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Quantifying the predation on sardine and hake by cetaceans in the Atlantic waters of the Iberian peninsula

M. Begoña Santos [a,*], Camilo Saavedra [a], Graham J. Pierce [b,c]

[a] Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, P.O. Box 1552, 36200 Vigo, Spain
[b] Oceanlab, University of Aberdeen, Main Street, Newburgh, Aberdeenshire, AB41 6AA, UK
[c] CESAM & Departamento de Biologia, Universidade de Aveiro 3810-193, Aveiro, Portugal

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ABSTRACT

Construction of ecosystem models requires detailed information on trophic interactions which may not be readily available, especially for top predators such as cetaceans. Such information can also be useful to estimate natural mortality (*M*) for fish stock assessments and to evaluate the potential for competition between cetaceans and fisheries. In the present paper we provide estimates and confidence limits, taking into account sampling error, for consumption of fish by the four most common cetaceans along the Atlantic coast of the Iberian Peninsula, while highlighting the uncertainties and biases inherent in the information presently available on energy requirements, diet and population size. We estimated that common dolphins (*Delphinus delphis*) consume around 6800 (95% CI, 4871–9476) tons of sardine (*Sardina pilchardus*), 8800 (6195–12,647) tons of gadids, 1100 (721–1662) tons of hake (*Merluccius merluccius*) and 1900 (1222–2752) tons of scads (*Trachurus* sp.) annually. For striped dolphins (*Stenella coeruleoalba*), prey consumed were 900 (196–2661) tons of sardine, 6200 (3448–11,129) tons of gadids, 200 (11–504) tons of hake and 1600 (0–5318) tons of scads. Estimated amounts taken by harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*) are much lower, reflecting their low abundance in the area. Cetacean predation on sardine represents 2–8% of the current *M* value, indicating that cetaceans probably have little influence on sardine population dynamics. For the southern hake stock, estimated average removal by cetaceans often exceeds *M*. While this may indicate that both *M* and the consumption estimates for hake require revision it also suggests that cetaceans could have a more significant impact on hake populations. Different approaches to estimation of energy requirements of cetaceans can result in figures that differ by at least a factor of 2. The lack of good estimates of field metabolic rate for most species probably represents the most serious barrier to reliably quantifying the role of cetaceans in the ecosystem.

1. Introduction

Competition between marine mammals and fisheries in European seas remains the subject of much debate despite several decades of relevant research, with new impetus currently provided by the implementation of an Ecosystem Approach to Fisheries, the adoption in the European Union of the Marine Strategy Framework Directive (MSFD) and the widespread use of dynamic ecosystem models such as ECOPATH with ECOSIM (EwE) to answer questions about direct and indirect fishery impacts on protected marine mammal populations (and vice versa), as recently demonstrated for the Bay of Biscay by Lassalle et al., (2012).

Ecosystem models such as EwE require information on the energy flow through a large number of trophic links. However, the extent of our knowledge about these links is highly variable and it is often necessary to use data from other systems, time periods or from other species/groups to fill in gaps. In many papers reporting on ecosystem properties, based on EwE models, the process of model construction takes place largely "off camera" and consequently the underlying assumptions may receive little scrutiny. This becomes particularly relevant as models are extended to include investigation of the ecological role of top predators, which are usually less well studied than commercially exploited fish species. In European waters, cetaceans are specifically protected under the EU Habitats Directive and in addition are used as indicators of marine biodiversity under the MSFD, necessitating improved understanding of their ecological role.

To integrate cetaceans into ecosystem models, three basic types of data are needed: on population size and structure, diet and energetic

* Corresponding author. Tel.: +34 986 492111; fax: +34 986 498626.
E-mail address: m.b.santos@vi.ieo.es (M. Begoña Santos).

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requirements or food consumption. Various authors have used such data to create population consumption estimates for cetaceans in different parts of the world (e.g. Hain et al., 1985; Kenney et al., 1985; Sigurjónsson and Víkingsson, 1997); all acknowledge the difficulties resulting from lack of reliable data, especially on energy requirements. Although most of the earlier studies did not investigate sources of error or estimate confidence limits, the ready availability of computer simulation-based approaches (e.g. bootstrapping) means that some elements of uncertainty can be readily quantified (e.g. Hammond and Rothery, 1996; Santos et al., 2001; Pierce et al., 2007).

In the present paper we examine the data available for some of the most abundant cetaceans along the Atlantic coasts of the Iberian Peninsula, an area with one of the biggest fishing fleets in Europe (EUROSTAT, 2010) and where the level of fishery by-catch mortality for cetaceans is suspected to be unsustainably high (López et al., 2012; Read et al., 2012).

Based on results from dedicate boat-based surveys (Small Cetaceans Abundance in the North Sea and Adjacent Waters carried out in July 2005 in shelf waters of the European Atlantic, SCANS-II, 2008), as well as information from surveys from platforms of opportunity, coastal sightings and strandings (e.g. López et al., 2002, 2004; Pierce et al., 2010), the most abundant cetacean species in this region are common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), bottlenose dolphin (*Tursiops truncatus*) and harbour porpoise (*Phoceoena phocena*).

These four species have distinct distributional patterns. Common and striped dolphins are considered oceanic species since sightings usually take place in offshore waters (>200 m deep) although both are also seen on the continental shelf (Aguilar, 1997; López et al., 2002, 2004; Covelo et al., 2008; SCANS-II, 2008; Brito et al., 2009; Pierce et al., 2010; Llavona et al., 2011; Spyrakos et al., 2011). Bottlenose dolphin and harbor porpoise are most frequently sighted in coastal waters in the area although individuals have been sighted beyond the shelf edge (López et al., 2002, 2004; Ruano et al., 2007; Covelo et al., 2008; Brito et al., 2009; Pierce et al., 2010). In Galicia, there is a resident population of bottlenose dolphins in the southern Galician rías (coastal inlets formed by partial submergence of river valleys) (Fernández et al., 2011a,b).

In the assessment of exploited fish stocks, predation mortality is implicitly included as an unspecified proportion of so-called natural mortality (M). M is extremely difficult to estimate yet its value is also highly influential on the outcome of stock assessments. Current estimates of M are generally calculated using multispecies assessment models but such estimates are not available for all stocks. For example, in the case of the Iberian sardine (*Sardina pilchardus*) stock, a value of M of 0.33 yr^{-1} was estimated in 1991 based on the rate of year-class disappearance (as estimated by acoustic surveys) not attributable to fishing mortality. This figure of 0.33 yr^{-1} has been used in subsequent assessments, assuming it to be constant and applicable to all fish age classes in all years (ICES, 2011b). It replaced an earlier M estimate of between 0.4 and 0.5 yr^{-1} for all fish age classes and years. Sánchez and Olaso (2004) obtained an estimate of 0.35 yr^{-1} for M for sardine using their ECOPATH model of the Cantabrian Sea shelf. This model did not include cetaceans. In the case of the southern stock of hake (*Merluccius merluccius*), a value of M is 0.4 yr^{-1} has been used since 2010 for all fish age classes, replacing an earlier figure of 0.2 yr^{-1} (ICES, 2012). Calculation of amounts of fish removed by important predator species and the values of M to which these amounts correspond can help identify whether the currently used values of M are realistic and hence either support the validity of current stock assessments or help to improve them.

Here we estimate the amounts of prey consumed by small cetaceans in shelf waters of the Atlantic Iberian Peninsula for the period 1990–2008 and show how the different assumptions made to gather the data needed for the models can impact on the final calculations and its confidence limits. The objectives of the present paper are therefore:

(1) to synthesise available information on population size, diet and energy requirements of the common cetacean species of shelf waters of the Atlantic coast of the Iberian Peninsula;
(2) to estimate the amounts of several commercially important fish species that are removed annually by these cetacean populations and calculate the uncertainty around these estimates;
(3) to compare the estimated mortality of sardine and hake due to cetaceans with the values of natural mortality (M) currently used in the assessment of the Iberian sardine and southern hake stocks.

2. Material and methods

2.1. Population sizes

Common dolphins are considered to form a single population in the Northeast Atlantic (Murphy et al., 2006; Luca et al., 2009) which has been estimated by Cañadas et al. (2009) to be composed of 185,204 individuals (CV=0.327; 99,200–345,772). These figures were obtained by combining the information provided by the SCANS-II survey and the CODA (Cetacean Offshore Distribution and abundance in the European Seas) survey carried out in 2007 that estimated cetacean density in offshore waters of the NE Atlantic (see SCANS-II, 2008; CODA, 2009). Abundance estimates are also available by survey block. The shelf waters of the Iberian Peninsula fall within SCANS-II - Block W, for which the estimate was 17,916 (CV=0.22), using mark-recapture line transect methods (Table 1).

No results are available on the genetic structure of striped dolphins in Northeast Atlantic waters. Because striped dolphins and common dolphins tend to be sighted in mixed schools and even single individuals are sometimes difficult to identify to species, especially when sighted at long distances, SCANS-II produced an estimate of abundance for the category "common and/or striped dolphin". For Block W, the estimate was 32,921 (CV=0.27) and was attained by pooling together all the sightings of common and striped dolphins including those sightings that could not be identified to one or the other species (SCANS-II, 2008) (Table 1). We obtained a crude estimate of the number of striped dolphins in

Table 1
Estimates of cetacean population sizes in SCANS-II Block W and in the portion of Block W that comprises Iberian Peninsula waters by subarea. Figures in parentheses are the coefficients of variation (CV) for the original estimates and figures in square parentheses are the estimated 95% confidence intervals (CI) based on a log-normal distribution. The original population estimates are reproduced from SCANS-II (2008). Codes for the subareas: GAL=Galicia, NSP=Northern Spain (including Asturias), PT=Portugal, SSP=Southern Spain (Gulf of Cadiz).

Species	SCANS-II block W estimate	Iberian peninsula
Common dolphin	17,916 (0.22)	7051 [4645–11,033] – GAL+NSP 6944 [4614–10,618] – PT+SSP 13,811 [8995–21,136] – All
Striped dolphin	32,921[a] (0.27)	2882 [1757–4744] – NSP 8587 [5183–13,912] – GAL+PT+SSP 11,684 [7044–19,467] – All
Bottlenose dolphin	3935 (0.38)	734 [349–1478] – NSP 2261 [1096–4319] – GAL+PT+SSP 2986 [1423–6179] – All
Harbour porpoise	1474 (0.78)	1115 [297–3798] – All

[a] Estimate given for "common and / or striped dolphins".