Vol. 484: 279–286, 2013
doi: 10.3354/meps10312

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published June 12

Fishery management has a strong effect on the distribution of Audouin's gull

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ABSTRACT: The effect of fisheries on seabirds is a key issue for seabird conservation and management. Fish discards, for instance, are an important and significant food resource for many bird species. Despite extensive research, the attractiveness of fishing fleets to seabirds has not been fully explored. We compare the densities of the near-threatened Audouin's gull *Larus audouinii* in 2 areas off the Ebro delta (NW Mediterranean) which are affected by 2 trawling moratoria in different months of the breeding season (May–June and July–August, respectively). We assessed and quantified the effect of fisheries and moratoria on the species' density in both areas under both fishing scenarios by monthly aerial surveys. The gull's distribution is strongly influenced by the trawling moratoria as it overlaps with that of the operating trawlers. Audouin's gulls are scarcer in areas where trawling is prohibited. A complementary analysis of the presence of color-ringed *L. audouinii* at Tarragona and Borriana harbours (located 75 km north and 100 km south of the delta, respectively) showed similar results, with a decrease in the number of individuals during the span of the moratoria. Our findings highlight the strong influence of fisheries on the distribution of *L. audouinii*. The strong dependence of *L. audouinii* on discards from the fishing fleet suggests that the management and conservation of this species must be directly linked to fishery management by the respective stakeholders. This will help ensure the long-term sustainability of *L. audouinii* colonies in this marine important bird area.

KEY WORDS: Seabird · Distribution · *Larus audouinii* · Ecology · Trawling · Fishery moratorium · Ebro delta · Mediterranean Sea

INTRODUCTION

Seabirds interact with fisheries in many different ways, which include negative and positive effects on their ecology, reproductive success or survival (Tasker et al. 2000). Accidental by-catch may have strong negative effects on the population demography and the conservation of some species (Barbraud et al. 2008, Igual et al. 2009). In addition, fisheries can deplete fish stocks by overexploitation (Furness & Tasker 2000, Grémillet et al. 2008). On the other hand, fish discards from vessels have been widely reported as an important food supply for many seabirds worldwide, positively affecting their fitness (Tasker et al. 2000, Furness et al. 2007). The management of these fisheries has far-reaching consequences for seabirds (e.g. Votier et al. 2004, Furness et al. 2007).

Fisheries can influence seabird foraging behavior (Torres et al. 2011) and their distribution at sea (Karpouzi et al. 2007, Cama et al. 2012a). However, the

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strength or scale of the influence of fishing fleets on the distribution of seabirds at sea is hardly known. Different attempts to analyze this key issue of seabird management have provided contrasting results as a function of scale, species and ecosystem. Votier et al. (2010) detected small scale attraction of Atlantic gannets *Morus bassanus* to fishing vessels, but not to the distribution of long-term averaged vessel density. Contrastingly, in the southern Indian Ocean, the distribution of white-chinned petrels *Procellaria aequinoctialis* and fisheries overlap on a broad scale, but not at a local level (Delord et al. 2010). At the transition between the Baltic and North seas, fisheries attract seabirds at a local level (<10 km), but the overall distribution of birds at sea is explained primarily by oceanographic conditions (Skov & Durinck 2001). On the other hand, in the NW Mediterranean the absence or presence of the fishing fleet correlated with changes in foraging destinations of Balearic shearwaters *Puffinus mauretanicus* and Cory's shearwaters *Calonectris diomedea* within a very short time frame (Bartumeus et al. 2010).

Fishery management policies regulate different aspects such as fishing quotas, prohibited fishing locations or temporal moratoria (i.e. periods when fishing is not allowed in particular areas). These regulations restrict the availability of fish discards accessible to birds (Oro et al. 1995, Oro 1996). As a consequence, moratoria are excellent opportunities to quantify the influence of fisheries' management regimes on seabird distribution at sea, by comparing areas or periods with and without fishing activity. We investigated the potential effect of fishing restrictions on the local and regional distribution of the near-threatened Audouin's gull *Larus audouinii* in a marine area affected by both temporal and spatial fishing moratoria.

Larus audouinii mainly reproduces on the Mediterranean coasts, with 65% of its worldwide breeding population occurring at the Ebro delta, NW Mediterranean Sea (Oro et al. 2009). Despite being one of the most endangered seabird species worldwide in the last century, the population increased considerably since the Ebro delta colony had established in 1981 (Genovart et al. 2008). This population increase was partly the consequence of new food resources provided by fish discards from trawlers (Oro et al. 1997). In the study area discards are easy to capture, energy-rich and predictable in space and time (Oro et al. 1997, Arcos 2001, Cama et al. 2012a). However, this resource is not available for breeding *L. audouinii* during the entire breeding season, since 1991 several trawling moratoria periods have been declared in the area to protect fish stocks.

In 1991, the moratoria overlapped with the breeding season of *L. audouinii* and most individuals shifted their diet from discards to epipelagic fishes, mainly clupeiformes that are their traditional food resource, and adapted to feed in freshwater habitats (Oro et al. 1997, Pedrocchi et al. 2002). Some individuals were reported to expand their foraging range to >110 km, reaching areas with operating trawlers (Arcos & Oro 1996, Oro et al. 1997, Mañosa et al. 2004). Despite this foraging plasticity (Christel et al. 2012), these alternative feeding strategies were not sufficient to meet the food demands of the entire colony, as the overall colony productivity was reduced in terms of egg and clutch sizes and recruitment (Oro et al. 1996, 1999). From 1997 onwards, the sea adjacent to the colony has been under a fishing moratorium during July and August, when the seabird breeding activity has already finished. In May and June a moratorium affects the area north of the Ebro river mouth, ~20 km north of the colony (see Fig. 1). Under this new fishing policy, the colony has grown reaching its maximum size in 2007 with ~16,000 pairs (Genovart et al. 2008). However, the intense fishing activity is depleting the fish stocks (Lleonart 1996) causing long-term conservation implications for Audouin's gull, the rich seabird community in the area and the associated marine ecosystem (Coll et al. 2009).

The aim of this work is to assess potential effects of fishing moratoria on the distribution of *Larus*

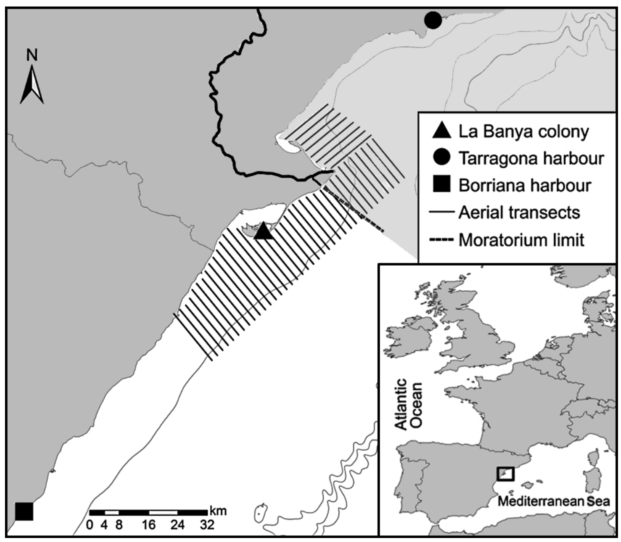

Fig. 1. The Ebro delta and the study area in the Western Mediterranean. Note the location of Tarragona and Borriana harbours as well as the limit of the 2 moratorium areas. North of the limit (shaded) the moratorium took place in May and June whereas south of the limit it took place in July and August

audounii at sea. For this purpose, we conducted surveys of *L. audouinii* to determine the local scale distribution at sea during its breeding period as a function of the distribution of the fishing effort, by means of aerial surveys in periods with and without moratoria. At a wider scale, a long-term ring-reading study was conducted at Tarragona harbour, 75 km north of the breeding colony, and Borriana harbour, 100 km to the south, to detect potential effects of the moratoria. We discuss these results and their direct implications on the management and conservation of the near-threatened *L. audouinii* in the northwestern Mediterranean, where most of the world's population of this gull occurs.

MATERIALS AND METHODS

Study area

The Ebro delta sea shelf (Fig.1), is a key foraging and breeding area for Mediterranean seabirds (Arcos 2001, Louzao et al. 2006), and has been identified as a marine Important Bird Area (IBA) by SEO/Birdlife (Arcos et al. 2009). This area is very productive because of the influence of the Liguro-Provençal-Catalán front and the Ebro river runoff (Salat et al. 2002, Arin et al. 2005), producing high fish densities, especially of European sardine *Sardina pilchardus* and anchovy *Engraulis encrasicolus* (Olivar et al. 2001, Sabatés et al. 2007). This fish abundance has favored the development of a very active fishing fleet, which provides resources for seabirds (Arcos 2001, Arcos et al. 2008). The demersal trawling fleet is of particular importance for seabirds because of the large amount of discards caused by unselective catching methods (for detailed information about discard composition see Arcos 2001).

Aircraft surveys

Monthly aerial surveys took place from May to October 2005 covering 1435 km^2 of the Ebro delta sea shelf (Fig. 1). All the study area was surveyed in a single day during periods with trawling allowed or banned according to the limits shown in Fig. 1. The area north of the moratorium limit was affected by the moratorium in May and June whereas the southern part was affected in July and August.

We used standard seabird aerial survey methods (Noer et al. 2000, Christensen et al. 2001) with minor adaptations. The surveys were done from a Partenavia P-68 twin-engined aircraft, commonly used for wildlife observation. The aircraft followed 45 predefined transect lines with a length ranging from 13 to 23 km because of coastal shape, and separated by a constant distance of 2 km. The flight altitude was 300 feet (~100 m). The flight speed was fixed to 100 knots (~185 km h^{-1}). All censuses were performed during clear days with very good visibility conditions and with wind not exceeding level 3 on the Beaufort scale. Each total census lasted ~6 h.

Two observers with previous experience in aircraft surveys (A.C. and Francisco Javier Macià) carried out the censuses. The observers used Steiner Commander V 7 × 50 binoculars. During these censuses all observed bird flocks in a 2 km band (1 km each side of the aircraft) were recorded. An inclinometer was used to define the limit of the 1 km band. With the established flight height, the limit of 1 km is ~6° to the horizontal axis. The extent of the transect lost because of the limits of the window view has been established as 59 m on the basis of previous studies (Noer et al. 2000, Christensen et al. 2001), reducing the real census band to 941 m width.

All *L. audouinii* groups were recorded on a dictaphone including information about the number of individuals and time of the observation. Although gull identification can be complicated in certain areas where closely related species occur sympatrically, *L. audouinii* identification is reliable from great distances in individuals >1 yr old. The mantle color is obviously different from that of the lesser black-backed gull *Larus fuscus* and slightly different from that of the yellow-legged gull *L. michahellis*, and wing-tip patterns between species are also distinctive. In birds <1 yr old the identification is reliable because of the distinctive rump-tail pattern (Olsen & Larsson 2003). At longer distances not all gulls were identified to species level, and this bias was consistent throughout the study. When the sun reflex on the sea occupied >50 % of the observer visual range, data were not recorded to avoid biased detection and identification rates.

Observations were linked to a GPS with a Turbo Pascal application (I. K. Petersen pers. comm.). We used the program ArcGIS version 9.2 to create a 2 × 2 km grid and to summarize all the information of the surveys in 378 grid cells (118 north of the moratorium limit and 260 south of it). Data were summarized in 2-monthly periods according to the trawling policy: (1) March and April (prior to the moratoria), (2) May and June (moratorium affecting only north of the river mouth), (3) July and August (moratorium affecting only south of the river mouth), (4) September and October (after the moratoria). We generated a density distribution model of the species for every 2-monthly period. We used a Generalized Linear Model following the negative binomial distribution (McCulloch & Searle 2001, Cama et al. 2012b) with a single variable: the sector (i.e. north or south of the moratorium limit). To test if this variable was significantly associated with the gull density, the log-likelihood of this model was compared with that of the model without any variable using the Likelihood Ratio Test (LRT). MASS library for R v2.13 was used for this analysis.

Ring-reading

To evaluate the potential effect of the moratoria on the regional distribution of the species, long-term ring-reading work was conducted at the Tarragona and Borriana harbours (Fig. 1). These harbours are located at the northern and southern limits of the Ebro sea shelf respectively and are also affected by fishing moratoria (see Fig. 1). Readings of color-rings were conducted from 2002 to 2007 during the same time of the year when the aerial surveys were performed, from March to October. Ring-reading often provides a biased sample of individuals, according to the different ringing effort in the different ringing areas or to the inter-annual ringing effort on each ringing locality (Bønløkke et al. 2006). The results from our study area can be taken as representative of the population since the population has been subjected to a large and constant ringing effort throughout the last 20 yr in the main breeding areas (Cam et al. 2004). In addition, during the study period 65% of the world's population bred in a single colony (La punta de la Banya at the Ebro delta, Oro et al. 2009). The mean number of ringed individuals per observation day was compared among the different moratorium scenarios. First calendar year individuals were not included in the analyses because their arrival at the harbours may correspond to their first departure from the colony, rather than to changes in their foraging areas. To test differences in mean values, we used Mann-Whitney U statistics with SPSS 15.0.

RESULTS

Aircraft surveys

During the first half of the study period, from March to June, the overall *L. audouinii* mean density was 0.28 gulls km^{-2} in March–April, very similar to the density found in May and June (0.27 gulls km^{-2}) when the moratorium affected the north (see Figs. 2, 3a). However, most of the observed *L. audouinii* were detected off the southern part of the Ebro delta, with an average density of 0.40 gulls km^{-2} in March–April and 0.37 gulls km^{-2} in May–June. In contrast, fewer individuals were detected north of the moratorium limit during the first half of the study, with 0.04 gulls km^{-2} in March–April and 0.13 gulls km^{-2} in May–June. North-south differences were significant both in March–April (LRT = 35.83, $p < 0.001$) and May–June, (LRT = 16.88, $p < 0.001$).

During the second half of the study period the situation reversed (Figs. 2 & 3a). In July–August, when the moratorium affected the southern part of the Ebro delta, most gulls were observed in the northern part. The average density across the whole study area (north and south) decreased (0.12 gulls km^{-2} in July–August and 0.13 gulls km^{-2} in September–October) and most gulls concentrated north of the moratorium limit, with 0.26 gulls km^{-2} in the north versus 0.05 gulls km^{-2} in the south for both periods. North-south differences were significant both in July–August (LRT = 34.70, $p < 0.001$) and September–October (LRT = 17.78, $p = 0.005$).

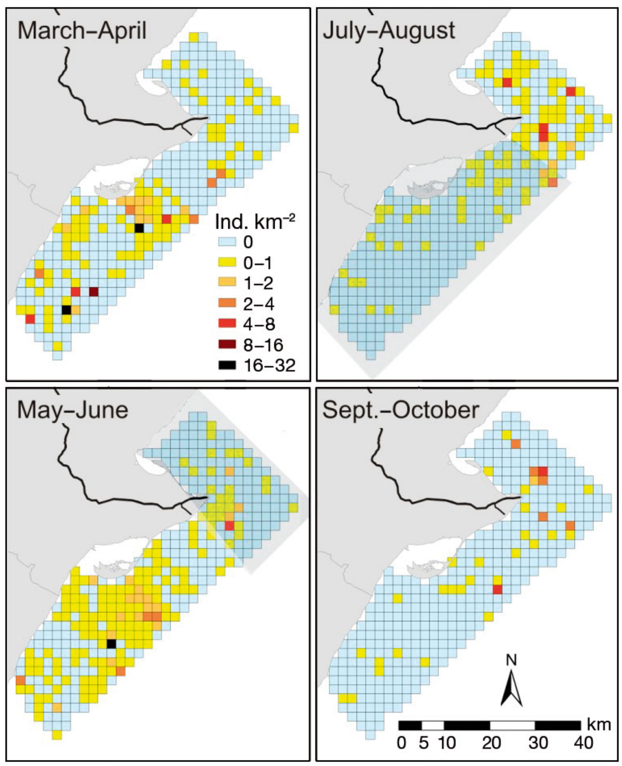

Fig. 2. *Larus andouinii*. Densities (2-monthly means; ind. km^{-2}) off the Ebro delta from March to October 2005. Shaded areas: affected by the moratoria during each survey

Ring-reading

At Tarragona harbour (north of the moratorium limit) 2590 readings of color-ringed *L. audouinii* were done in 169 observation days (see Table 1 & Fig. 3b). The lowest average number of readings was produced in March–April with 2.45 rings d^{-1}. The readings increased in May–June to 14.96 rings d^{-1}, reaching a maximum of 34.88 rings d^{-1} in July–August, and decreasing again in September–October to 5.48 readings d^{-1} (Fig. 3b). The number of readings per day showed significant statistical differences in all the inter-period comparisons (Mann-Whitney U tests $p < 0.05$). South of the moratorium limit (Borriana), 401 readings were achieved in 58 observation days (see Table 1 & Fig. 3b). Only in July–August when the moratorium affected the area, was the mean number of rings significantly lower (1.89 rings d^{-1}) than in March–April (7.64 rings d^{-1}; U = 59.5, p = 0.017) and May–June (8.21 rings d^{-1}; U = 24.0, p = 0.048).

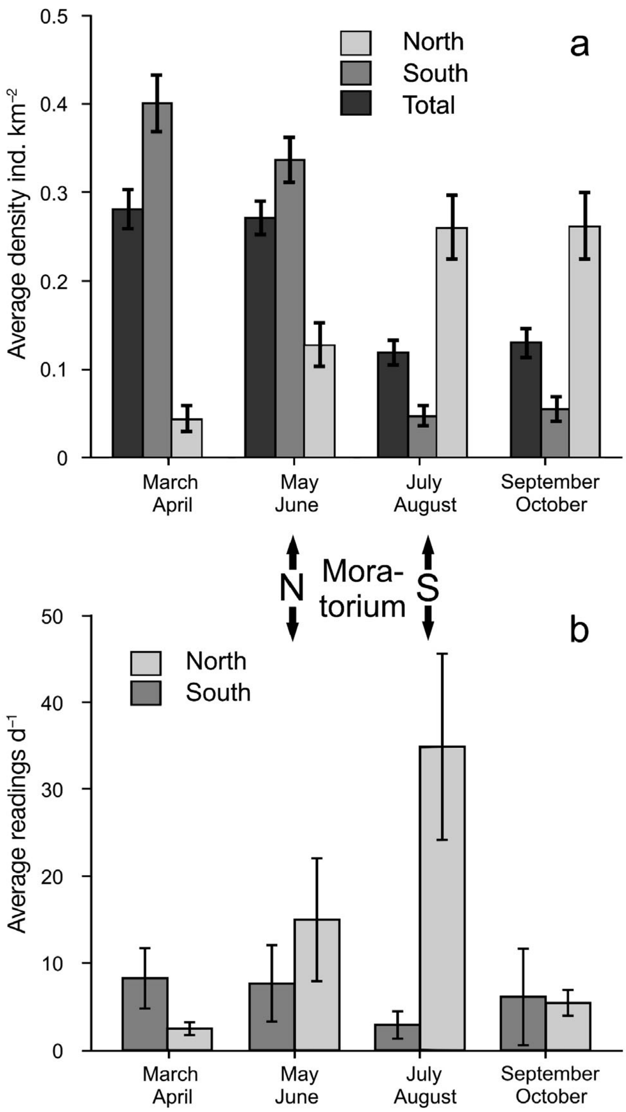

Fig. 3. *Larus andouinii*. (a) 2-monthly density (ind. km^{-2}) off the Ebro delta from March to October 2005. (b) 2-monthly number of read rings per day in Tarragona (North) and Borriana (South) harbours from 2002 to 2007. Means ± 95% CI

Table 1. *Larus andouinii*. Number of rings read from 2002 to 2007 in Tarragona (North) and Borriana (South) according to the fishing scenario: March and April (prior to the moratoria), May and June (moratorium affecting the north of the river mouth), July and August (moratorium affecting the south of the river mouth), September and October (after the moratoria). The number of observation days and the mean number of rings per day are also shown. Shaded parts of the table highlight the periods affected by moratoria

	March–April	May–June	July–August	Sept.–October	Total
Tarragona					
No. of readings	98	404	1814	274	2590
No. of days	40	27	52	50	169
Mean rings d^{-1}	2.45	14.96	34.88	5.48	15.33
Borriana					
No. of readings	230	84	26	61	401
No. of days	28	11	9	10	58
Mean rings d^{-1}	8.21	7.64	2.89	6.10	6.41

DISCUSSION

This is the first fine-scale, at-sea distribution study of *L. audouinii* near its main breeding location. Moreover, the fishery management policy in the Ebro delta sea shelf allowed us to test and quantify the effect of the trawling fleet on the spatial density distribution of a near-threatened seabird.

The density and area of occupancy of the species decreased significantly in the areas and periods affected by the moratoria which indicated a strong influence of the fishing policies on the marine distribution of *L. audouinii*. The aerial surveys showed lower average densities in the areas affected by the moratoria, both in May and June in the north, and in July and August in the south. Similar results were obtained with the supplementary analysis of ring-reading data in harbours placed ~100 km from the breeding colony but affected by the same moratoria. The number of ringed ind. d^{-1} was significantly higher when the moratorium occurred beyond the borders of each surveyed area. Results from the 2 independent survey methods highlight the capacity of *L. audouinii* to shift its distribution according to the presence of fishing boats, concentrating mainly where trawling is allowed and avoiding areas where it is banned.

Since the moratorium shift coincides with the end of the chick rearing period, the post-breeding dispersal could also have an important role in the observed distribution changes, but the ring-reading results show that birds preferentially disperse to where trawlers operate. We hypothesize that the lack of trawling activity around the colony likely forced the start of the dispersal process.

It is well known that fishery waste attracts seabirds. In many cases seabird distribution at sea overlaps with fisheries (e.g. Karpouzi et al. 2007, Cama et al. 2012a). However, no general response pattern to fisheries seems to exist at a population (Skov & Durinck 2001, Bartumeus et al. 2010) or individual level (Votier et al. 2010, Torres et al. 2011), but more species and ecosystems need to be studied to assess which factors affect the seabird response to fisheries. This is an important aspect of seabird conservation and ecology that will likely need to be addressed case by case, especially regarding threatened species for which fishery policies may influence their behavior, ecology and population dynamics.

The knowledge of a species′ specific responses to changes in food resources is key for that species′ management. In our example, when no moratoria affect the breeding colony surroundings, fishery waste is available leading to increased breeding success. The opposite situation, with restricted available discards around a breeding colony, could be used as a population control tool (instead of culling) if the species′ population size was considered to be excessive in a particular location . This can also be applicable to the management of other seabird species that sometimes are considered as pests, such as the conspecific *L. michahellis* that competes with the *L. audouinii* for breeding places (Oro et al. 2009) and food resources (Arcos et al. 2001). The potential effect of fishing policies on seabird conservation can have many different applications, and should be explored further. For instance, since fishing policies can shape seabird distribution, these policies can be used as another marine spatial planning tool to keep seabirds away from dangerous areas. This has already been suggested for the Patagonian shelf, where fisheries with considerable by-catch effect operate (Granadeiro et al. 2011).

According to our results, the conservation of *L. audouinii* may depend on how the fishing fleet and their activities are managed. The activity of the fleet may be necessary to sustain the main breeding population of this species through fish discards. However, excessive fisheries may overexploit the fish stocks and deplete the natural prey of the gulls, compromising the long-term sustainability of the colony. This may be the case with the present fishery, which is known to have already reduced the fish stocks (Lleonart 1996), changed the trophic webs in the ecosystem (Coll et al. 2009), and which could collapse in the future. The new European Common Fisheries Policy calls for a reduction of the fish waste from vessels (Penas 2007), but if this is not accompanied with measures to favor the sustainability of the stocks, this could have the same negative effect on the long-term sustainability of both seabirds and the fish they depend on.

Acknowledgements. We are very grateful to Xescu Macià for his work during the aircraft surveys. The help of Ib Krag Petersen has been very valuable for survey planning, development and data processing. We are grateful to the Ebro delta Natural Park team: David Bigas, Francesc Vidal and Antoni Curcó, for the information and facilities provided. We also thank those colleagues with whom we have shared many hours during the seabird ring-reading at Tarragona: Joan Ferrer, Matxalen Pauly, Raül Aymí and Camil Albert. The ring-reading was possible because of the intense ringing work performed by the IMEDEA (Institut Mediterrani d′Estudis Avançats), the Ebro delta Natural Park, the Conselleria de Medi Ambient i Mobilitat del Govern de les Illes Balears and the Plan de Accion de Aves Marinas Comunidad Valenciana. Also thanks to Raül Aymí, Jordi Muntaner and Blanca Sarzo for their work and help on reporting of seabird rings, to Stephen Mills for improving the English of this manuscript, to Pep Arcos for comments and material provided, and to the Tarragona Harbour Authority (Autoritat Portuària de Tarragona) for allowing us access to the restricted areas where the gulls roost. We are very grateful to 3 anonymous referees for their valuable comments on a previous version of this paper. Capital Energy funded the aircraft surveys. The Fundació Bosch i Gimpera has made possible the relationship between the research team and Capital Energy (projects 303052, 303289 and 303833). IC acknowledges the University of Barcelona for the APIF grant and AC the Generalitat de Catalunya for the financial support of a Doctoral fellowship of the FI programme (2009FIC75).

LITERATURE CITED

Arcos JM (2001) Foraging ecology of seabirds at sea: significance of commercial fisheries in the NW Mediterranean. Universitat de Barcelona, Barcelona. http://www.tdx.cesca.es/TESIS_UB/AVAILABLE/TDX-0219102-114337//TOL38.pdf

➤ Arcos JM, Oro D (1996) Changes in foraging range of Audouin's gulls *Larus audouinii* in relation to a trawler moratorium in the western Mediterranean. Colon Waterbirds 19:128–131

Arcos JM, Oro D, Sol D (2001) Competition between the yelow-legged gull *Larus cachinnans* and Audouin's gull

Larus audouinii associated with commercial fishing vessels: the influence of season and fishing fleet. Mar Biol 319:807–816

Arcos JM, Louzao M, Oro D (2008) Fishery ecosystem impacts and management in the Mediterranean: seabirds point of view. In: Nielsen JL, Dodson JJ, Friedman K, Hamon TR, Musick J, Verspoor E (eds) Reconciling fisheries with conservation: Proc 4th world fish congr. Amer Fish Soc, Bethesda, Maryland, p 1471–1479

Arcos JM, Bécares J, Rodriguez B, Ruiz A (2009) Áreas importantes para la conservación de aves marinas en España. LIFE04NAT/ES/000049-Sociedad Española de Ornitología (SEO/Birdlife), Madrid. http://www.seo.org/avesmarinas/flash.html

Arin L, Estrada M, Salat J, Cruzado A (2005) Spatio-temporal variability of size fractioned phytoplankton on the shelf adjacent to the Ebro river (NW Mediterranean). Cont Shelf Res 25:1081–1095

Barbraud C, Marteau C, Ridoux V, Delord K, Weimerskirch H (2008) Demographic response of a population of white-chinned petrels *Procellaria aequinoctialis* to climate and longline fishery bycatch. J Appl Ecol 45:1460–1467

Bartumeus F, Giuggioli L, Louzao M, Bretagnolle V, Oro D, Levin SA (2010) Fishery discards impact on seabird movement patterns at pegional Scales. Curr Biol 20:215–222

Bønløkke J, Madsen JJ, Thorup K, Pedersen KT, Bjerrum M, Rahbek C (2006) Dansk Traekfugleatlas [The Danish bird migration atlas]. Forlaget Rhodos & Zoologisk Museum - Københavns Universitet, Rhodos, Humlebaek

Cam E, Oro D, Pradel R, Jimenez J (2004) Assessment of hypotheses about dispersal in a long-lived seabird using multistate capture–recapture models. J Anim Ecol 73:723–736

Cama A, Abellana R, Christel I, Ferrer X, Vieites DR (2012a) Living on predictability: modelling the density distribution of efficient foraging seabirds. Ecography 10:912–921

Cama A, Abellana R, Christel I, Ferrer X, Vieites DR (2012b) Moving to the sea: a challenge for an inshore species, the slenderbilled gull, *Chroicocephalus genei*. Mar Ecol Prog Ser 463:285–295

Christel I, Navarro J, del Castillo M, Cama A, Ferrer X (2012) Foraging movements of Audouin's gull (*Larus audouinii*) in the Ebro Delta, NW Mediterranean: a preliminary satellite-tracking study. Estuar Coast Shelf Sci 96:257–261

Christensen TK, Clausager I, Petersen IK (2001) Base-line investigations of birds in relation to an offshore wind farm at Horns Rev: results and conclusions 2000/2001. National Environmental Research Institute report. http://www.hornsrev.dk/Miljoeforhold/miljoerapporter/Baseline_investigations_of_birds.pdf

Coll M, Palomera I, Tudela S (2009) Decadal changes in a NW Mediterranean Sea food web in relation to fishing exploitation. Ecol Model 220:2088–2102

Delord K, Cotté C, Péron C, Marteau C and others (2010) At-sea distribution and diet of an endangered top predator: relationship between white-chinned petrels and commercial longline fisheries. Endang Species Res 13:1–16

Furness R, Tasker M (2000) Seabird-fishery interactions: quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Mar Ecol Prog Ser 202:253–264

Furness R, Edwards AE, Oro D (2007) Influence of management practices and of scavenging seabirds on availability of fisheries discards to benthic scavengers. Mar Ecol Prog Ser 350:235–244

Genovart M, Bertolero A, Martínez-Abraín A (2008) Gaviota de Audouin. In: Bertolero A, Genovart M, Martínez-Abraín A, Molina B, Mouriño J, Oro D, Tavecchia G (eds) Gaviotas cabecinegra, picofina, de Audouin y tridáctila, y gavión atlántico en España. Población en 2007 y método de censo. SEO/Birdlife, Madrid, p 44–67

Granadeiro JP, Phillips RA, Brickle P, Catry P (2011) Albatrosses following fishing vessels: How badly hooked are they on an easy meal? PLoS ONE 6:e17467

Grémillet D, Lewis S, Drapeau L, van Der Lingen CD and others (2008) Spatial match–mismatch in the Benguela upwelling zone: should we expect chlorophyll and sea-surface temperature to predict marine predator distributions? J Appl Ecol 45:610–621

Igual JM, Tavecchia G, Jenouvrier S, Forero MG, Oro D (2009) Buying years to extinction: Is compensatory mitigation for marine bycatch a sufficient conservation measure for long-lived seabirds? PLoS ONE 4:e4826.

Karpouzi VS, Watson R, Pauly D (2007) Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment. Mar Ecol Prog Ser 343:87–99

Lleonart J (1996) La pesca a Catalunya i la seva gestió. Bull Inst Cat Hist Nat 64:135–158

Louzao M, Hyrenbach KD, Arcos JM, Abelló P, Gil de Sola L, Oro D (2006) Oceanographic habitat of an endangered Mediterranean procellariiform: Implications for marine protected areas. Ecol Appl 16:1683–1695

Mañosa S, Oro D, Ruiz X (2004) Activity patterns and foraging behaviour of Audouin's gulls in the Ebro delta, NW Mediterranean. Sci Mar 68:605–614

McCulloch CE, Searle SR (2001) Generalized, linear and mixed models. John Wiley & Sons, New York, NY

Noer H, Christensen TK, Clausager I, Petersen IK (2000) Effects on birds of an offshore wind park at Horns Rev: environmental impact assessment. National Environmental Research Institute report. http://www.hornsrev.dk/miljoeforhold/miljoerapporter/Baggrundsrapport_18.pdf

Olivar MP, Salat J, Palomera I (2001) Comparative study of spatial distribution patterns of the early stages of anchovy and pilchard in the NW Mediterranean sea. Mar Ecol Prog Ser 217:111–120

Olsen KM, Larsson H (2003) Gulls of Europe, Asia and North America. 2nd edn. Christopher Helm, London

Oro D (1996) Effects of trawler discard availability on egg laying and breeding success in the lesser black-backed Gull *Larus fuscus* in the western Mediterranean. Mar Ecol Prog Ser 132:43–46

Oro D, Bosch M, Ruiz X (1995) Effects of trawl moratorium on the breeding parameters of the yellow-legged gull *Larus cachinnans.* Ibis 137:347–349

Oro D, Jover L, Ruiz X (1996) Influence of trawling activity on the breeding ecology of a threatened seabird, Audouin's gull *Larus audouinii.* Mar Ecol Prog Ser 139:19–29

Oro D, Ruiz X, Jover L, Pedrocchi V, González-Solís J (1997) Diet and adult time budgets of Audouin's gull *Larus audouinii* in response to changes in commercial fisheries. Ibis 139:631–637

Oro D, Pradel R, Lebreton JD (1999) Food availability and nest predation influence life history traits in Audouin's gull, *Larus audouinii.* Oecologia 118:438–445

Oro D, Pérez-Rodríguez A, Martínez-Vilalta A, Bertolero A, Vidal F, Genovart M (2009) Interference competition in a threatened seabird community: A paradox for a successful conservation. Biol Conserv 142:1830–1835

Pedrocchi V, Oro D, González-Solís J, Ruiz X, Jover L (2002) Differences in feeding ecology between the two largest breeding colonies of Audouin's gulls: the effects of fishery activities. Sci Mar 66:313–320

Penas E (2007) The fishery conservation policy of the European Union after 2002: towards long-term sustainability. ICES J Mar Sci 64:588–595

Sabatés A, Olivar MP, Salat J, Palomera I, Alemany F (2007) Physical and biological processes controlling the distribution of fish larvae in the NW Mediterranean. Prog Oceanogr 74:355–376

Salat J, Garcia MA, Cruzado A, Palanques A and others (2002) Seasonal changes of water mass structure and shelf slope exchanges at the Ebro Shelf (NW Mediterranean). Cont Shelf Res 22:327–348

Skov H, Durinck J (2001) Seabird attraction to fishing vessels is a local process. Mar Ecol Prog Ser 214:289–298

Tasker ML, Camphuysen CJ, Cooper J, Garthe S, Montevecchi WA, Blaber SJM (2000) The impacts of fishing on marine birds. ICES J Mar Sci 57:531–547

Torres LG, Thompson DR, Bearhop S, Votier S, Taylor GA, Sagar PM, Robertson BC (2011) White-capped albatrosses alter fine-scale foraging behavior patterns when associated with fishing vessels. Mar Ecol Prog Ser 428:289–301

Votier SC, Furness RW, Bearhop S, Crane JE and others (2004) Changes in fisheries discard rates and seabird communities. Nature 427:727–730

Votier SC, Bearhop S, Witt MJ, Inger R, Thompson D, Newton J (2010) Individual responses of seabirds to commercial fisheries revealed using GPS tracking, stable isotopes and vessel monitoring systems. J Appl Ecol 47: 487–497

Editorial responsibility: Christine Paetzold, Oldendorf/Luhe, Germany

Submitted: February 3, 2012; Accepted: February 19, 2013
Proofs received from author(s): May 17, 2013