Leisure activities as a main threat for the conservation of waterbirds in an estuary in northern Iberia

J. Arizaga, R. Garaita, A. Galarza

Abstract

Leisure activities as a main threat for the conservation of waterbirds in an estuary in northern Iberia. Human disturbances can have a severe impact on avian conservation, decreasing diversity and carrying capacity of ecosystems. Coastal wetlands are hotspots for the conservation of biodiversity but they commonly suffer the impact of human activity because they are usually priority areas for socio–economic development. The aim of this study was to determine the role of several factors on the potential and real disturbances of human origin on waterbirds over an annual cycle, and to evaluate their impact on the waterbird community. The study was carried out at the Urdaibai estuary (Spain). Although Urdaibai is a main coastal refuge for aquatic birds in Northern Spain (a Ramsar site, Natura 2000 site, Reserve of Biosphere), it faces high levels of human–induced distur-bances. We found disturbances varied across the day, week and year, with peak disturbance coinciding with hours, days and months with highest activity, mostly associated with leisure options. The impact on waterbirds varied between species and the response to such impacts was also species–specific. Disturbances were highest near the river mouth and decreased towards the upper parts of the estuary. Efforts to increase protection of waterbirds should consider reducing the disturbance in areas with the highest impact in order to increase the functional carrying capacity of the estuary for waterbirds and to create quiet feeding and resting areas, maybe by establishing reserves with restricted access.

Key words: Biodiversity conservation, Coastal wetland, Disturbance, Waterfowl

Resumen

Las actividades recreativas como principal amenaza para la conservación de las aves acuáticas en un estuario del norte de Iberia. Las perturbaciones antropogénicas pueden tener graves repercusiones en la conservación de especies avícolas, lo que contribuye a reducir la diversidad y la capacidad de carga de los ecosistemas. Aunque los humedales costeros son zonas de gran interés para la conservación de la biodiversidad, suelen estar sometidos a importantes presiones humanas, ya que, con frecuencia, son zonas prioritarias para el desarrollo socioeconómico. La finalidad del presente artículo es determinar el papel de varios factores en las perturbaciones antropogénicas que afectan y pueden afectar a las aves acuáticas durante todo el ciclo anual, y evaluar los efectos de dichas perturbaciones en el conjunto de la comunidad de aves acuáticas. El estudio se llevó a cabo en el estuario de Urdaibai (España). Incluso aunque Urdaibai sea uno de los princi-pales refugios costeros de aves acuáticas en el norte de España (es un lugar protegido por la Convención de Ramsar, forma parte de la Red Natura 2000 y es una reserva de la biosfera), es objeto de una elevada frecuencia de perturbaciones inducidas por humanos. La cantidad de perturbaciones varió en el tiempo, de forma diaria, semanal y anual; el máximo coincidía con las horas, días o meses de mayor actividad en la zona, en su mayoría asociada a actividades recreativas. Los efectos en las aves acuáticas también variaron entre especies y la respuesta a tales efectos también fue distinta según la especie. Las perturbaciones fue-ron máximas cerca de la desembocadura del río y disminuyeron en dirección a las zonas altas del estuario. Las iniciativas dirigidas a aumentar la protección de las aves acuáticas deberían sopesar la posibilidad de reducir la cantidad de perturbaciones en las zonas más conflictivas, a fin de aumentar la capacidad de carga funcional del estuario para las aves acuáticas y crear zonas tranquilas de alimentación y descanso, tal vez estableciendo reservas con acceso restringido.

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Introduction

Human–induced disturbances can have a severe impact on avian conservation (Platteeuw and Henkens, 1997; Frid and Dill, 2002; McLeod et al., 2013; Collop et al., 2016), becoming a major threat to conservation even in protected areas (e.g., Sutherland, 2007). Response to such disturbances can be multiple, from null (such as no impact, e.g. causing flush but no effect on fitness) to physiological alterations (causing changes in feeding and resting patterns) and abandonment of the disturbed zone (Triplet et al., 2003). During the breeding season, disturbance can increase the risk of predation (Mikola et al., 1994), leading to loss of eggs or offspring (Gillett et al., 1975) and nest abandonment (Miller et al., 1998). Disturbances can also lead to changes in the spatial distribution pattern of birds, forcing them to use sub–optimal and less safe areas, which can have negative long–term carryover effects on reproduction and survival (Riddington et al., 1996; Lepage et al., 2000). Disturbances can also generate a decrease in the diversity and carrying capacity of ecosystems (Davenport and Davenport, 2006; Platteeuw and Henkens, 1997).

Coastal wetlands are hotspots for the conservation of biodiversity but they commonly support multiple human pressures because they are usually priority areas for socio–economic development (Beazley, 1993; Weller, 1999). The conflict between biodiversity conservation and the use of coastal marshes by human societies remains unsolved in many regions of the world (e.g. Glover et al., 2011; McFadden et al., 2017). The impact of a disturbance can differ between species. While some species can be particularly sensitive (Garaita and Arizaga, 2015) others are highly tolerant (Beja, 1996). The impact can also vary temporally, from hourly (Fernández–Juricic and Tellería, 2000) or daily (Lafferty, 2001) to seasonally (Stillman and Goss–Custard, 2002). In this context, identifying the type and patterns of disturbances and evaluating their impact on populations is a basic first step towards the development of efficient conservation management policies.

Many aquatic bird populations around the world use coastal marshes as breeding sites, as stopovers during migration, or as wintering quarters (Boere et al., 2006). Waterbird conservation thus depends largely on preservation of coastal marshes that are of high ecological value, and all levels of disturbance should be considered (Davenport and Davenport, 2006).

Depending on the type of disturbance, the impact on waterbirds can differ substantially between species and sites. A species–dependent or site–dependent approach is therefore commonly needed to solve problems from a small–scale, local perspective (Glover et al., 2011; Samia et al., 2015). Long–term monitoring programs can help plan appropriate conservation measures and evaluate their effectiveness in mitigating disturbances. Such programs can also help prompt interventions when needed. Data collected can be used to assess whether a given value at a particular time unit is exceptional or whether it falls within a range that can be considered normal (Peach et al., 1999; Jiguet et al., 2012; Dubos et al., 2018).

The aim of this study was to evaluate the impact of human disturbances on waterbirds at the Urdaibai estuary (Spain) over the day and year. Hypotheses to be tested were: (1) temporally, disturbances would be higher during peaks of human activity, e.g. in summer as compared to winter, in holidays as compared to working days, or around midday as compared to the early and later hours of the day; (2) spatially, zones closest to the river mouth may be more influenced by human disturbances since people tend to accumulate on sandy beaches (Martín et al., 2014) rather than on mudflats or upper marsh zones with dense vegetation; and (3) taxonomically, some taxa would be more tolerant to disturbances than others. For example, spoonbills or ducks are likely more sensitive and would show a stronger response than gulls.

Material and methods

Sampling area

This study was carried out at the Urdaibai estuary, one of the main tidal marshes along the coast of northern Iberia. With a surface area of 918 ha, it is a focal site for the conservation of waterbirds in Spain (Galarza and Domínguez, 1989). The estuary is included in the Urdaibai Biosphere Reserve, established in 1984, and the area was declared a Ramsar site in 1993. The estuary is also designated as a Special Area of Conservation (SAC ES2130007) and included in a Special Bird Protected Area (SPAB ES0000144). However, waterbirds at Urdaibai are impacted by human disturbance arising from several activities, such as fishing, angling, recreational walking, and sailing. These disturbances are the main reason why some migrant bird species of conservation interest, such as the Eurasian spoonbill (*Platalea leucorodia*), have shortened their stopover in the area (Garaita and Arizaga, 2015).

Specifically, our study area covered the main places used by waterbirds in the estuary and ranged from the river mouth (Laida Beach) to the upper part of the estuary (Orueta Lagoon) (Arizaga et al., 2014). Between these two sites, the estuary was divided into five sectors to facilitate bird counts (fig. 1): (1) Zone 1, that comprises mostly sandy areas (214.8 ha); (2) Zone 2, chiefly mudflats (258.2 ha); (3) Zone 3, upper marsh, consisting of mudflats with halophytic vegetation (103.6 ha); (4) Zone 4, upper marsh (151.5 ha); and (5) Zone 5, a brackish water lagoon which is connected with the marsh during high spring tides (12.4 ha) (Arizaga et al., 2014). We excluded the areas situated still further away from the mouth, which were mostly occupied by reed beds. Human access to these areas is difficult and they are little used by most waterbirds.

Sampling protocol

Sub–lethal effects of a disturbance are not easy to record since many of them could generate physiological

disorders that are very difficult (or impossible) to detect unless individual birds are captured and/or monitored long–term. Therefore, and for practical purposes, here we considered an impact as a disturbance that forced a bird to stop its activity and change to either a position of alert, to move to another part within the wetland, or to leave Urdaibai. We assigned the category 'leaving' to flocks or individual birds which took off and followed a straight–flight trajectory, disappearing from the area. This behavior was not very common, but was recorded for several large species, like Eurasian spoonbills. In this case, it was not rare that disturbed flocks took off, gained height, and followed their straight flight course in a W/SW direction (autumn) or E/NE direction (spring), hence resuming their migration.

The censuses were carried out from May 2017 to April 2018. Potential disturbances and real disturbances (hereafter, PD and RD, respectively) were identified by direct observation from a number of strategically located sampling points along the shore, covering the five zones described above. A PD was considered to be all disturbances with the potential to disturb a bird or flock of birds. The presence of a person, boat, dog or any other human–related item included within any of the 12 categories shown below, therefore, constituted a PD. For instance, a boat passing through the estuary channel in one of the zones was counted as a PD, whether or not there were birds in the zone (as the boat could potentially have caused a disturbance if there were birds present). A PD became an RD when it generated one of the following real reactions in a bird or flock of birds: abandonment of Urdaibai, movement to another site within the zone, or activity and change to a position of alert. For given individual birds, we always considered the higher–scored reaction (e.g., if a bird was alerted and then flew to another site, we considered the second reaction for that bird).

We considered a bimester as the time unit for the analyses. Smaller time units were not considered due to logistic constraints. Within each two–month period, we conducted 10 sampling days, from dawn to dusk, five coinciding with weekends or holidays, and five coinciding with working days. We therefore conducted 60 sampling days over study period. On each sampling day, we carried out a 30–minute census in each zone, starting on the hour. To guarantee surveillance in each zone within each two–monthly analysis, the observer surveyed all the sampling points once within each possible hourly interval on a working day and also on a weekend day or holiday. Double counts within each zone were excluded because censuses were done from elevated survey points, allowing us to follow individual flocks/birds. Conducting the survey from an elevated position also ruled out the observer as a source of RD .

Within each census, the number of PD and RD was recorded for all the waterbirds within the zone. Disturbances were grouped into 12 categories: slow boat (slow–motor boats; BOAT); fast boat (fast–motor boats, including Zodiac boats, and aquatic scooters; FAST); canoes (boats without motor; KANO); dogs (DOGS); shellfish gathering (SHELL); angling (FISH); tourists (anyone walking through the estuary; TOUR); naturalists (birdwatchers and nature lovers, normally ornithologists; NATU); guided visits (with personnel from local tourist sites; VISI); surf (kite–surf, wind–surf; SURF); paddle boards (PADD); and others (OTHERS).

Within each RD, we recorded the species and the number of affected individual birds. This allowed us to identify which species were most affected, the type of reaction, and where and when the disturbance was generated. Moreover, the PD–RD difference allowed us to quantify the impact of the PD and to evaluate the role of human activities within the study area as a source of conflict for the conservation of waterbirds.

Statistical approach

The original sample of PD had many zeros (true zero values) so we modelled the PD and the factors affecting it with zero–altered (ZA) or hurdle models, i.e. models that consider two modeling approaches: a negative binomial model to estimate the probability of having a zero, and a zero–truncated model to estimate effects on data which are not zero. Using the 'pscl' package (Jackman, 2017) for R (R Core Team, 2014), we conducted a saturated global model using the *hurdle* function to test for the fit of the data to the Poisson and the negative binomial approach. Between these two model approaches, that with a lower Akaike value was considered to better fit the data (Akaike, 2011). A model would fit the data better if the Akaike value was lower than 2, as compared to a second model (Burnham and Anderson, 1998).

In our model the number of PD was used as an object variable, with the following explanatory variables: hour (seven categories: hours 1 to 3, corresponding to the first three after dawn; hours 5 to 7, corresponding to the last three hours before dusk; 'hour' 4, pooled hours around midday, before hours 3 and 5); zone (zone 1 to 5, as shown above), period (bimester), tide (4 categories: high, decreasing, low, increasing); day of the week (working day –Monday to Friday–, and weekend) (Perona et al., 2019; Sastre et al., 2009); and type of disturbance (12 categories, as shown above). The area of each sampling zone could also have an effect. Preliminary comparisons considering this area (log–transformed) as an offset variable showed area had an effect on the intercept and the beta–parameter estimates associated with factor 'zone', but not on the other factors in either the Poisson or negative binomial models. However, it should be kept in mind that as most waterbirds tend to concentrate along the banks of the chief channel, each sampling zone has only relative importance, and its inclusion in the models may mask the true weight of PD within each zone. This is relevant if we consider that, as shown in Results, negative binomial models fitted the data better than Poisson models (i.e., our data were more adequate to assess occurrence probabilities rather than to quantify PD per unit of area and time). Thus, we conducted hurdle models twice: first, with all the fixed factors shown above and, second, including area as an offset variable.

To determine which variables caused a real disturbance (RD) we used a generalized linear model (GLM) using a logit–link function with negative binomial
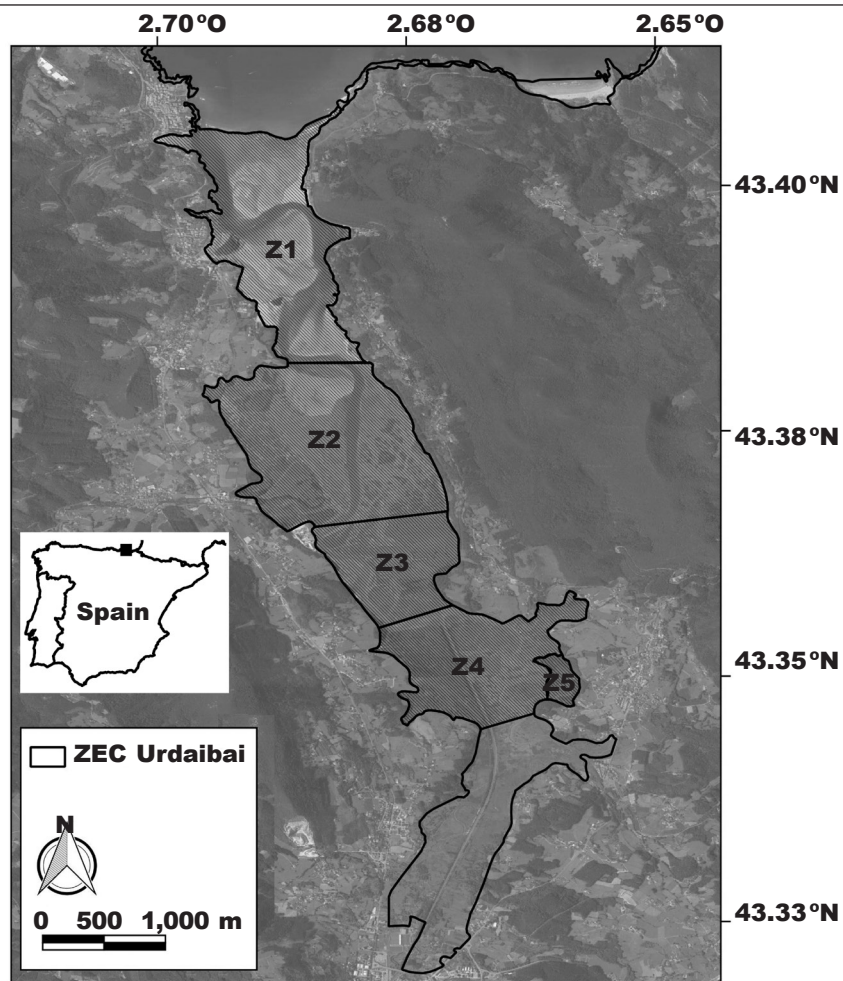
Fig. 1. Sectorization of waterbird surveys and disturbances at Urdaibai. The solid line shows the limits of Natura 2000 (Special Area of Conservation, ZEC Urdaibai). Dashed polygons indicate survey zones.

Fig. 1. Sectorización de los estudios sobre aves acuáticas y perturbaciones en Urdaibai. La línea continua muestra los límites de la Red Natura 2000 (Zona Especial de Conservación, ZEC, de Urdaibai). Los polígonos sombreados indican las zonas del estudio.

errors distribution. As compared to PD, in this case the *hurdle* function to test for the fit of the data to the Poisson and the negative binomial approach may not be used due to problems of convergence (see Results for details). Factors/covariates considered in this model were those taken into account for the models on PD, except the type of disturbance, which was omitted in this case due to sample size constraints.

We also conducted a GLM on the proportion of waterbirds affected by a real disturbance as an object variable, with a linear link function with Gaussian error distribution. Factors/covariates considered in this model were those taken into account for the models on PD, except the type of disturbance, omitted in this case due to sample size constraints. In this situation we did not consider the area of each zone as an offset as we used here a percentage, rather than counts as an object variable.

Results

Potential disturbances

Overall, over 495.5 sampling hours we identified 30,602 PD, with a global mean of 2.38 PD/0.5 h/zone (95 % CI = 0.90 PD/0.5 h/zone; controlled for the area of each zone: 1.16 ± 0.4 PD/0.5 h/100 ha). The ZA models provided a better result for the approach assuming a negative binomial effect, i.e. that PD were better modelled when we tested for the effect of factors driving the occurrence of a PD than for the amount of a PD (AICc values: negative binomial models, 11,703.26; Poisson, 48140.86). According to the negative binomial approach (annex 1), the occurrence of a PD tended to (1) increase progressively from dawn to midday, and then decrease until the end of the day, though the chance of a PD occurring

during the last hour of the day was still higher than during the first hour; (2) increase during summer, from May to October, with no significant difference between the winter/spring period (from November to April); (3) decrease on working days as compared to weekends or holidays; (4) be higher in case of slow–motor boats, canoeing or dogs, without significant difference between these three types of disturbances; (5) increase with decreasing tide; and (6) progressively decrease from Zone 1 to Zone 5, i.e. with increasing distance from the Laida Beach (river mouth) (annex 1). After controlling for the area of each zone, we obtained fairly similar parameter estimates for the zone effect (Zone 2: -0.79 ± 0.08, $P < 0.001$; Zone 3: -1.00 ± 0.10, $P < 0.001$; Zone 4: -3.51 ± 0.19, $P < 0.001$; Zone 5: -2.47 ± 0.36, $P < 0.001$).

Real disturbances

Overall, 10,633 individual birds were found to be disturbed during the study period. These corresponded to 122 disturbances detected in 64 sampling zones/hours out of 991 zones/hours sampled overall (i.e., 6.5 %). According to our negative binomial approach, RD were less likely to happen (1) in Zones 3 and 5 than in Zone 1 (Zones 2 and 4 showed no significant differences compared to Zone 1), and (2) on working days as compared to weekends/holidays (annex 2). Period and hour did not have a significant effect on the chance of having an RD (annex 2). This model was shown to better fit the data than a null (constant) model (Akaike values: 379.64 and 449.31, respectively). Disturbances were highest at weekends ($n = 92$, 75.4 %), and in Zones 1 and 2 ($n = 53$ and 49, respectively, 83.6 %). After controlling for the area of each zone, however, the 'Zone' effect became non–significant (Zone 2: -0.55 ± 0.33, $P = 0.090$; Zone 3: -0.57 ± 0.41, $P = 0.166$; Zone 4: NA; Zone 5: -0.78 ± 1.03, $P = 0.447$), i.e., the occurrence of a disturbance per area unit did not vary between zones.

Tourists (people walking across the wetland and getting too close to birds) were the cause of almost 32 % of the disturbances and 40 % of disturbed birds (fig. 2). Altogether, an additional 40 % of disturbances were due to some kind of boat (categories BOAT, KANO, PADD) moving across Urdaibai, though these were shown to affect just 18 % of total disturbed birds. In contrast, almost 25 % of the disturbed birds were affected by a disturbance categorized as 'others', but these last did not comprise more than a 6.5 % of disturbances. Overall, therefore, recreational activities (excluding here motor boats, shell–fishing and fishing) caused 73 % of the disturbances and affected 80.2 % of the total number of disturbed birds.

Bird counts conducted in parallel to the survey period of real disturbances revealed that 8.4 % of the waterbirds were affected by a disturbance. On average, however, the percentage of waterbirds affected by a disturbance was 3.2 % (95 % confidence interval = 1.2 %, $n = 928$). By taxa, not all groups of waterbirds showed the same proportion of disturbances (chi–square test: 5,636.5, $df = 8$, $P < 0.001$). Thus,

the osprey, divers/grebes and waterbirds classified as 'others' did not suffer any disturbance coinciding with the census period. In contrast, 14.2 % of gulls/terns (mainly gulls) were affected by a disturbance. The proportions for the other taxa were: ducks/geese, storks/herons, cormorants, 1.0 %; spoonbills, 4.4 %; and waders, 4.4 %.

Annex 3 summarizes the beta–parameter estimates from a model which tests for the effect of factors on the proportion of disturbed birds in relation to those occurring in a zone and time interval (hour) when the census was done. Overall, this proportion tended to decrease from Zone 1 to 5 (annex 3). More than 85 % of real disturbances were detected in Zone 1 (fig. 3). This proportion also tended to increase during mid–summer as compared to the rest of year and during the weekends/holidays (annex 3; fig. 4, 5).

Among disturbed birds, 62 % and 30 % showed a type B or C reaction (i.e., escape movement within Urdaibai). Six per cent of the birds did not move from their site but showed just a type A reaction (alarming position), and the remaining 2 % showed a type D reaction (take off and abandonment of Urdaibai). By taxa, 90 % of RD involved gulls, since these are the most abundant waterbirds in Urdaibai, followed by waders (6.2 %), ducks/geese (3.0 %), herons (0.8 %), Eurasian spoonbill (0.6 %), cormorants (0.2 %), and the Northern gannet (< 0.1 %). Not all the taxa had the same reaction (chi–square test: 4504.5, $df = 15$, $P < 0.001$, gannets removed due to low sample size for this taxon; fig. 6). Thus, type D reaction only involved ducks/geese and spoonbills, but not gulls, which were found to habituate to a non–lethal disturbance source better than others (proportionally, they had more type A and B reactions; fig. 6).

Discussion

Coastal wetlands constitute particular habitats because they often occupy relatively small areas but have high rates of human–induced disturbances. In the present study in the Urdaibai marshlands in northern Iberia, we found waterbirds were subjected to disturbances all year round. In absolute values, 8.4 % of birds were affected by a disturbance, comprising more than 10,000 individual birds per year. Although some individual birds could have been disturbed more than once (pseudo–replications cannot be controlled since most birds are not individually marked), we consider our results reflect only a fraction of the birds that may have been disturbed during the study period. This is because the surveys were carried out in such a way that for any given moment they covered only a fraction of the wetland, and samples were taken only on 60 days. A rough estimate based on these results would thus result in more than 60,000 birds being disturbed over one year in this wetland.

Potential disturbances on waterbirds across the annual cycle peaked around mid–day, at weekends and holidays, during summer months, and in the areas closest to the river mouth (i.e. sandy areas where people concentrate). The real chances of disturbance
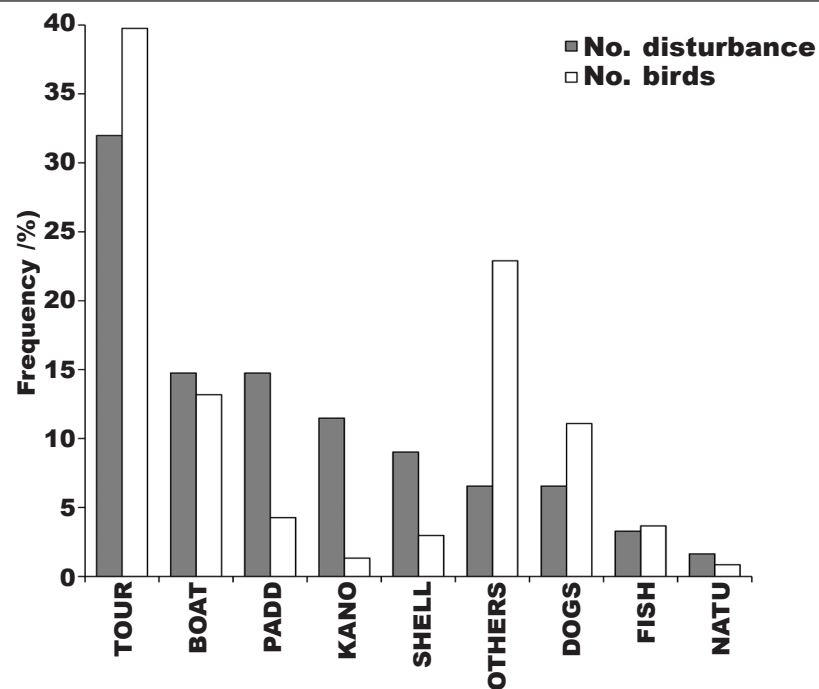
Fig. 2. Distribution of frequency of number of disturbances and birds affected by a disturbance at Urdaibai over one year. Sample sizes: disturbances, *n* = 122; birds, *n* = 10,633. (Abbreviations for the type of disturbance are shown in Methods).

Fig. 2. Distribución de frecuencias del número de perturbaciones y de aves que se vieron afectadas por una perturbación en Urdaibai, durante un año completo. Tamaños de muestra: perturbaciones, n = 122; aves, n = 10.633. Las abreviaciones de los tipos de perturbación se muestran en el apartado Methods.

agreed with this schedule regarding zone and weekends *vs.* workdays, and regarding the proportion of disturbed birds in relation to those occurring at Urdaibai for zone, period and day within a week). Thus, it can be concluded that disturbances varied temporally, over the day, week and year, and also spatially, with a higher absolute impact closer to river mouth (Zone 1). Overall, the findings show that leisure activities are the main source of human–induced disturbances throughout the year and may be the main threat for the conservation of waterbirds within this wetland site. Such spatio–temporal patterns would allow managers to plan greater protection in those zones. Reducing current potential disturbances by increasing protection levels would also allow managers/stakeholders to evaluate the carrying capacity of this wetland with a higher degree of accuracy. Information about the types and magnitude of potential disturbances is, in this context, an elementary tool in conservation management of any protected area.

A question that remains unanswered is whether or not a disturbance rate of less than 10 % is admissible. It is difficult to establish an optimal (or desired) value that represents a 'tolerable' amount of disturbances at Urdaibai (i.e. to find whether a value below or above of 8.4 % is acceptable or should be achieved). Further-

more, it is probable that such a value would also differ between species (Samia et al., 2015). For example, in the case of gulls, which are abundant and seem to be more habituated to disturbances, the proportion of 'sustainable' disturbances could be higher than that for species with a stronger reaction (including a definite abandonment of Urdaibai), or those that are under higher levels of protection (e.g., Triplet et al., 2008), such as ducks, geese, and particularly, the Eurasian spoonbill (Garaita and Arizaga, 2015) and the osprey (Monti et al., 2018). Osprey behavior can be modified significantly by touristic activities, leading to breeding failure even in a well–enforced marine protected area (Monti et al., 2018). Therefore, even very low levels of disturbance could have a high impact on some species.

From a European perspective, the proportion of waterbirds affected by real disturbances at Urdaibai was very low and negligible (mean percentage of waterbirds affected by a RD equalled 0.01 % of European waterbirds populations; BirdLife International, 2015). However, these calculations are conservative as they only took into account the number of adult breeding birds in Europe, but not the juvenile and immature population that was also included among the birds disturbed at Urdaibai. In this context, distur-
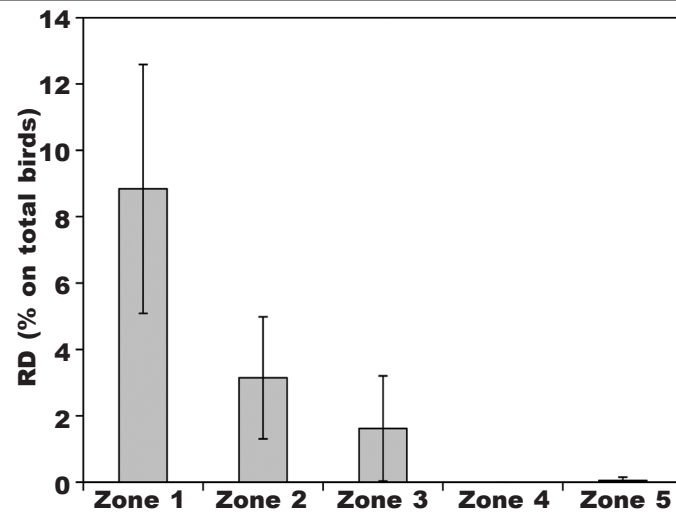
Fig. 3. Percentage of waterbirds affected by a real disturbance, RD (mean ± 95 % confidence interval) in relation to the zone; Zone 1, river mouth; Zone 5, upper marsh.

Fig. 3. Porcentaje de aves acuáticas afectadas por una perturbación real (RD) (media ± intervalo de confianza del 95 %) en Urdaibai, en relación con la zona; Zona 1, desembocadura del río; Zona 5, marisma aguas arriba.

bances at Urdaibai did not have the impact observed in nearby wetlands like the Santoña Marshes, where disturbances might cause the flush of up to 1.5 % of the Eurasian curlew population (Navedo and Herrera, 2012), for example.

The type of reaction to disturbance varied substantially between species. Even though gulls were

the most abundant bird taxon, the most severe reaction, consisting of a long flight within the wetland or definite abandonment was mostly performed by other taxa, some of which are endangered waterbirds, such as waders and the Eurasian spoonbill (BirdLife, 2015). A very specific local problem would be that concerning the Eurasian spoonbill. Spoonbills
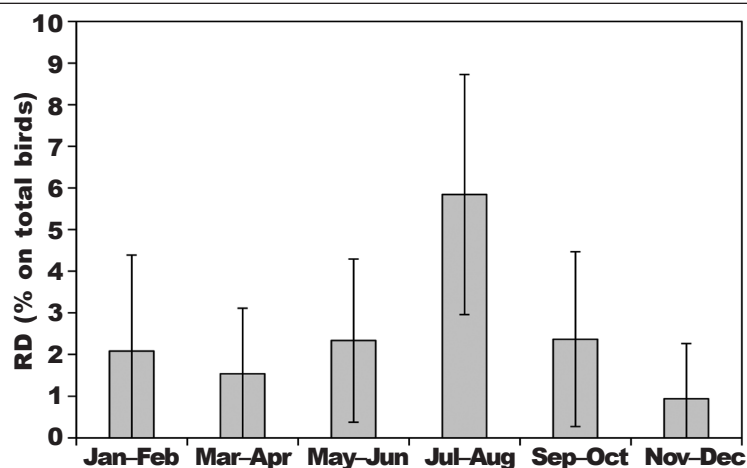

Fig. 4. Percentage of waterbirds affected by a real disturbance, RD (mean ± 95 % confidence interval) in relation to time of year.

Fig. 4. Porcentaje de aves acuáticas afectadas por una perturbación real (RD) (media ± intervalo de confianza del 95 %) en Urdaibai, en relación con el período del año.
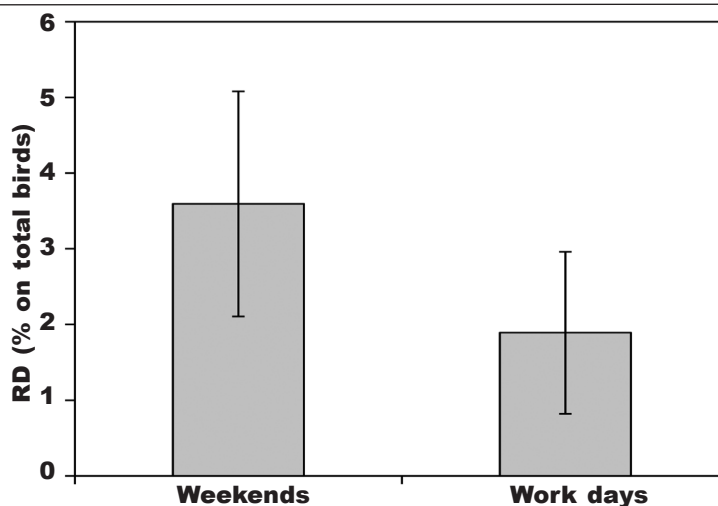
Fig. 5. Percentage of waterbirds affected by a real disturbance, RD (mean ± 95 % confidence interval) in relation to day of the week.

Fig. 5. Porcentaje de aves acuáticas afectadas por una perturbación real (RD) (media ± intervalo de confianza del 95 %) en Urdaibai, en relación con el día de la semana.
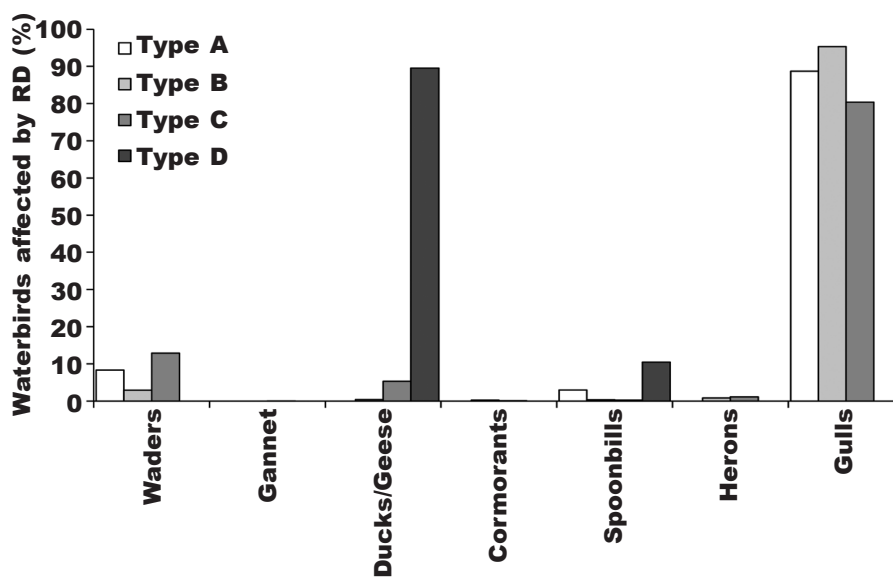

Fig. 6. Number of individuals (in percentage) affected by real disturbances at Urdaibai in relation to their taxonomic group and the type of reaction. Reactions: tipe A, alarm position, *n* = 735; type B, short displacements within Urdaibai, *n* = 6,648; type C, long displacements within Urdaibai, *n* = 3,116; D, take off and abandonment of Urdaibai, *n* = 134.

Fig. 6. Número de individuos (en porcentaje) afectados por perturbaciones reales en Urdaibai en relación con su grupo taxonómico y el tipo de reacción producida. Reacciones: A, posición de alarma, n = 735; B, desplazamientos a corta distancia dentro de los límites de Urdaibai, n = 6.648; C, desplazamientos a larga distancia dentro de los límites de Urdaibai, n = 3.116; D, levantar el vuelo y abandonar Urdaibai, n = 134.

passing through the Atlantic flyway from northern Europe to Iberia and Africa make long stopovers in coastal marshes of the southeastern part of the Bay of Biscay, with Urdaibai being a major (potential) stopover site (Arizaga et al., 2016). However, the occurrence of continuous disturbances commonly shortens such stopovers dramatically, often to less than 24 h (Overdijk and Navedo, 2012, Garaita and Arizaga, 2015). Clearly, the establishment of reserves with restricted access within the marsh may be set as a conservation priority in Urdaibai. According to our results, efforts should focus on zones 2 and 3, which host large numbers of waterbirds (especially Zone 2), including target species of concern, such as the Eurasian spoonbill, with herons and waders also having a good representation in these areas (annex 4). Effective conservation measures should consider strategies oriented to reduce/minimize disturbances in Zone 2, and to a lesser extent Zone 3, where most of the conflicts between waterbirds and humans occur. Creating integral reserves or places with restricted access for pedestrians are two of the possible management measures that should be studied in detail. Zone 1, in contrast, was the most frequented area by people, and here only gulls were found in large numbers. Human activities might therefore be concentrated in this part of Urdaibai, in a strategy aiming to reduce dispersion of the people across the estuary. Zone 5, comprising the Orueta Lagoon, hosted high numbers of waterbirds, confirming previous analyses demonstrating the importance of this artificial lagoon for the conservation of waterbirds at Urdaibai (Arizaga et al., 2014). Given the comparatively low number of disturbances in this zone and the high number of birds present there, the Lagoon may be a good candidate area for planning a zone of integral protection in Urdaibai. Zones 3 and 4 host a relatively low number of waterbirds (with the exception of Zone 3 for the osprey) and have few absolute disturbances. Additional protection measures in these zones are not therefore a priority unless ospreys or other priority species are found to be breeding therein. Collaboration with the local tourism industry is also strongly recommended in order to increase the efficacy of conservation measures.

In conclusion, even though Urdaibai is one of the chief coastal refuges for aquatic birds in Northern Spain (it is a Ramsar site, Natura 2000 site, Reserve of Biosphere), it is subject to high rates of human–induced disturbances. The disturbances vary temporally, across the day, week and year, with peaks coinciding with those times of highest activity, particularly that related to leisure options. The impact on waterbirds varied between species, and the response to such impact was also species–specific. Disturbances were maximal near the river mouth and decreased towards the upper parts of the estuary. Efforts to increase protection of waterbirds should consider reducing the disturbances in areas where the conflict is highest in order to increase the functional carrying capacity of the estuary for waterbirds and to create quiet feeding and resting areas, maybe by establishing reserves with restricted access.

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Supplementary material

Annex 1. *Beta*–parameter estimates of a zero–altered model with logit link function and negative binomial distribution errors used to test for the effect of several factors on the occurrence of a potential disturbance on waterbirds at Urdaibai. Abbreviations for the type of disturbance are shown in Methods. Reference values (*Beta* = 0): Hour = 1; Zone = 1; Period = Jan–Feb; Tide = high; Week = weekend/holiday; Type = BOAT.

Anexo 1. Estimaciones del parámetro beta de un modelo de cero alterado con función de enlace logit y distribución binomial negativa del error utilizado para determinar el efecto de varios factores en la manifestación de una posible perturbación que afectara a las aves acuáticas de Urdaibai. Las abreviaciones de los tipos de perturbación se muestran en el apartado Methods. (Para los valores de referencia, véase arriba).

Factor	Beta	SE(Beta)	P
Intercept	−7.43	0.25	< 0.001
Hour: 2	+0.62	0.26	0.018
Hour: 3	+1.18	0.25	< 0.001
Hour: 4	+1.94	0.21	< 0.001
Hour: 5	+1.61	0.24	< 0.001
Hour: 6	+1.70	0.24	< 0.001
Hour: 7	+1.09	0.25	< 0.001
Zone: 2	−0.61	0.08	< 0.001
Zone: 3	−1.72	0.10	< 0.001
Zone: 4	−3.85	0.19	< 0.001
Zone: 5	−5.32	0.36	< 0.001
Period: Mar–Apr	+0.13	0.15	0.402
Period: May–Jun	+1.04	0.14	< 0.001
Period: Jul–Aug	+1.26	0.14	< 0.001
Period: Sep–Oct	+0.87	0.15	< 0.001
Period: Nov–Dec	+0.23	0.16	0.151

Factor	Beta	SE(Beta)	P
Tide: low	−0.02	0.10	0.860
Tide: decreasing	−0.27	0.10	0.008
Tide: increasing	−0.05	0.11	0.664
Week: workdays	−0.45	0.07	< 0.001
Type: DOGS	−0.17	0.14	0.200
Type: FAST	−2.66	0.23	< 0.001
Type: FISH	−1.10	0.15	< 0.001
Type: KANO	−0.12	0.13	0.383
Type: NATU	−2.58	0.22	< 0.001
Type: OTHERS	−2.39	0.16	< 0.001
Type: PADD	−1.39	0.16	< 0.001
Type: SHEL	−1.28	0.16	< 0.001
Type: SURF	−2.96	0.26	< 0.001
Type: TOUR	+1.19	0.13	< 0.001
Type: VISI	−3.53	0.32	< 0.001

Annex 2. *Beta*–parameter estimates of a generalized linear model using a logit link function with negative binomial distribution errors used to test for the effect of several factors on the occurrence of a real disturbance on waterbirds at Urdaibai. Abbreviations for the type of disturbance as shown in Methods: NA, non–estimable parameter. Reference values (*Beta* = 0): Hour = 1; Zone = 1; Period = Jan–Feb; Week = weekend/holiday; Tide: high.

Anexo 2. Estimaciones del parámetro beta de un modelo lineal generalizado utilizando una función de enlace logit con una distribución binomial negativa para los errores utilizados para determinar el efecto de varios factores en la manifestación de una perturbación real que afectara a las aves acuáticas de Urdaibai. Las abreviaciones de los tipos de perturbación tal como se muestran en el apartado Methods: NA, parámetro no estimable. (Para los valores de referencia, véase arriba).

Factor	Beta	SE(Beta)	P	Factor	Beta	SE(Beta)	P
Intercept	−8.02	0.81	0.001	Period: Mar–Apr	−1.02	0.65	0.117
Hour: 2	−0.07	0.88	0.932	Period: May–Jun	−0.07	0.53	0.896
Hour: 3	+0.70	0.80	0.376	Period: Jul–Aug	+0.70	0.46	0.128
Hour: 4	+0.47	0.65	0.469	Period: Sep–Oct	+0.19	0.52	0.719
Hour: 5	+0.32	0.83	0.704	Period: Nov–Dec	−0.24	0.58	0.682
Hour: 6	+0.91	0.76	0.230	Week: workdays	−0.95	0.31	0.002
Hour: 7	NA	NA	NA	Tide: low	+1.08	0.47	0.021
Zone: 2	−0.41	0.32	0.201	Tide: decreasing	+0.72	0.49	0.142
Zone: 3	−1.32	0.41	0.001	Tide: increasing	+1.29	0.49	0.009
Zone: 4	NA	NA	NA				
Zone: 5	−3.60	1.03	< 0.001				

Annex 3. *Beta*–parameter estimates of a linear model using linear link function and normal distribution errors to test for the effect of several factors on the proportion of waterbirds affected by a real disturbance at Urdaibai. Reference values (*Beta* = 0): Hour = 1; Zone = 1; Period = Jan–Feb; Week = weekend/holiday; Tide = high.

Anexo 3. Estimaciones del parámetro beta de un modelo lineal utilizando una función lineal de enlace logit con una distribución binomial negativa para los errores utilizados para determinar el efecto de varios factores en la proporción de aves acuáticas afectadas por una perturbación real en Urdaibai. (Para los valores de referencia, véase arriba).

Factor	Beta	SE(Beta)	P	Factor	Beta	SE(Beta)	P
Intercept	+8.31	3.29	0.012	Period: Mar–Apr	−0.22	2.25	0.920
Hour: 2	+0.01	3.25	0.999	Period: May–Jun	+1.54	2.25	0.490
Hour: 3	+4.96	3.21	0.120	Period: Jul–Aug	+5.04	2.17	0.020
Hour: 4	+1.17	2.49	0.640	Period: Sep–Oct	+0.91	2.28	0.690
Hour: 5	+5.50	3.18	0.080	Period: Nov–Dec	−1.31	2.41	0.590
Hour: 6	+3.20	3.22	0.320	Week: workdays	−2.44	1.23	0.050
Hour: 7	−1.70	3.34	0.610	Tide: low	+2.25	1.67	0.180
Zone: 2	−7.62	1.94	< 0.001	Tide: decreasing	+0.84	1.76	0.640
Zone: 3	−9.22	1.95	< 0.001	Tide: increasing	+1.26	1.87	0.500
Zone: 4	−11.24	2.02	< 0.001				
Zone: 5	−11.18	1.94	< 0.001				
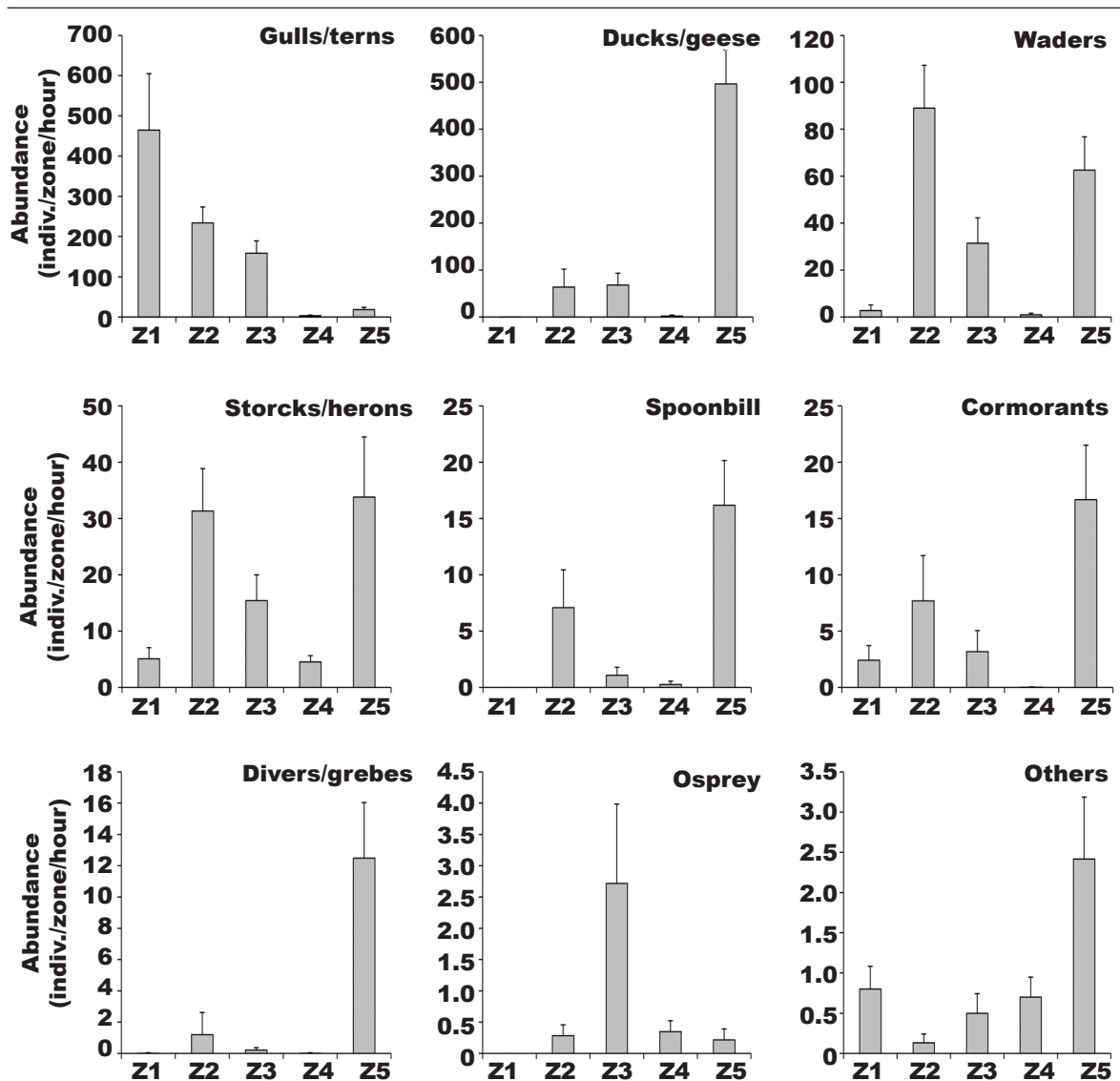
Annex 4. Mean (± 95 % confidence interval) spatial abundance pattern by taxa of waterbirds in the Urdaibai estuary over an annual cycle. The common coot (*Fulica atra*) has been included in the ducks/geese group. 'Others' included: rallids other than common coot and northern gannet (*Morus bassanus*).

*Anexo 4. Media (± intervalo de confianza del 95 %) de la pauta de abundancia espacial por taxón de aves acuáticas en el estuario de Urdaibai durante todo el ciclo anual. La focha común (*Fulica atra*) se ha incluido en el grupo de los patos y las ocas (ducks/geese). El grupo "otros" incluye: rálidos (excepto la focha común) y alcatraz atlántico.*