24 h (median: 1 day; mean ± SE: 1.2 ± 0.1 day). We observed that the longest staying periods (three birds that stayed >5 days) only occurred at the Orueta Lagoon (5, 6 and 14 days), but the proportion of spoonbills stopping over >2 days did not differ between the two studied sites ($\chi^2 = 0.888$, $P = 0.450$).

Table 1
Observed number of spoonbills landing at each site in September of 2011 and 2012, and the typified residual values (in parenthesis) obtained from subtracting the expected values from the observed values, assuming a similar proportion between 2011 and 2012. Absolute residual values >3 indicate a significant difference between the observed and the expected values.

Site	2011	2012
Orueta Lagoon	597 (45.5%) (+2.1)	183 (33.0%) (−3.2)
Rest of Urdaibai	653 (49.8%) (−0.8)	306 (55.2%) (+1.3)
Both	61 (4.7%) (−2.9)	65 (11.8%) (+4.5)

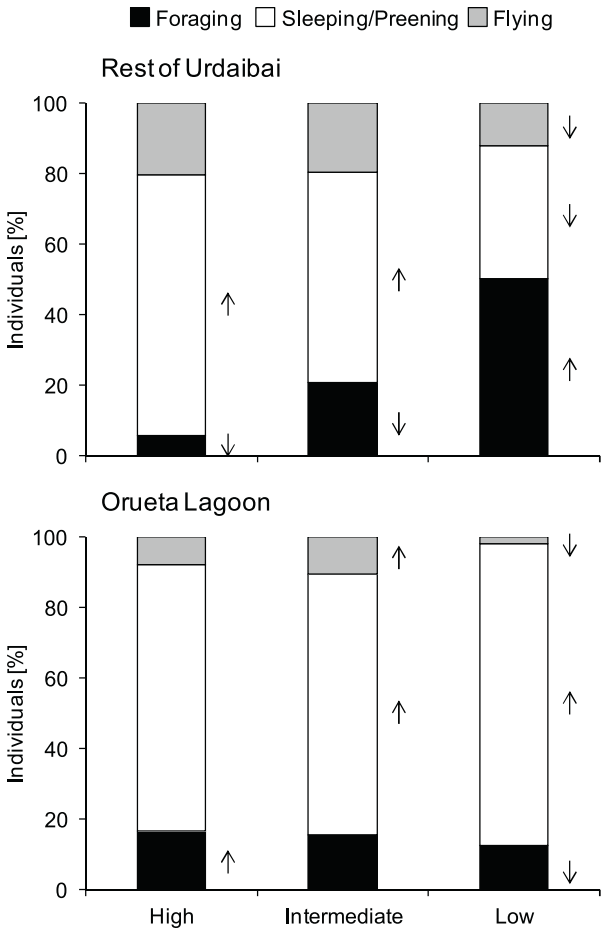

Fig. 3. Activity patterns of spoonbills at Urdaibai in relation to tide height at two study sites: Urdaibai, a tidal marsh; Orueta Lagoon, a proximate constructed wetland. Arrows indicate the observed values seen to be statistically higher/lower than the expected values assuming a constant proportion of each activity independent of tide height at each site.

Activity patterns

Activity patterns varied at both the Orueta Lagoon and the rest of Urdaibai in relation to tide height (Orueta Lagoon: $\chi^2 = 547.153$, $df = 4$, $P < 0.001$; Rest of Urdaibai: $\chi^2 = 1610.306$, $df = 4$; $P < 0.001$; for details see Fig. 3). At the Orueta Lagoon the proportion of spoonbills foraging tended to decrease slightly from high to low tide, whilst the opposite was detected for the proportion of spoonbills sleeping/preening. During intermediate tide height a much higher than expected proportion of spoonbills was observed flying at the Orueta Lagoon (Fig. 3). In the rest of Urdaibai, however, we detected the opposite pattern, with a markedly higher proportion of spoonbills foraging during low tide and a higher proportion of birds sleeping/preening during high tide (for details see Fig. 3).

Fig. 4. Proportion of spoonbills (bars) detected at each site in Urdaibai from 2002 to 2012 (data considered here relative to September), and the number of spoonbills counted overall (black dots).

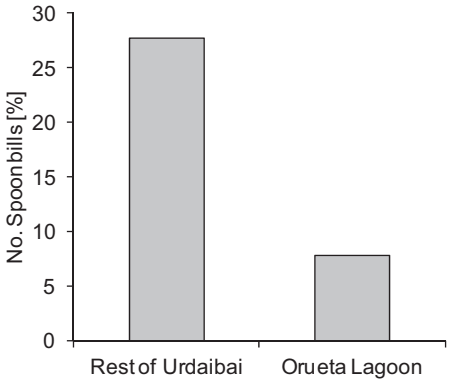

Fig. 5. Reaction of spoonbills stopping-over at Urdaibai to disturbance in September of 2012. We show for each site the proportion of birds which left the area out of the total birds showing some kind of reaction (from flying to alerting) to a disturbance. Data obtained from Garaita (2012).

Population size

The number of spoonbills observed stopping over at Urdaibai each year in September ranged from 196 (in 2002) to 1311 (in 2011) (Fig. 4). The model supporting an increasing linear tendency fitted better to our data than the one supporting no tendency (AICc values: 879.54 versus 1746.06, respectively). Assuming a linear tendency in population growth, the population was observed to have a moderate increase at a rate of +11.9 ± 4.2%/year (Wald test: 7.99, $df = 1$, $P = 0.005$).

Discussion

Spoonbills using a newly constructed lagoon (Orueta Lagoon) at a tidal marsh in northern Iberia were observed to have higher foraging success rates than those in adjacent habitats. This suggests that restored habitats can provide greater food densities than found on other habitats which are being used during migration. This result has importance for the continued recovery of threatened spoonbill populations. However, several things remain unclear and require further studies. Understanding the true energy benefits of this new habitat would require a computation of energetic budgets including the amount of energy saved from using a relatively less disturbed site. We cannot reject the idea that the apparent importance of this lagoon is only relative to what is a relatively marginal site for spoonbills in the flyway. Interestingly, other studies have shown that habitat management does not always result in improved foraging rates in relation to sites with natural habitat (Mander et al., 2013; Choi et al., 2014), so this result does indicate that this kind of habitat creation has likely benefitted the birds in this area, and even might have benefitted spoonbills more widely. It would be interesting to see if similar habitat management at more relevant stopover sites might yield similar results.

From 2011 on, a fraction of the population was observed to stop over in the Orueta Lagoon. However, this fraction did not exceed 45%, so the rest of Urdaibai still hosted more spoonbills during the autumn migration period. Proportionally, nonetheless, even 45% is a remarkable figure if we consider that the Orueta Lagoon occupies ca. 1% of Urdaibai, and is ca. 6% of the area used by spoonbills at Urdaibai. Considering the area of each study site, the Orueta Lagoon definitely hosted a much greater spoonbill density than the rest of Urdaibai. The increasing use of the Orueta Lagoon by the spoonbills was likely to be caused by the fact that it apparently provided better foraging conditions and it had less disturbance (<1 disturbance/h) than the lower marsh of Urdaibai. Disturbances at the Orueta Lagoon were also detected to be less aggressive than those found in other areas of Urdaibai, where in 2012 a 27.8% of spoonbills left the marsh after the disturbance (Fig. 5). The origin of these human disturbances also varied between the two sites (Fig. 6).

Interestingly, whilst spoonbills at the Orueta Lagoon were able to forage at a faster rate, the stopover duration was similar between the two sites. Accordingly, in theory, these birds might be able to accumulate larger fuel reserves whilst at this lagoon (Alerstam & Lindström, 1990). Again, if spoonbills stopping over at the Orueta Lagoon depart with higher fuel reserves, this marginal site may fit the role of a true refuelling stopover site. This idea should be considered cautiously as there are still several factors not yet accounted for, and the foraging rate at the Orueta Lagoon was measured only in a single year (2012).

Few birds were found to visit both sites during their stopover, suggesting that once they land in a particular area at Urdaibai (i.e. the Orueta Lagoon and the rest of Urdaibai), they remain in it, and are not likely to move to the other one. Migrants stopping over at a particular site could consider local conditions as representative for the whole site, even if there is a better area nearby within that same stopover site (Alerstam & Lindström, 1990; Delingat & Dierschke, 2000). In this scenario, the use of the new Orueta Lagoon is expected to increase with time, since (1) birds with experience that already know this lagoon will tend to stop over in it and (2) these birds would attract other birds to stop over at Urdaibai (Newton, 2008). This is a prediction that must be tested in future studies. If spoonbills experience less disturbance at the Orueta Lagoon, a site with little recorded human activity (Garaita, 2012), and additionally they can find better foraging conditions, it can be speculated that this lagoon may be used by an increasing proportion of spoonbills stopping over at Urdaibai.

The time budget of the spoonbills varied between the Orueta Lagoon and the rest of Urdaibai. Although there were some slight differences in relation to tide height, only ca. 15% of spoonbills at the Orueta Lagoon were observed foraging, with the rest sleeping or preening and very few flying. Outside the Orueta Lagoon the proportion of spoonbills foraging was very low during high tide (ca. 5%), but very high when the tide was low (50%). Thus, it can be concluded that, probably due to its independence from tide height, the Orueta Lagoon offers conditions which allow spoonbills to forage constantly. By contrast, spoonbills from the rest of Urdaibai seem to have difficulties feeding during high tide, so they must compensate for that when the tide is low. As we do not know the size, energy reward or digestibility of selected prey, or the condition of birds on arrival, it is impossible to know for sure if spoonbills stopping over at the Orueta Lagoon departed with higher fuel reserves.

The population of spoonbills stopping over during the autumn migration period at Urdaibai, one of the main coastal marshes in

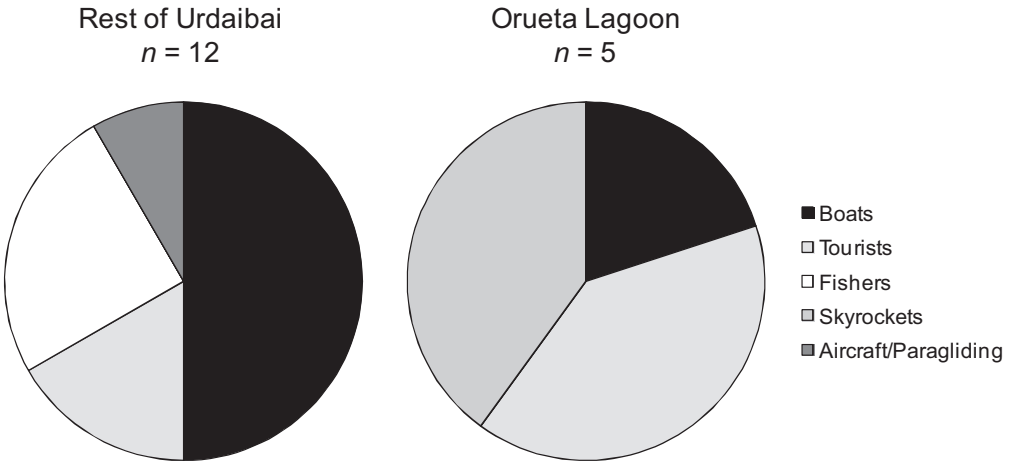

Fig. 6. Origin (%) of human disturbances found to affect spoonbills stopping over at Urdaibai during the autumn migration period of 2012. Data obtained from Garaita (2012).

northern Iberia, tended to increase in abundance from 2002 to 2012. This increase, however, does not seem to be associated with the recently created Orueta Lagoon. Rather, the increasing tendency of spoonbills stopping-over at Urdaibai is similar to the trend found for the central-western European population (Lok et al., 2009).

Although the creation of the Orueta Lagoon had benefits on spoonbills stopping over at Urdaibai, the lower marsh site still plays a fundamental role for the conservation of this species during the autumn migration period. Therefore, we feel it is important to note here that the management of the lower marsh also has to continue to be a priority. It is especially critical to regulate recreational disturbance (Navedo & Herrera, 2009) in or near the sites which are used by spoonbills in this region (Garaita et al., 2002; Garaita, 2012).

In conclusion, in only its second year the recently constructed Orueta Lagoon at Urdaibai appeared to have benefitted spoonbills in the area. Although comprising only ca. 1% of Urdaibai's area, this lagoon hosted up to 45% of the spoonbill population stopping over at this wetland. It also provided a site apparently rich in food and free from disturbance. Therefore, the lagoon has improved the quality of Urdaibai as a stopover site for the spoonbill in the Bay of Biscay. Small, undisturbed, stable water bodies situated in, or close to, tidal marsh habitat areas might represent management actions which would benefit spoonbills in other staging areas, possibly also even other waterbirds.

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