Cetacean occurrence, habitat preferences and potential for cetacean-fishery interactions in Iberian Atlantic waters: results from cooperative research involving local stakeholders

Authors: Sabine Goetz[1,2], Fiona L. Read[2,3], Marisa Ferreira[4], Julio Martínez Portela[2], Maria Begoña Santos[2], José Vingada[1,4], Ursula Siebert[5], Ana Marçalo[1,4], Jorge Santos[1,4], Hélder Araújo[1,4], Silvia Monteiro[4], Mara Caldas[2], Marcos Riera[6] & Graham J. Pierce[1,7]

[1] Centro de Estudos do ambiente e do mar (CESAM), Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

[2] Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, PO Box 1552, 36200, Vigo, Spain

[3] Instituto de Investigaciones Marinas (C.S.I.C.), Eduardo Cabello 6, 36208 Vigo, Spain

[4]Centro de Biologia Molecular e Ambiental (CBMA) / Sociedade Portuguesa de Vida Selvagem (SPVS), Departamento de Biologia, Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal.

[5]Institute for Terrestrial and Aquatic Wildlife Research (ITAW), University of Veterinary Medicine Hannover, Foundation (TiHo), Werftstr. 6, 25761 Büsum, Germany

[6]INNFISH Technological Innovation, Av. Gran Via 36 – 4º, 36203 Vigo, Spain

[7]Oceanlab, University of Aberdeen, Main Street, Newburgh, Aberdeenshire AB41 6AA, UK

Corresponding author address:

Centro de Estudos do Ambiente e do Mar (CESAM)

Universidade de Aveiro, Campus Universitário de Santiago

3810-193 Aveiro, Portugal
Tel. +351 234370200; fax. + 351 234370985
E-mail address: sa.goetz@web.de

Abstract

1. Iberian Atlantic waters are heavily exploited by Spanish and Portuguese fisheries. Overlaps between fishery target species and cetacean diet, and between fishing grounds and cetacean foraging areas, can lead to cetacean-fishery interactions including bycatch mortality of cetaceans.
2. The present study assesses cetacean distribution, habitat preferences and hotspots for cetacean-fishery interactions by using a cooperative research approach with stakeholder participation (fishers, fisheries observers, fisheries authorities, scientists), as well as the combination of different opportunistic data sources (interviews, on-board observations). The usefulness of each data type is evaluated. The implications of results for the monitoring and mitigation of cetacean-fishery interactions are discussed.
3. Generalized linear models and GIS maps were used to relate cetacean occurrence patterns to environmental variables (geographic area, water depth, coastal morphology) and to fishing activities (fishing grounds, fisheries target species).
4. Common and bottlenose dolphin were the most frequently sighted species, the former in waters > 50 m, frequently from purse seiners and trawlers, and the latter particularly inside the south Galician rías and close to vessels operating further offshore in Portuguese waters. Harbour porpoises were seen over the whole continental shelf, often next to beach seines, while long-finned pilot whales and striped dolphins were mostly seen from vessels fishing offshore.
5. Results suggest that cetacean occurrence is linked to prey distribution and that interactions with fisheries are most likely for common dolphins (with coastal purse seines and offshore trawls), bottlenose dolphins and harbour porpoises (coastal nets). The different data sources were complementary and provided

results broadly consistent with previous studies on cetacean occurrence in the same area, although sightings frequency for some cetacean species was biased by survey method. Opportunistic sampling has certain restrictions concerning reliability, but can cover a wide area at comparatively low cost and make use of local ecological knowledge to yield information required for cetacean conservation.

6 – 10 Keywords: ocean, habitat mapping, , distribution, mammals, fishing

Introduction

Iberian Atlantic waters are highly productive and rich in marine resources (Wooster *et al*., 1976), which are heavily exploited by Spanish and Portuguese fisheries. The Spanish fishing fleet is the largest within the European Union in terms of total tonnage and value of landings (EUROSTAT, 2010), with almost one-half of its landings being registered in Galicia (Spanish Ministry of Agriculture, Food and Environment, 2013). Several species of cetaceans can be found in Iberian Atlantic waters, the most abundant being short-beaked common dolphin (*Delphinus delphis*), common bottlenose dolphin (*Tursiops truncatus*) and striped dolphin (*Stenella coeruleoalba*). Other species present include long-finned pilot whale (*Globicephala melas*), harbour porpoise (*Phocoena phocoena*), Risso's dolphin (*Grampus griseus*) and other large toothed and baleen whales (Sequeira *et al*., 1996; López *et al*., 2002, 2004; Kiszka *et al*., 2007; Wise *et al*., 2007; Brito *et al*., 2009; Pierce *et al*., 2010; ICES, 2011; Spyrakos *et al*., 2011; Vingada *et al*., 2011; Santos *et al*., 2012).

It has been recently suggested by Lasalle *et al*. (2012) and Santos *et al*., In Press) that there is a substantial overlap between cetaceans' principal prey species/foraging grounds and the main target species and areas exploited by fisheries in Iberian Atlantic waters, indicating some degree of competition for resources. A detailed knowledge of cetacean occurrence patterns in relation to environmental variables and fishing activities can help to identify hotspots for conflicts between cetaceans and fisheries (Torres *et al*., 2003), and therefore represents an first step in the assessment of cetacean-fishery interactions (MacLeod *et al*., 2008), which may have a negative impact on cetacean populations through depletion of cetacean food resources (Bearzi *et al*., 2006) and incidental bycatch mortality (Read *et al*., 2006). In addition, EU legislation such as the Habitats Directive (European Commission, 1992) and the Marine Strategy Framework Directive (European Commission, 2008) specify requirements for Member States to monitor and report on the status of cetacean populations. A fundamental part of this monitoring is gathering data on distribution and abundance.

There are many methodologies to assess cetacean abundance, distribution and habitat preferences, each with their respective strengths and weaknesses.

In Iberian Atlantic waters, dedicated, systematic cetacean surveys to determine abundance and/or distribution have been carried out by plane, ship and from land (Lens *et al*., 1989; Sanpera and Jover, 1989; Hammond *et al*., 2002; López *et al*., 2004; SCANS II, 2008; CODA, 2009; Pierce *et al*., 2010; Santos *et al*., 2012). However, dedicated aerial and ship-based surveys are logistically complex and costly, while land-based surveys are clearly restricted to coastal waters. Scientists have therefore increasingly resorted to the use of data collected by on-board observers from platforms of opportunity , such as fishing vessels (López *et al*., 2004; Spyrakos *et al*., 2011), passenger ferries (Kiszka *et al*., 2007) and whale-watching boats (Moura *et al*., 2012), as well as using data derived from interview surveys with fishers (Johannes *et al*., 2000; Gilchrist *et al*., 2005; Maynou *et al*., 2012), historical records (Brito *et al*., 2009; Brito and Vieira, 2010) and cetacean strandings (López *et al*., 2002; Silva and Sequeira, 2003). These alternative data sources allow for the coverage of a wide range of marine habitats (coastal and offshore) at comparatively low cost, although data reliability is usually lower than for dedicated scientific surveys, and sampling effort tends to be unquantified or unsystematic, especially if vessels with fixed routes are used as platforms of opportunity (Isojunno *et al*., 2012). Despite these limitations and due to the fact that international large-scale dedicated surveys are unlikely to be feasible more than once a decade, considerable effort has gone into developing protocols to allow data from small-scale and opportunistic surveys to be integrated into the evaluation of the status of cetacean populations, including the detection of trends in distribution and abundance (see Joint Cetacean Protocol; JNCC, 2013).

In addition, opportunistic surveys offer the opportunity to actively involve resource users, such as fishers, wildlife observers, seamen, etc., into data collection and make use of their local ecological knowledge (LEK), which can be a useful additional source of information to scientific research (Johannes *et al*., 2000). LEK may be particularly useful when monitoring/managing wildlife populations that occur in remote locations where extensive scientific studies may be impractical (Johannes, 1998; Gilchrist *et al*., 2005). This approach, known as "cooperative research", is thought to strengthen relationships and trust among resource users, scientists and managers through participation, and consequently improve the scientific data required for management and governance (Johnson and van Densen, 2007). Scientific methods and LEK often yield complementary information that can be combined to improve data quality. Nevertheless, it is important to carefully compare the outcomes of both approaches to validate their reliability (Huntington *et al*., 2004).

The present study assesses cetacean occurrence patterns and habitat preferences using a cooperative research approach that involved the participation of different stakeholders (fishers, fisheries observers, fisheries authorities, scientists) as well as the combination of opportunistic data sources (observations on-board fishing vessels, face-to-face interviews). Besides improving present knowledge of cetacean occurrence, distribution and, potentially, hotspots for cetacean-fishery interactions in the study area, the aim was also to evaluate the reliability and usefulness of each data source independently and combined.

Methods

Study area and local fisheries

The study area included the waters off Northern Spain (Basque Country, Cantabria, Asturias and Galicia) and the entire coast of mainland Portugal (43°21'N/1°47'W - 37°12'N/7°25'W).

Due to the large environmental variability within the study area (in terms of coastal morphology, special marine landscapes, oceanographic conditions and marine living resources), the area was divided into six subregions, roughly following the zoning proposed by the ICES Working Group on Ecosystem Assessment of Western Shelf Seas (WGEAWESS; ICES, 2011) (Table 1, Figure 1).

The Iberian Atlantic coastal margin is characterized by a relatively narrow continental shelf, with some wider sections between the Miño River (41º54'N) and the Nazaré Canyon (39º36'N) and in the eastern part of the Gulf of Cádiz.. Galicia is the most irregular sector of the Iberian Peninsula due to the presence of a series of coastal inlets called "rías", the North Galician rías being smaller and, due to their orientation and the absence of sheltering islands, much more exposed to the oceanic influence than the South Galician rías (Figueiras *et al*., 2002; ICES, 2011). Coastal seasonal upwelling produced by northerly winds is primarily observed along the West Iberian coast and leads to the ascent of cold, nutrient-rich water to the surface, enhancing productivity in this area (Wooster *et al*., 1976; Fiúza, 1983; Álvarez Salgado *et al*., 1993).

The Galician and Portuguese fishing fleets are mainly composed of small-scale vessels (< 12 m in length) which are usually equipped to use several types of "minor gears", such as artisanal longlines, dredges, traps and gillnets (single panel bottom-set gillnets, trammel nets, driftnets, and beach- and boat seines) to target a large variety of fish, cephalopods, crustaceans and bivalves in coastal waters. Many fishing vessels are classified as "polyvalent", i.e. change the fishing gear seasonally or use two or more gears simultaneously in the same area. Purse seiners (12 – 24 m in length) target shoaling pelagic fish in coastal waters. Large-scale offshore fisheries (vessel length > 18 m) target demersal and pelagic species with trawls, bottom-set longlines and large bottom-set gillnets. Boats based in Galician ports operate in waters all along the Northern Spanish coast (Galician Ministry of Fisheries, 2013; Portuguese Directorate General of Natural Resources, Security and Maritime Services, 2013).

Methodology and data collection

The research approach used involved active cooperation between fishers, fisheries observers, regional fisheries authorities and scientists in project management, data collection and data analysis. Cetacean sighting data were derived from a large-scale interview survey with Galician and Portuguese fishers (mainly vessel skippers), as well as from long-term on-board observations by fisheries observers and records kept by skippers on Galician trawling vessels. The face-to-face interview survey was conducted in local fishing harbours with a structured interview questionnaire. Trawl skippers and fisheries observers were provided with a short version of the interview questionnaire and were additionally asked to register if cetaceans were sighted during navigation or during fishing. All questionnaires were kept as short as possible and pre-tested in a pilot survey (first with colleagues and then with a small number of fishers) prior to the start of the surveys. Unclear or ambiguous wording was corrected and sequence of questions adjusted to improve clarity and flow. In order to guarantee consistency in data collection, all interviewers, fisheries observers and skippers were thoroughly briefed about the appropriate procedure to fill in the questionnaires at the beginning of the respective surveys. In addition, a cetacean identification catalogue, with photographs taken in the area and a list the distinctive features of each species was provided to facilitate the correct identification of the sighted cetacean species. If fishers/observers were not sure about the species identification, they had the option to choose the option "non-identified cetaceans" in the questionnaire.

Interview survey with fishers

The large-scale interview survey was primarily designed to collect data on cetacean-fishery interactions in Iberian Atlantic waters, which were analysed in other works by the authors (see Goetz *et al*., in press for Galician fisheries and Vingada *et al*., 2011 for Portuguese fisheries).

Interviews were conducted between May 2008 and August 2010. In order to cover the largest variety of fishing areas (coastal/offshore) and target species, all important types of fisheries (see Table 2) were sampled in the study area. Sampling followed a stratified random procedure, with strata based on the type of fishing gear, selecting harbours according to their representativeness for a certain fishing gear and then sampling boats opportunistically (i.e. all fishers present and available for interviewing were targeted) within the selected harbours (Lauriano *et al*., 2009).

The interview questionnaire was mainly composed of closed-ended questions, making sure all possible answers were covered, but also included some open-ended questions in order to account for fishers' opinions and suggestions. Apart from information on occurrence of interactions with cetaceans, consequences of these interactions and mitigation measures employed, the questionnaire also included questions about cetacean sightings (species and number of animals sighted) and characteristics of the fishing activity (type of gear used, most important target species, catch volume and main fishing grounds, i.e. geographical location, water depth and distance to coast). A nautical map was provided to fishers and they were asked to point to the location of their usual fishing grounds. To obtain an overview of cetacean occurrence in the area that also accounts for potential seasonal variations, fishers were asked to specify cetacean species regularly or occasionally seen rather than reporting specific sightings during their last fishing trip.

Interviews took 15 - 20 minutes and were conducted face-to-face by two interviewers who surveyed professionally active fishers - if possible the skippers of the vessels – simultaneously, but separately, in the pre-selected fishing harbours (23 harbours in Galicia and 27 in Portugal). If an interviewee switched between gears in the course of the year, answers were recorded for each gear separately. When asking about cetacean sightings during the interview, fishers were asked to point to the species seen and indicate the name in the cetacean identification catalogue, the pictures not being labelled with species names. If species identification was incorrect, the interview was excluded from further analysis. For further details on the interview procedure see Goetz *et al*. (in press).

Fisheries observer records

Fisheries observers involved in the survey formed part of the Galician Fisheries Control Program (Technical Unit for Inshore Fisheries, Galician Council for Rural and Marine Affairs, Galician Government), which was initiated in 1999 to assess the status of fisheries resources and the use of the different types of fishing gears in Galician coastal waters (< 100 m water depth), as well as to implement and monitor experimental fishing programmes. The fisheries control programme employs ten observers who systematically survey the artisanal fishing fleet, covering a large variety of fishing gears, such as single panel bottom-set gillnets, trammel nets, driftnets, purse seines, hand and boat dredges, longlines and traps. In 2008, a collaboration between the Spanish Institute of Oceanography (IEO) in Vigo and the Galician Council for Rural and Marine Affairs was established with the objective to additionally record cetacean sightings as part of the observer programme. Sighting data included in the study were collected between March 2008 and July 2012.

Skipper records

Data on cetacean occurrence were registered by the skippers of ten large-scale pair trawl vessels operating in waters off Galicia and Asturias between November 2011 and July 2012, as part of the project *Whalewatch Galicia* (10TUR009E) financed by the Galician government. The aim of the Whalewatch project was to gather information on cetacean distribution and abundance, and to evaluate the possible implementation of a whale-watching activity in collaboration with the Galician pair trawl fleet. The trawlers involved in the survey, usually performed fishing trips of 1-2 days, mainly targeting blue whiting, hake, Atlantic mackerel and horse mackerel in deep offshore waters (100 - 400 m).

Data analysis

In order to simplify the dataset and to avoid digit preference, the answers given for questions concerning the main fishing grounds (geographic location, water depth and distance to coast), catches (most important target species and catch volume) and cetacean group size were grouped into categories (Table 1). If a respondent indicated a range of values, the midpoint value was used.

Geographic coordinates of cetacean sighting locations were registered only by fisheries observers and skippers in North Spain. Sighting records were entered into a geographical information system (GIS) created in ArcView 3.3 to display spatial patterns of cetacean occurrence in relation to oceanographic features and coastal morphology.

To achieve an adequate coverage of coastal and offshore areas, data were weighted based on water depth for the purpose of summary statistics to control for the different numbers of observations for shallow (< 50 m), intermediate, and deep (≥ 100 m) waters. For statistical modelling, water depth is an explanatory variable and no weighting was necessary.

Generalized linear models (GLM) were used to describe the preferred habitat (geographic area, i.e. subregion, water depth, distance to coast and fisheries target species) for the most abundant cetacean species (all species representing ≥ 4% of sighting records) in the study area. GLMs are mathematical extensions of linear regression models that allow for non-linear relationships and non-normal (e.g. binomial) distribution of response variables and are therefore well suited for analysing ecological data, such as the distribution, i.e. presence-absence, of cetaceans in a certain area (Chambers and Hastie, 1992; Guisan *et al*., 2002).

Due to the different time horizons of the three data sources, the combined data set needed to be standardised for modelling. While the interview survey provided information about long-term general cetacean occurrence patterns, sighting records by trawl skippers and on-board observers were derived from specific fishing trips. As a consequence, all interviewed fishers saw cetaceans regularly or occasionally during their work at sea (i.e. cetacean presence was 100%), whereas cetacean presence was only observed during some fishing trips by fisheries observers and trawl skippers. Cetacean absence in a certain area could therefore not be derived from the interview data. In order to analyse all three datasets jointly, only cetacean presence records were included into the model. For each species pseudo-absence records were generated using the presence records for the other cetacean species (see Barbet-Massin *et al.*, 2012).

The main target species of the fishery was used as a proxy for available cetacean prey species. Furthermore, the variable "data source" was included as an explanatory variable into the model in order to assess whether sampling methodology had a significant effect on the sighting frequency of the different cetacean species. Missing values for water depth were derived from a linear regression relating the variables water depth and distance to coast. Due to the collinearity between both variables, distance to coast was excluded from the subsequent analysis.

For binary response variables, i.e. presence-absence of cetaceans, a binomial distribution was used, with the logit link function if a dataset contained more ones than zeros and the cloglog link function otherwise. A GLM with all relevant covariates and interaction terms between variables was run, using a backward selection procedure. At each step, non-significant variables were dropped (F-Test) and the model was re-run, until all remaining covariates were significant. All variables included in the analysis are listed in Table 1. The final model was validated by verifying if the assumptions of homogeneity of variance and independence of residuals were met, also checking for the existence of influential data points (Zuur *et al.*, 2010). For categorical covariates with more than two categories, dummy variables were created to investigate which categories of the covariate are significantly different from each other, and where there was a significant overall effect, a Bonferroni correction for subsequent pairwise comparisons was applied.

Statistical analysis was performed using SPSS Statistics 19 (IBM) and, for modelling, Brodgar 2.7.2 (Highland Statistics Ltd.).

[TABLE 1 ABOUT HERE]

Results

A total of 1275 cetacean sighting records were collected between March 2008 and July 2012, including 73 by fisheries observers (corresponding to 2525 observed fishing trips), 48 by trawl skippers (corresponding to 604 fishing trips) and 1154 records derived from the interview survey (corresponding to 283 and 310 face-to-face interviews in Galicia and Portugal, respectively; note that individual interviews often include records for more than one cetacean species).

Characteristics of the sampled fleet section

The surveys covered trawls (20.3% of records), purse seines (17.1%), gillnets (trammel nets 11.8%, single panel bottom-set gillnets 9.1%, driftnets 1.5%), traps (11.3%), longlines (5.5%), hand and boat dredges (3.3%) and beach seines (1.6%); 18.5% of sampled boats were polyvalent. The sampled vessels operated in fishing areas from the coastline to 60 nm offshore ($\bar{x}$ = 9.2 ± 9.1 nm) in waters of 2 - 442 m depth ($\bar{x}$ = 94.4 ± 87.5 m). The characteristics of each type of fishery are summarized in Table 2.

[TABLE 2 ABOUT HERE]

Cetacean sighting frequency, species composition and group size

All interviewed fishers stated that they usually see cetaceans both during fishing and navigating. Trawl skippers and on-board observers saw cetaceans infrequently (during 7.9% and 3% of fishing trips, respectively). The cetacean species most frequently sighted in the study area were common dolphin (44.2% of sightings records) and bottlenose dolphin (23.2%), the former in intermediate and large groups (6 – 50 animals), while for the latter mostly small and intermediate group sizes were observed (1 – 25). Long-finned pilot whale (9.3%), harbour porpoise (8.5%) were also commonly sighted, mainly in small groups (≤ 5 animals), while striped dolphin (4%) mostly formed intermediate and large groups (6 – 50 animals). Small groups of baleen whales (1.8%), mainly common minke whale (*Balaenoptera acutorostrata*), as well as Risso's dolphin (1%), killer whale (*Orcinus orca*) (0.8%) and sperm whale (*Physeter macrocephalus*) (0.7%) were occasionally seen. Cetacean species could not be identified in 6.5 % of sighting records.

Cetacean occurrence patterns and habitat preferences

Common dolphin was the dominant cetacean species in almost all subregions (except for South Galicia and the Western Gulf of Cádiz) (Figure 1), sighting probability being significantly higher in Portuguese waters than off the northern Spanish coast (Table 3). Common dolphins were more likely to be seen in intermediate to deep water (≥ 50 m) (Tables 3,4) particularly over the continental shelf break (200 m), but also in coastal waters where they occurred in small groups (Figure 2), and more frequently when large demersal and shoaling pelagic fish were the main fisheries target species (Table 3).

In contrast, the presence of bottlenose dolphin was significantly higher off South Galicia, particularly within the rías (Figure 2), and in the Western Gulf of Cádiz (Figure 1; Table 3), sightings probability being significantly higher in shallow water (< 50 m) with no clear association to any of the main fishery target species (Tables 3,4).

The frequency of occurrence of harbour porpoise was unrelated to water depth (Figure 2; Table 4), but significantly increased towards the south of the study area (Figure 2), especially if shoaling pelagic fish were the main target species of the fishery (Table 3).

Long-finned pilot whales were mostly sighted in the northern part of the Iberian Peninsula (Southern Bay of Biscay, North Galicia and North Portugal) (Figures 1,2) and more frequently when blue whiting and European hake were targeted (Table 3). Their frequency of occurrence was highest in deep water (≥ 100 m), over the continental shelf break (Tables 3,4; Figure 2).

The likelihood of striped dolphin sightings was highest in deep waters, particularly off North Portugal and in the Western Gulf of Cádiz (Tables 3,4; Figures 1,2). Furthermore, the likelihood of seeing striped dolphin was highest when large demersal species were targeted (Table 3).

The few sightings of baleen whales, Risso's dolphins, killer whales and sperm whales did not allow for any clear conclusions about the geographical or bathymetrical occurrence patterns of these species, or any link with particular fishery target species (Figures 1,2).

[FIGURES 1,2 AND TABLES 3,4 ABOUT HERE]

Potential for cetacean-fishery interactions

Cetacean sightings were registered by all fisheries. Common dolphins were observed in the vicinity of almost all types of fishing gears, more frequently close to vessels fishing in intermediate to deep waters with trawls, polyvalent gear and purse seines. Trawl skippers reported that the majority (87%) of common dolphin sightings were made during fishing operations, while for coastal artisanal vessels on-board observers reported a higher sightings frequency (82%) of common dolphins during navigation, than during fishing. Bottlenose dolphins were mostly sighted close to coastal fishing gears such as traps, driftnets, dredges and beach seines, at least in Spanish fisheries, while in Portuguese fisheries they were also frequently seen close to longline, polyvalent and purse seine vessels. On-board observers in coastal waters reported a slightly higher sighting frequency of bottlenose dolphins during fishing (55%) than during navigation (45%). Long-finned pilot whales that were more often (71% of sightings) observed during fishing operations, and striped dolphins (this species was only seen twice by on-board observers) were mainly seen from vessels operating in intermediate to deep water with trawls, longlines and polyvalent gear. Harbour porpoises were most frequently sighted during navigation (75% of on-board observations of this species). During fishing, they were primarily seen close to set gillnets in Spanish fisheries, while in Portuguese fisheries they were most often seen by fishers operating polyvalent gear, purse seines and beach seines (Figure 3).

[FIGURE 3 ABOUT HERE]

Influence of survey method on results

Survey method had a significant effect in the models for three of the main cetacean species (although since it is included as a factor in the models, we thus control for the effect of method).

Interviewed fishers reported a significantly higher sightings frequency of common dolphins than fisheries observers. Furthermore, records by trawl skippers included a significantly lower proportion of bottlenose dolphin sightings and a significantly higher proportion of long-finned pilot whale sightings compared to the other two survey methods (Table 3).

Harbour porpoise and striped dolphin sightings were equally likely for all survey methods.

During the interview survey, the majority (73.5%) of fishers were able to identify the common cetacean species correctly. In 8.4% of the interviews, fishers stated that they were not able to identify the cetacean species observed, and therefore classified them as "non-identified cetaceans". For fisheries observers and trawl skippers the proportion of non-identified cetacean records was 6.9% and 27%, respectively.

Discussion

Cetacean habitat preferences and potential for cetacean-fishery interactions

The cetacean species sighted, their frequency of occurrence and group sizes observed were consistent with those previously described by other authors for Atlantic Iberian waters (Aguilar, 1997; OSPAR, 2000; López *et al*., 2002, 2003, 2004; Kiszka *et al*., 2007; Wise *et al*., 2007; Brito *et al*., 2009; Pierce *et al*., 2010; ICES, 2011; Spyrakos *et al*., 2011; Santos *et al*., 2012).

Common dolphins preferred deep shelf edge waters (≈ 200 m), but were also frequently observed in small groups in coastal waters. Their occurrence patterns, which are similar to those reported earlier by López *et al*. (2004), Kiszka *et al*. (2007), Pierce *et al*. (2010), Méndez Fernández *et al*. (2012, 2013) and Santos *et al*. (2012), are probably linked to the depth range of their principal prey which includes mesopelagic fish, such as blue whiting, which can be found over the continental shelf and slope (Robles, 1970; Whitehead *et al*., 1989), as well as more coastal species (Massé, 1996; Abaunza *et al*., 2003; Carrera and Porteiro, 2003; Santos *et al*., 2013b), such as horse mackerel, European sardine and European anchovy (Silva, 1999; Pusineri *et al*., 2007; Méndez Fernández *et al*., 2012; Santos *et al*., 2013a). Due to their preferred foraging areas and prey species common dolphins are likely to interact with trawl, longline and polyvalent fisheries offshore, as well as with coastal purse seine fisheries . Bycatch of common dolphins in trawl nets has been reported by Aguilar (1997), López *et al*. (2003), Fernández Contreras *et al*. (2010) and Goetz *et al*. (in press). Coastal groups of common dolphins have been reported to scatter fish schools in the vicinity of fishing gear, potentially reducing catch rates in purse seine fisheries (López *et al*., 2003; Wise *et al*., 2007).

Bottlenose dolphins, in contrast, were more frequently found in shallow, coastal waters, particularly inside the rías of South Galicia and in the Western Gulf of Cádiz.
This is consistent with previous findings (Aguilar, 1997; López *et al*., 2002, 2003, 2004; Pierce *et al*., 2010; Spyrakos *et al*., 2011) and supports the hypothesis of Fernández *et al*. (2011a,b), who suggested the existence of a resident bottlenose dolphin population

inside the South Galician rías that has a broader diet than animals occurring further north and in offshore waters. Bottlenose dolphin mainly feed on blue whiting and European hake, but also to a lesser extent on silvery pout (*Gadiculus argenteus),* mullet (*Mugil* spp.), pouting, European conger, horse mackerel, European sardine and cephalopods (Santos *et al*., 2007; Sollmann, 2011), all of which are abundant in the shallow (< 50 m), highly productive waters inside the rías (Gabeiras Véres *et al*., 1993; OSPAR, 2000). The high dietary diversity of bottlenose dolphins could explain why its sightings probability was not related to any particular fisheries target species. Coastal waters are intensively used fisheries operating artisanal trammel nets, driftnets, beach seines and dredges. Gear damage, depredation on catch, and bycatch of bottlenose dolphins in set gillnets have been reported for the South Galician rías by Aguilar (1997) and López *et al*. (2003). Based on additional results of the present interview survey, Goetz *et al*., (in press) estimated the annual bycatch mortality of bottlenose dolphins in Galician fisheries as at least 1.6% of the local population size, which is very close to the maximum acceptable limit of 1.7% recommended by ASCOBANS[1]. In Portuguese waters, in contrast, where bottlenose dolphin is only the fifth most frequently species registered among cetacean strandings (Ferreira, 2007; Ferreira *et al*., 2012), the animals were frequently observed close to longline, polyvalent and purse seine vessels that mostly operate in water depths over 50 m. This may indicate that bottlenose dolphin occurrence off Portugal is less coastal than in Galician waters, which may explain the apparently lower bycatch frequency of this species in coastal gillnets in Portugal.

As in previous surveys in Spain and Portugal, harbour porpoise were always sighted within shelf waters, mostly close to the coast, but sometimes also in deeper waters over the shelf edge, and more frequently in areas where the continental shelf is relatively narrow, such as in South Portugal (Sequeira, 1996; Kiszka *et al*., 2007; Pierce *et al*., 2010; Spyrakos *et al*., 2011; Méndez Fernández *et al*., 2012; Santos *et al*., 2012). However, there was no linear relationship between water depth and sightings frequency which may indicate that harbour porpoises feed over the whole continental shelf. In Galician waters their main prey species include pouting, blue whiting, horse mackerel

[1] Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas

and garfish (*Belone belone*) (Read *et al*., 2012), the first being a shallow-water species while the latter three are more abundant in deep shelf water (Wheeler, 1978; Whitehead *et al*., 1989). Similar patterns were described for the Bay of Biscay, where harbour porpoise were found to feed on both benthic coastal and offshore prey species (Spitz *et al*., 2006a). As bottlenose dolphins, harbour porpoises are likely to interact with coastal fishing gears. The minimum annual bycatch mortality of harbour porpoises due to interactions with fisheries was estimated as 4.3% of the Iberian harbour porpoise population, based on stranding records (Read *et al*., 2012). In Portugal, the species is frequently bycaught in beach seines (Silva and Sequeira, 2003; Ferreira, 2007).

Long-finned pilot whale and striped dolphin are considered oceanic species that prefer deep water over the continental shelf edge and slope (Perrin *et al*., 1994; Rice, 1998). In the current survey, long-finned pilot whales were mainly sighted off North Spain, which confirms the occurrence patterns observed for this species in earlier studies (Aguilar, 1997; López *et al*., 2004; Kiszka *et al*., 2007; Spyrakos *et al*., 2011), while striped dolphins were slightly more often seen off North Portugal and in the Gulf of Cádiz. Santos *et al*. (2012) observed the highest density of striped dolphins and mixed groups of common and striped dolphins off North and Central Portugal. Long-finned pilot whales and striped dolphins mainly feed on deep-water cephalopods and fish (Santos *et al*., 1996; Spitz *et al*., 2006b, 2011; Sollmann, 2011; Méndez Fernández *et al*., 2012). The current survey did not include fisheries for deep-water cephalopods, and therefore it is not possible to draw any conclusions about this particular type of prey. Nevertheless, long-finned pilot whales and striped dolphins were also seen in shelf waters, most frequently when blue whiting, European hake and other large demersal fish were targeted, which supports the hypothesis that both cetacean species exploit oceanic, as well as neritic foraging areas (Kiszka *et al*., 2007; Spitz *et al*., 2011; Méndez Fernández *et al*., 2012). However, due to their preference for oceanic cephalopods, long-finned pilot whales and striped dolphins show the lowest degree of overlap with fishing areas and fisheries target species and consequently a low probability to interact with fishing activities in Iberian Atlantic waters.

Usefulness of the different data sources for the assessment of cetacean occurrence patterns and interactions with fisheries

The results obtained from each data source were consistent with previous studies on the occurrence and habitat preferences of cetaceans in the same area. All three data sets provided sightings records at low cost and reduced time expenditure when compared to logistically complex dedicated cetacean surveys. On-board observations by fisheries observers and skippers offer the possibility to identify the exact locations of cetacean presence and to assess bathymetric preferences of cetaceans in a more restricted survey area, while interview surveys have the potential to capture broad-scale distributional patterns and long-term sightings trends over a wide geographic range. Therefore, the different survey methods, apart from performing well independently, were also complementary to each other (Table 5).

[TABLES 5 ABOUT HERE]

By surveying different fisheries, coastal as well as offshore habitats could be covered, with the limitation that survey effort was restricted to fishing areas (< 450m deep). It is therefore possible that sighting records for deep-water cetaceans, such as striped dolphin, long-finned pilot whale, Risso's dolphin and sperm whale, are underestimated in the present study. In addition, certain bias in the sighting frequency for some cetacean species may be related to the fisheries covered by each survey method. The interview survey included small-scale and large-scale fisheries, while fisheries observers covered only small-scale fishing vessels, which mainly operate in coastal waters where the sightings probability for common dolphin is lower. Sighting records by skippers were only obtained from trawling vessels operating in offshore waters where high sightings frequency of long-finned pilot whales can be expected. Nevertheless, by pooling the different data sources together, by weighting data based on water depth for summary statistics and by including "data source" as a factor into the statistical models, this source of error can be reduced.

The use of pseudo-absence records, which is a widely used approach, has certain limitations (see Barbet-Massin *et al.*, 2012), the main issue being that any habitat types visited by observers but not used by any of the cetacean species will not be represented in the dataset.

The reliability of studies based on reports from fishers is often questioned, since personal perceptions and interests may bias the information provided (Bearzi *et al*., 2011). In addition, due to the nature of their work, fishers and fisheries observers are inevitably less effective in detecting cetaceans than dedicated marine mammal observers because observation effort is clearly restricted and consequently reliability of absence records may be reduced (Spyrakos *et al*., 2011). Their low level of observer experience may also increase the risk of incorrect species identification.

In order to ensure a good quality of recorded data, interviews with fishers were always conducted face-to-face, because, in contrast to questionnaire surveys, personal interviewing is thought to create more confidence between interviewer and respondents (White *et al*., 2005). Interviewers made sure that records of incorrectly identified cetaceans were excluded from the data analysis. Fisheries observers and trawl skippers were thoroughly briefed about the correct observation methodology and identification of cetaceans, and they were all provided with illustrative material. To avoid the possibility that interviewees chose the answer they thought the interviewer would want to hear and to avoid that fishers/observers "guessed" the cetacean species sighted in case they were not able to identify them, the informants were always given the choice to say that they did not know the answer or that they saw "non-identified" cetaceans. Despite all these efforts to improve the quality of sighting records, opportunistically collected data are inevitably less reliable than data collected by dedicated cetacean observers. Especially the differentiation of physically very similar species, such as common and striped dolphins, is very difficult for an untrained observer. This is for instance reflected in the high proportion of "non-identified" cetacean records from trawl skippers that operate offshore where they mainly encounter common and striped dolphins that sometimes form mixed groups. Fishers/fisheries observers are obviously less consistent in reporting than dedicated observers e.g. in the present project, the fisheries observers sent in more complete questionnaires directly after feedback meetings, with a gradual decrease of reports afterwards until the next meeting.

It should also be noted that the use of fisheries stakeholder data will imply a bias towards areas with fishing activity. Therefore it is difficult to determine if the cetaceans are in the area just for feeding purposes or if they use the habitat where the fisheries occur for other aspects of their life history, e.g. nursing, resting, socializing. In order to explore this knowledge gap, it would be interesting to note the activity (e.g. feeding, travelling, etc.) of the animals in future work as this will improve our knowledge of their habitat preferences.

Apart from these methodological constraints, the biology and behaviour of certain cetacean species may also cause certain bias in the data. Harbour porpoises, for instance, are comparatively small and shy and are therefore difficult to detect, even under calm sea conditions (Embling *et al*., 2010).

Ultimately, the greatest benefits of cooperative research involving stakeholders may be through incorporating fishers' LEK into assessment and management of cetacean – fishery interactions and through establishing trust and dialogue that can be extended into participatory management and governance, ultimately helping to ensure that measures taken to meet conservation and sustainability goals are successfully implemented (Coffey, 2005).Problems such as cetacean bycatch will not be solved by demonizing fishers. The ecological knowledge of fishers represents a valuable complement to data obtained through scientific research (Gilchrist *et al*., 2005). They have long-term knowledge about abundance and occurrence of marine mammals and their prey (Johannes *et al*., 2000) and their active involvement into cetacean surveys also offers the possibility to gain a better insight into issues of concern, such as cetacean-fishery interactions (Moore *et al*., 2010; Goetz *et al*., in press). Through cooperative research, fishers' knowledge is verified and translated into scientific knowledge for use in policy-making (Johnson, 2010). Furthermore, participating in cooperative research may contribute to greater mutual understanding and trust between stakeholders and help the formation of partnerships between them (Hartley and Robertson, 2006).

Conclusions

Apart from the methodological constraints discussed above, the results of the combined data sets provide important information about cetacean occurrence patterns, habitat preferences and potential hotspots for cetacen-fishery interactions in Iberian Atlantic waters. The potential of a given cetacean species to interact with fisheries is largely determined by the degree of overlap in time and space of foraging and fishing activities, as well as on the type (species and size classes) of marine living resources used by cetaceans and fisheries. The results of this work indicate that cetaceans occur in marine areas also exploited by fisheries in Iberian Atlantic waters. In extensively fished areas, such as the South Galician rías, the resident bottlenose dolphin population may be impacted more severely by bycatch mortality, especially if additionally exposed to other threatening human activities such as habitat degradation, pollution and boat traffic (Fernández *et al*., 2011b). Such areas with high conflict potential should be monitored more intensively and methods to reduce interactions (e.g. use of acoustic deterrent devices, spatio-temporal restrictions of fishing activity) should be trialled in the fisheries primarily affected by interactions with cetaceans.

Acknowledgements:

We wish to express our gratitude to all Galician and Portuguese fishers that took part in the survey for sharing their time and information with us. We would also like to acknowledge the support of the Galician Council for Rural and Marine Affairs (Consellería do Medio Rural e do Mar, Xunta de Galicia), namely the cooperation of the fisheries´ observers (Luis Pérez Miser, Francisco José López, Juan Chapela Portela, Felix Barreiro, Candido Aguiar Couto, José María García Rozamontes, José Manuel Garrido Vispo, José Manuel Pérez Veres, Javier García Romero, Juan González Pérez), the coordinators (Ricardo Arnaiz Ibarrondo, Francisco Filgueira Rodríguez) and the staff (Manuel García Tasende, Jorge Ribó Landín, José Manuel Campelos Álvarez) of the Technical Unit for Inshore Fisheries. Furthermore, we would like to thank Baltasar Patiño and Gersom Costas for provision of background information and logistical support, and Juan Santos and Edward Morgan, for assisting with the interviewing. Interviews in Galicia were carried out in the framework of the project *ECOSUMMER*

(*ECOsystem approach to Sustainable Managament of the Marine Environment and its living Resource*) with EU funding (projects MEXC-CT-2006-042337 and MEST-CT-2005-020501). The interview survey in Portugal was conducted under the *SafeSea Project* (*Sustainable local fisheries and promotion of a safe sea for cetaceans*) and supported by the EEA Grants programme (EEA Financial Mechanism 2004-2009). SG was also funded by the German Academic Exchange Service (DAAD) and the Fundação para a Ciência e a Tecnologia (FCT). MBS participation was part of the EU FP7 grant MYFISH (no. 289257) and the LOTOFPEL project (Plan Nacional de I + D + I, CTM 2010-16053). The Whalewatch Project was financed by the Xunta de Galicia (programme PEME I+D e I+D SUMA).

References:

Abaunza P, Gordo L, Karlou-Riga C, Murta A, Eltink ATGW, García Santamaría MT, Zimmermann C, Hammer C, Lucio P, Iversen SA, *et al*. 2003. Growth and reproduction of horse mackerel, *Trachurus trachurus* (carangidae). *Reviews in Fish Biology and Fisheries* **13**: 27–61.

Aguilar A. 1997. Inventario de los cetáceos de las águas atlánticas peninsulares: aplicación de la directiva 92/43/CEE. Memoria Final. Departamento de Biología Animal (Vert.), Facultad de Biología, Universitat de Barcelona.

Álvarez Salgado XA, Rosón G, Pérez FF, Pazos Y. 1993. Hydrographic variability off the Rías Baixas (NW Spain) during the upwelling season. *Journal of Geophysical Research* **98**: 14 447– 14 455.

Barbet-Massin M, Jiguet F, Albert CH, Thuiller W. 2012. Selecting pseudo-absences for species distribution models: how, where and how many? *Methods in Ecology and Evolution* **3**: 327–338.

Bearzi G, Politi E, Agazzi S, Azzellino A. 2006. Prey depletion caused by overfishing and the decline of marine megafauna in eastern Ionian Sea coastal waters (central Mediterranean). *Biological Conservation* **127**:373-382.

Bearzi G, Bonizzoni S, Gonzalvo J. 2011. Dolphins and coastal fisheries within a Marine Protected Area: mismatch between dolphin occurrence and reported depredation. *Aquatic Conservation: Marine and Freshwater Ecosystems* **21**: 261-267.

Brito C, Vieira N. 2010. Using historical accounts to assess the occurrence and distribution of small cetaceans in a poorly known area. *Journal of the Marine Biological Association of the United Kingdom* **90**: 1583–1588.

Brito C, Vieira N, Sá E, Carvalho I. 2009. Cetaceans' occurrence off the west central Portugal coast: a compilation of data from whaling, observations of opportunity and boat-based surveys. *Journal of Marine Animals and their Ecology* **2**: 10–13.

Carrera P, Porteiro C. 2003. Stock dynamic of the Iberian sardine (*Sardine pilchardus*, W.) and its implication on the fishery off Galicia (NW Spain). *Scientia Marina* **67**: 245–258.

Chambers JM, Hastie T. 1992. *Statistical Models in S*. Chapman and Hall, London.

CODA. 2009. Cetacean Offshore Distribution and Abundance. Final report. Available from SMRU, Gatty Marine Laboratory, University of St Andrews, St Andrews, Fife, KY16 8LB, UK.

Coffey C. 2005. What role for public participation in fisheries governance? In *Participation in fisheries governance. Reviews: methods and technologies in fish biology and fisheries*, Gray TS (ed.). Springer; Netherlands: 27–44.

.

Embling CB, Gillibrand PA, Gordon J, Shrimpton J, Stevick PS, Hammond PS. 2010. Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (*Phocoena phocoena*). *Biological Conservation*: **143:** 267-279.

European Commission. 1992. Directive 92/43/EEC of the Council of the European Community of 21st May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora. *Official Journal* **L 206**: 7-50.

European Commission. 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal* **L 164**: 19-40.

EUROSTAT. 2010. *Fishery statistics. Data 1995 – 2008*. Eurostat Pocketbooks. European Commission, Publications Office of the European Union, Luxembourg.

Fernández R, García Tiscar S, Santos MB, López A, Martínez Cedeira JA, Newton J, Pierce GJ. 2011a. Stable isotope analysis in two sympatric populations of bottlenose dolphins *Tursiops truncatus*: evidence of resource partitioning? *Marine Biology* **158**: 1043–1055.

Fernández R, Santos MB, Pierce GJ, Llavona A, López A, Silva MA, Ferreira M, Carrillo M, Cermeño P, Lens S, *et al*. 2011b. Fine-scale genetic structure of bottlenose dolphins, *Tursiops truncatus*, in Atlantic coastal waters of the Iberian Peninsula. *Hydrobiologia* **670**: 111–125.

Fernández Contreras MM, Cardona L, Lockyer CH, Aguilar A. 2010. Incidental bycatch of short-beaked common dolphins (*Delphinus delphis*) by pair trawlers off Spain. *ICES Journal of Marine Science* **67**: 1732–1738.

Ferreira M. 2007. Occurrence and accidental capture of cetaceans in centre/north Portugal. M. Sc. thesis, Escola de Ciências, Universidade do Minho, Portugal.

Ferreira M, Marçalo A, Nicolau L, Araújo H, Santos J, Pinheiro C, Lopes T, Mendes S, Vaqueiro J, Medina P, *et al*. 2012. Estado actual das redes de arrojamentos e de reabilitação em Portugal Continental. Annex to the Midterm Report of project LIFE MarPro PT/NAT/00038.

Figueiras FG, Labarta U, Fernández Reiriz JM. 2002. Coastal upwelling, primary production and mussel growth in the Rías Baixas of Galicia. *Hydrobiologia* **484**: 121–131.

Fiúza AFG. 1983. Upwelling patterns of Portugal. In *Coastal upwelling, its sedimentary record. Part A. Responses of the sedimentary regime to present coast upwelling*, Suess E, Thiede J (eds). Plenum Press, New York; 85-97.

Gabeiras Véres JM, Valiela Villar J, Lema Bouzas L. 1993. *Onde Galicia é mar*. Servicio de Extensión de Pesca, Consellería de Pesca, Xunta de Galicia.

Galician Ministry of Fisheries [Xunta de Galicia, Consellería do Mar], 2013. Online statistics. http://www.pescadegalicia.com [08 August 2013]

Goetz S, Read FL, Santos MB, Pita C, Pierce GJ. In press. Cetacean-fishery interactions in Galicia (NW Spain): results and management implications of a face-to-face interview survey with local fishers. *ICES Journal of Marine Science*, doi 10.1093/icesjms/fst149

Gilchrist HG, Mallory ML, Merkel F. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society* **10**:20.

Guisan A, Edwards TCJr, Hastie T. 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling* **157**: 89-100.

Hammond PS, Berggren P, Benke H, Borchers DL, Collet A, Heide-Joergensen MP, Heimlich S, Hiby AR, Leopold MF, Oeien N. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* **39**: 361-376.

Hartley TW, Robertson RA. 2006. Stakeholder engagement, cooperative fisheries research and democratic science: the case of the Northeast Consortium. *Human Ecology Review* **13**: 161-171.

Huntington HP, Callaghan TV, Gearheard SF, Krupnik I. 2004. Matching traditional and scientific observations to detect environmental change: a discussion on arctic terrestrial ecosystems. *Ambio Special Report* **13**: 18-23.

ICES [International Council for the Exploration of the Sea]. 2011. Report of the Working Group on Ecosystem Assessment of Western Shelf Seas (WGEAWESS), Nantes, France. ICES CM 2011/SSGRSP:05.

Isojunno S, Matthiopoulos J, Evans PGH. 2012. Harbour porpoise habitat preferences: robust spatiotemporal inferences from opportunistic data. *Marine Ecology Progress Series* **448**: 155-170.

Johannes RE. 1998. The case for data-less marine resource management: examples from tropical nearshore fisheries. *Trends in Ecology and Evolution* **13**:243-246.

Johannes RE, Freeman MMR, Hamilton RJ. 2000. Ignore fishers' knowledge and miss the boat. *Fish and Fisheries* **1**: 257-271.

Johnson TR. 2010. Cooperative research and knowledge flow in the marine commons: Lessons from the Northeast United States. *International Journal of the Commons* **4**: 251-272.

Johnson TR, van Densen WLT. 2007. Benefits and organization of cooperative research for fisheries management. *ICES Journal of Marine Science* **64**: 834–840.

JNCC (Joint Nature Conservation Committee). 2013. Joint Cetacean Protocol. http://jncc.defra.gov.uk/page-5657 [08 August 2013]

Kiszka J, Van Canneyt O, Macleod K, Walker D, Ridoux V. 2007. Distribution, encounter rates and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform of opportunity data. *ICES Journal of Marine Science* **64**: 1033-1043.

Lauriano G, Caramanna L, Scarnó M, Andaloro F. 2009. An overview of dolphin depredation in Italian artisanal fisheries. *Journal of the Marine Biological Association of the United Kingdom* **89**: 921–929.

Lassalle G, Gascuel D, Le Loc'h F, Lobry J, Pierce GJ, Ridoux V, Santos MB, Spitz J, Niquil N. 2012. An ecosystem approach for the assessment of fisheries impacts on marine top-predators: the Bay of Biscay case study. *ICES Journal of Marine Science* **69**: 925-938.

Lens S, Quiroga H, Gil de Sola L. 1989. Report of the cruise undertaken by Spain as part of the North Atlantic sightings survey, 1987. International Whaling Commission (IWC), Report of the Commission 39.

López A, Santos MB, Pierce GJ, González AF, Valeiras X, Guerra A. 2002. Trends in strandings and by-catch of marine mammals in north-west Spain during the 1990s. *Journal of the Marine Biological Association of the United Kingdom* **82**: 513–521.

López A, Pierce GJ, Santos MB, Gracia J, Guerra A. 2003. Fishery by-catches of marine mammals in Galician waters: Results from on-board observations and an interview survey of fishermen. *Biological Conservation* 111: 25–40.

López A, Pierce GJ, Valeiras X, Santos MB, Guerra A. 2004. Distribution patterns of small cetaceans in Galician waters. *Journal of the Marine Biological Association of the United Kingdom* **84**: 283–294.

López A, Vázquez JA, Martínez Cedeira JA, Cañadas A, Marcos E, Maestre I, Ruano A, Larias L, Llavona A, MacLeod K, *et al*. 2013. Abundance estimates for harbour porpoise (*Phocoena phocoena*) in the Spanish area of the Iberian Peninsula Management Unit. IWC Scientific Committee Annual Meeting, 4-15 June 2013, Jeju Island, Republic of Korea. SC/65a/SM20.

MacLeod CD, Mandleberg L, Schweder C, Bannon SM, Pierce GJ. 2008. A comparison of approaches to modelling the occurrence of marine animals. *Hydrobiologia* **612**: 21-32.

Massé J. 1996. Acoustic observations in the Bay of Biscay: schooling, vertical distribution, species assemblages and behaviour. *Scientia Marina* **60**: 227−234.

Maynou F, Sbrana M, Sartor P, Maravelias C, Kavadas S, Damalas D, Cartes JE, Osio G. 2011. Estimating Trends of Population Decline in Long-Lived Marine Species in theMediterranean Sea Based on Fishers' Perceptions. *PLoS ONE* ***6***: e21818. doi:10.1371/journal.pone.0021818

Méndez Fernández P, Bustamante P, Bode A, Chouvelon T, Ferreira M, López A, Pierce GJ, Santos MB, Spitz J, Vingada JV, *et al.* 2012. Foraging ecology of five toothed whale species in the Northwest Iberian Peninsula, inferred using carbon and nitrogen isotope ratios. *Journal of Experimental Marine Biology and Ecology* **413**: 150-158.

Méndez Fernandez P, Pierce GJ, Bustamante P, Chouvelon T, Ferreira M, González AF, López A, Read FL, Santos MB, Spitz J, et al. 2013. Ecological niche segregation among five toothed whale species off the NW Iberian Peninsula using ecological tracers as multi-approach. *Marine Biology* ***160***:2825–2840.

Moore JE, Cox TM, Lewison RL, Read AJ, Bjorkland R, McDonald SL, Crowder LB, Aruna E, Ayissi I, Espeut P, *et al*. 2010. An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation* **143**: 795-805.

Moura AE, Sillero N, Rodrigues A. 2012. Common dolphin (*Delphinus delphis*) habitat preferences using data from two platforms of opportunity. *Acta Oecologica* **38**: 24-32.

OSPAR. 2000. Quality Status Report 2000: Region IV – Bay of Biscay and Iberian Coast. OSPAR Commission, London, UK.

Perrin WF, Wilson CE, Archer FI. 1994. Striped dolphin *Stenella coeruleoalba* (Meyen, 1833). In *Handbook of Marine Mammals 5, The First Book of Dolphins and the Porpoises*, Ridgway SH, Harrison R (eds). Academic Press, London, UK; 129–159.

Pierce GJ, Caldas M, Cedeira J, Santos MB, Llavona A, Covelo P, Martínez G, Torres J, Sacau M, López A. 2010. Trends in cetacean sightings along the Galician coast, north-western Spain, 2003–2007, and inferences about cetacean habitat preferences. *Journal of the Marine Biological Association of the United Kingdom* **90**: 1547-1560.

Portuguese Directorate General of Natural Resources, Security and Maritime Services [Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos]. 2013. Online statistics. http://www.dgrm.min-agricultura.pt/xportal/xmain?xpid=dgrm [08 August 2013]

Pusineri C, Magnin V, Meynier L, Spitz J, Hassani S, Ridoux V. 2007. Food and feeding ecology of the common dolphin (*Delphinus delphis*) in the oceanic Northeast Atlantic and comparison with its diet in neritic areas. *Marine Mammal Science* **23**: 30–47.

Read AJ, Drinker P, Northridge S. 2006. Bycatch of Marine Mammals in U.S. and Global Fisheries. *Conservation Biology* **20**: 163–169.

Read FL, Santos MB, González AF, López A, Ferreira M, Vingada J, Pierce GJ. 2012. Understanding harbour porpoise (*Phocoena phocoena*) and fishery interactions in the north-west Iberian Peninsula. Final report to ASCOBANS (SSFA/ASCOBANS/2010/4)

Rice DW. 1998. *Marine Mammals of the World: Systematics and Distribution*, Special publication 4. The Society for Marine Mammalogy.

Robles R, 1970. La bacaladilla, *Micromesistius poutassou* (Risso, 1810). *Boletín del Instituto Español de Oceanografía* **142**: 1–17

Sanpera C, Jover L. 1989. Density estimate of fin whales in the North Atlantic from NASS-87 Spanish cruise data. International Whaling Commission Report of the Commission 39.

Santos J, Araújo H, Ferreira M, Henriques A, Miodonski J, Monteiro S, Oliveira I, Rodrigues P, Duro G, Oliveira F, *et al.* 2012. Chapter I: Baseline estimates of abundance and distribution of target species. Annex to the Midterm Report of project LIFE MarPro PT/NAT/00038.

Santos MB, Pierce GJ, López A, Barreiro A, Guerra A. 1996. Diets of small cetaceans stranded NW Spain. Report to the International Council for the Exploration of the Sea (ICES), 11. Marine Mammal Committee, Copenhagen, Denmark. C.M. 1996/N:11

Santos MB, Fernández R, López A, Martínez JA, Pierce GJ. 2007. Variability in the diet of bottlenose dolphin, *Tursiops truncatus* (Montagu), in Galician waters, NW Spain, 1990–2005. *Journal of the Marine Biological Association of the United Kingdom* **87**: 231–242.

Santos MB, German I, Correia D, Read FL, Martinez Cedeira J, Caldas M, López A, Velasco F, Pierce GJ. 2013a. Long-term variation in common dolphin diet in relation to prey abundance. *Marine Ecology Progress Series* **481**: 245-268.

Santos MB, González Quirós R, Riveiro I, Iglesias M, Louzao M, Pierce GJ. 2013b. Characterization of the pelagic fish community of the north-western and northern Spanish shelf waters. *Journal of Fish Biology* ***83**:* 716-738.

Santos MB, Saavedra C, Pierce, GJ. In press. Quantifying the predation on sardine and hake by cetaceans in the Atlantic waters of the Iberian Peninsula. *Deep Sea Research II*. Topical Studies in Oceanography.

SCANS II. 2008. Small Cetaceans in the European Atlantic and North Sea. Final Report to the European Commission under project LIFE04NAT/GB/000245. SMRU, Gatty Marine Laboratory, University of St Andrews, St Andrews, UK.

Sequeira M, 1996. Harbour porpoises, *Phocoena phocoena*, in Portuguese waters. International Whaling Commission (IWC) Report of the Commission 46.

Sequeira M, Inácio A, Silva, Reiner MA. 1996. Arrojamentos de mamíferos marinhos na Costa Continental Portuguesa entre 1989 e 1994. Estudos de Biologia e Conservação da Natureza 19. Instituto da Conservação da Natureza. Lisbon, Portugal. 52pp.

Silva MA. 1999. Diet of common dolphins, *Delphinus delphis*, off the Portuguese continental coast. *Journal of the Marine Biological Association of the United Kingdom* **79**: 531-540.

Silva MA, Sequeira M. 2003. Patterns in the mortality of common dolphins (*Delphinus delphis*) on the Portuguese coast, using stranding records, 1975-1998. *Aquatic Mammals* **29**: 88-98.

Sollmann K. 2011. Diet and distribution of the bottlenose dolphin (*Tursiops truncatus*) in Galicia, north-west Spain. M. Sc. thesis, Bayrische Julius-Maximilians-Universität Würzburg, Germany..

Spanish Ministry of Agriculture, Food and Environment [Ministerio de Agricultura, Alimentación y Medio Ambiente]. 2013. Online fisheries statistics. http://www.magrama.gob.es/es/pesca/estadisticas/ [08 August 2013]

Spitz J, Rousseau Y, Ridoux V. 2006a. Diet overlap between harbour porpoise and bottlenose dolphin: An argument in favour of interference competition for food? *Estuarine, Coastal and Shelf Science* **70**: 259-270.

Spitz J, Richard E, Meynier L, Pusineri C, Ridoux V. 2006b. Dietary plasticity of the oceanic striped dolphin, *Stenella coeruleoalba*, in the neritic Bay of Biscay. *Journal of Sea Research* **55**: 309–320.

Spitz J, Cherel Y, Bertin S, Kiszka J, Dewez A, Ridoux V. 2011. Prey preferences among the community of deep-diving odontocetes from the Bay of Biscay, northeast Atlantic. *Deep-Sea Research Part I: Oceanographic Research Papers* **58**: 273-282.

Spyrakos E, Santos Diniz TC, Martínez Iglesias G, Torres Palenzuela JM, Pierce GJ. 2011. Spatiotemporal patterns of marine mammal distribution in coastal waters of Galicia, NW Spain. *Hydrobiologia* **670**: 87–109.

Torres LG, Rosel PE, D'Agrosa C, Read, AJ. 2003. Improving management of overlapping bottlenose dolphin ecotypes through spatial analysis and genetics. *Marine Mammal Science* ***19:*** 502–514.

Vingada J, Ferreira M, Marçalo A, Santos J, Araújo H, Oliveira I, Monteiro S, Nicolau L, Gomes P, Tavares C, *et al.* 2011. SafeSea - Manual de Apoio para a Promoção de uma Pesca Mais Sustentável e de um mar seguro para cetáceos; Programa EEAGrants - EEA Financial Mechanism 2004-2009 (Projecto 0039), Braga, Portugal.

Wheeler A. 1978. *Key to the fishes of Northern Europe, A guide to the identification of more than 350 species*. Frederick Warne, London.

White PCL, Jennings N, Renwick AR, Barker NHL. 2005. Questionnaires in ecology: a review of past use and recommendations for best practice. *Journal of Applied Ecology* **42**: 421-430.

Whitehead PJP, Bauchot ML, Hureau JC, Nielsen J, Tortonese E. 1989. *Fishes of the North-eastern Atlantic and the Mediterranean, Volume III*. UNESCO, Paris.

Wise L, Ferreira M, Silva M, Sequeira M, Silva A. 2007. Interactions between small cetaceans and the purse-seine fishery in western Portuguese waters. *Scientia Marina* **71**: 405-412.

Wooster WS, Bakun A, McClain DR. 1976. The seasonal upwelling cycle along the eastern boundary of the North Atlantic. *Journal of Marine Research* **34**: 131–141.

Zuur AF, Ieno EN, Elphick S. 2010. A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution* **1**: 3–14.

Table 1. List of variables used for analysis with their description and categories

Variables	**Description and categories**
Survey method	Interviews with fishers, fisheries observer records, skipper records
Subregion (main fishing area)	Southern Bay of Biscay (43°21'N/1°47'W – 43°48'N/7°41'W)
	North Galicia (43°48'N/7°41'W – 42°44'N/9°05'W)
	South Galicia (42°44'N/9°05'W – 41°54'N/8°52'W)
	North Portugal (41°54'N/8°52'W – 39°36'N/9°24'W)
	South Portugal (39°36'N/9°24'W – 37°01'N/9°0'W)
	Western Gulf of Cádiz (37°01'N/9°0'W – 37°12'N/7°25'W)
Mean water depth	in metres: shallow (< 50 m), intermediate, deep (≥ 100 m)
Mean distance to coast	in nautical miles: coastal (< 12 nm), offshore (≥ 12 nm)
Fishery target species	Shoaling pelagic fish
	Atlantic mackerel (*Scomber scombrus*), horse mackerel (*Trachurus* spp.), European sardine (*Sardina pilchardus*), European anchovy (*Engraulis encrasicolus*)
	Blue whiting (*Micromesistius poutassou*)
	European hake (*Merluccius merluccius*)
	Other large demersal fish
	pouting (*Trisopterus luscus*), common sole (*Solea solea*), turbot (*Psetta maxima*), ballan wrasse (*Labrus bergylta*), European seabass (*Dicentrarchus labrax*), white seabream (*Diplodus sargus*), blackspot seabream (*Pagellus bogaraveo),* red mullet (*Mullus surmuletus*), black scabbardfish (*Aphanopus carbo*), European conger (*Conger conger*), skates (*Raja* spp.), catshark (*Scyliorhinus* spp)
Presence-absence (individuals or groups)	Common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), long-finned pilot whale (*Globicephala melas*), harbour porpoise *(Phocoena phocoena)*
Cetacean group size	Small (1 - 5 animals), intermediate (6 - 25), large (26 - 50), very large (> 50 animals)

Table 2. Detailed description of the sampled fleet segment covered in the survey including the main fishing grounds (expressed through mean water depth and distance to coast), main target species and the mean catch volume for each type of fishery. For each descriptor, the categories to which the majority of vessels in each fishery can be assigned are indicated by the symbol "x". Where this differs between countries, the country is indicated in parentheses (ES = Spain, P = Portugal). SPBG are single panel bottom-set gillnets.

	Type of fishing gear									
	Trawl	Longline	SPBG	Polyvalent	Purse seine	Trammel net	Trap	Driftnet	Beach seine	Dredge
mean water depth:										
shallow (< 50 m)					x	x	x (ES)	x(ES)	x (P)	x (ES)
intermediate		x	x	x (P)	x	x	x (P)			
deep (≥ 100 m)	x	x								
mean distance to coast:										
coastal (< 12 nm)		x (ES)	x	x (P)	x	x	x	x	x (P)	x (ES)
offshore (≥ 12 nm)	x	x (P)								
main target species:										
European hake		x	x							
other large demersal fish		x	x	x (P)		x	x (P)			
blue whiting	x									
shoaling pelagic fish	x				x			x	x (P)	
cephalopods							x			x (ES)
shellfish						x (ES)	x (ES)			x (ES)
mean catch volume:										
low (< 100 kg)			x			x	x (ES)	x		x (ES)
intermediate		x	x	x (P)			x (P)	x	x (P)	
high (≥ 500 kg)	x				x					

Table 3. GLM results (n = 786). All response variables relate to presence-absence of cetaceans and thus followed a binomial distribution. Results displayed are as follows: nominal explanatory variables included in the final model, their significance (sign) based on Chi-Square-Tests (χ^2), with p-value (the significantly different categories of each explanatory variable are specified in the text of section 3.3), the degrees of freedom (d.f.) and the overall percentage of deviance explained (%dev) by the model. For a detailed description of variables see Table 1.

Response variables	**Explanatory variables**	χ^2	***p*-value**	**d.f.**	**%dev**
common dolphin	water depth	20.31	< 0.0001	2	28.2
	survey method	22.81	< 0.0001	2	
	fishing area	105.24	< 0.0001	5	
	target species	12.75	0.0258	5	
bottlenose dolphin	water depth	23.90	< 0.0001	2	22.6
	survey method	163.9	< 0.0001	5	
	fishing area	165.39	< 0.0001	2	
harbour porpoise	fishing area	36.39	< 0.0001	5	13.9
	target species	27.06	< 0.0001	5	
long-finned pilot whale	water depth	50.79	< 0.0001	2	17.4
	survey method	20.36	< 0.0001	2	
	target species	31.55	< 0.0001	5	
striped dolphin	target species	15.58	0.0081	5	11.4
	fishing area	14.2	0.0144	5	
	water depth	7.0	0.0302	2	

Table 4. Water depth range (metres) of cetaceans sighted in Iberian Atlantic waters. Number of observations (n) is also given.

	depth range (m)	mean ± SD	n
common dolphin	3 – 417	98 ± 86	564
bottlenose dolphin	2 – 417	67 ± 79	298
harbour porpoise	3 – 267	79 ± 59	108
long-finned pilot whale	11 – 400	168 ± 98	116
striped dolphin	5 – 400	104 ± 91	50
baleen whale	27 – 442	155 ± 127	23
Risso's dolphin	27 – 400	173 ± 139	12
sperm whale	20 – 150	82 ± 39	10
killer whale	60 – 417	174 ± 127	11

Table 5. Cost, time expenditure and spatio-temporal coverage of the data sources used in the present study.

		On-board observations	
	interview survey	fisheries observers	trawl skipper
low cost	x	x	x
low time expenditure	x	x	x
broad-scale sampling	x		
coastal habitats	x	x	
offshore habitats	x		x
exact locations of cetacean presence		x	x
long-term sighting trends	x		

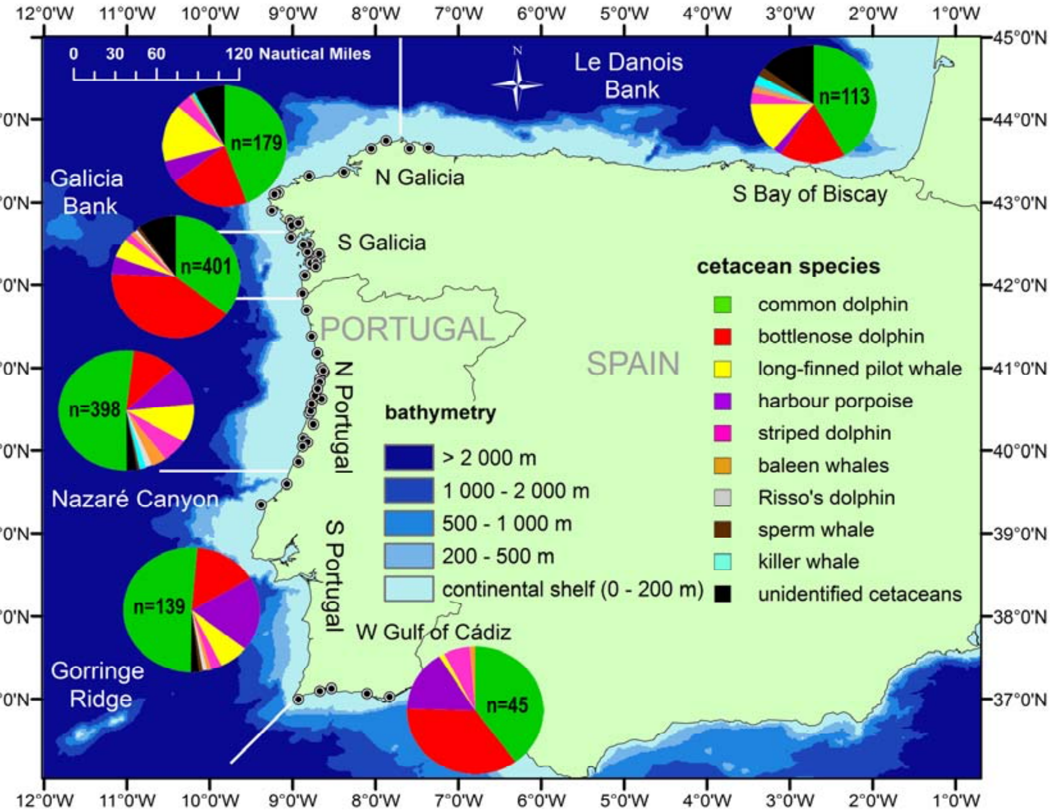

Figure 1. Cetacean species composition in Atlantic waters (from the coastline until 60 nm) along the Iberian Peninsula, as derived from interview data (with fishers) and on-board observations (by skippers and fisheries observers) off the North Spanish and Portuguese Atlantic coast. The species composition (proportions derived from weighted data) and the number of observations is shown for each of the six subregions. *White lines* indicate the limits between the subregions. *Black dots* indicate fishing harbours where interviews were conducted.

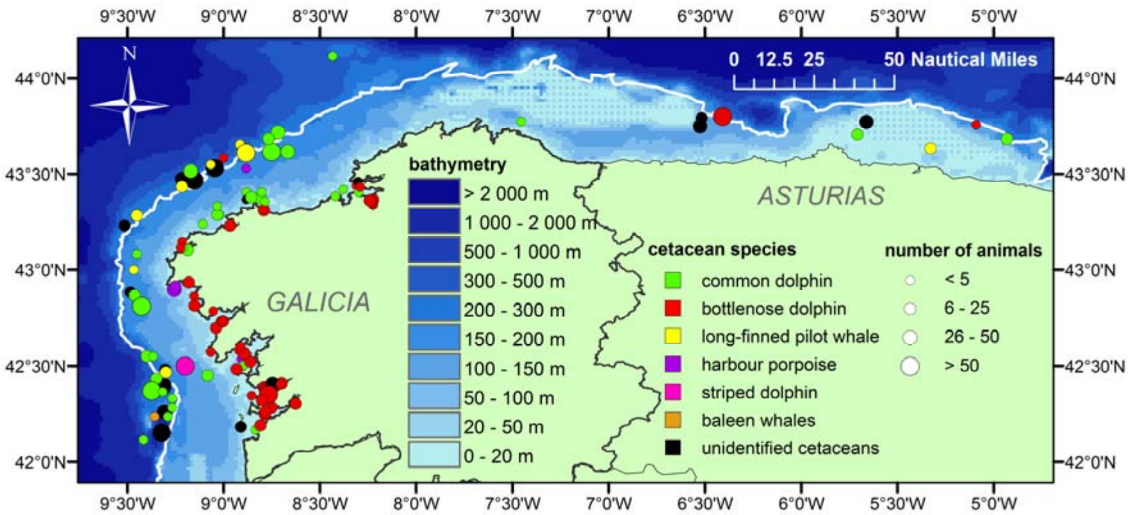

Figure 2. Distribution and group sizes of cetaceans off North Spain, as derived from on-board observations by fisheries observers (covering coastal waters < 100 m along the Galician coast) and by trawl skippers (operating in littoral waters of 100 – 400 m off Galicia and Asturias). The *white line* marks the continental shelf break (200 m water depth). The size of the coloured circles is proportional to the cetacean group size. Raw (unweighted) data were used to create this figure.

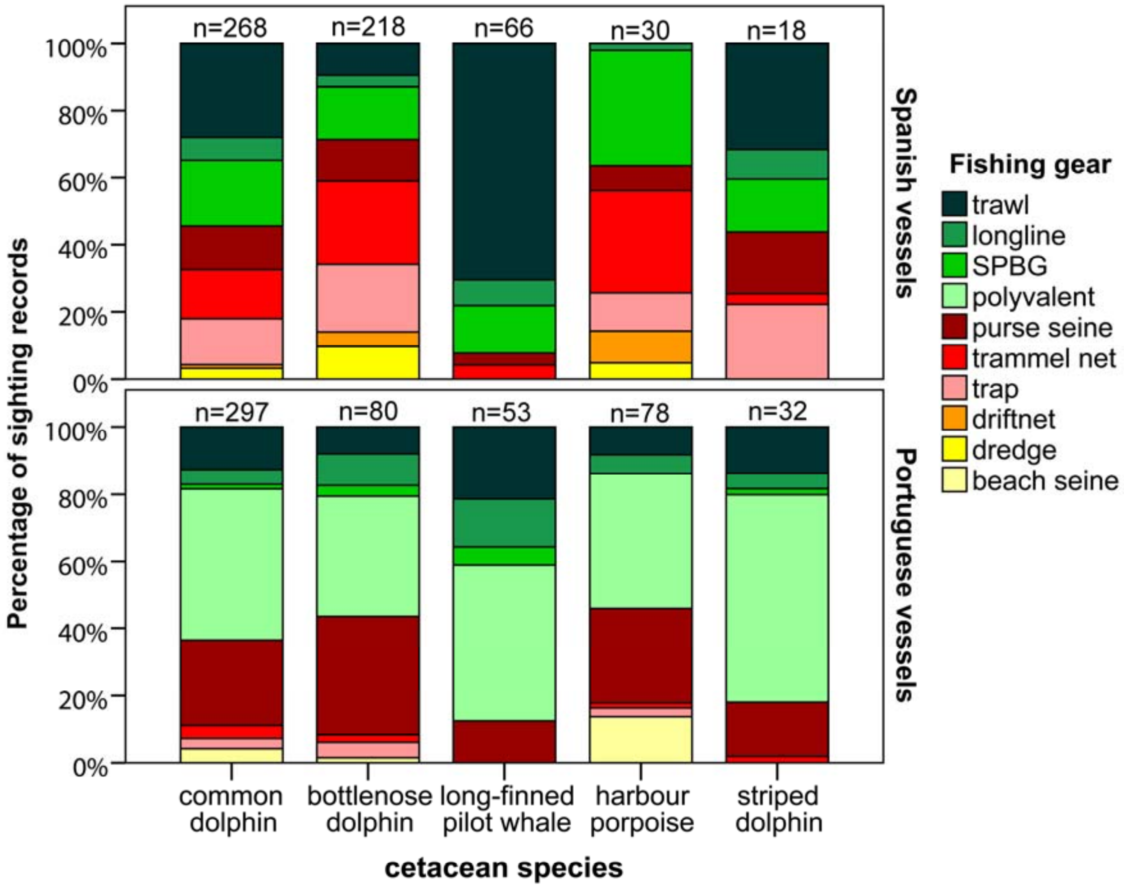

Figure 3. Relative percentage of sightings (weighted data) of the five most frequently sighted cetacean species by different fisheries as derived from interview data and on-board observations from Spanish and Portuguese vessels. Colouring of fishing gears indicates their main fishing depths, *green* representing deep to intermediate water, *red* intermediate to shallow water and *orange/yellow* shallow water. The number of observations (n) is given for each cetacean species. Abbreviations: SPBG – single panel bottom-set gillnet.