Habitat suitability of short-beaked common dolphin in the Aegean and Ionian Seas in relation to sardine presence

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Abstract

The purpose of the present study was the assessment of the summertime suitable habitat for *Delphinus delphis* (short-beaked common dolphin) in the Greek Seas. For this purpose presence/absence data from surveys at sea were modeled by means of a cetacean – prey species relationship. Specifically, Generalized Additive Models were applied to identify potential areas of common dolphins' distribution using sardine probability of presence data. GIS (Geographic Information Systems) were subsequently used to determine the persistent and occasional habitat of the species. Modeling results indicated higher common dolphins' presence in areas with high probability of sardine presence. In both seasons, the North Aegean Sea and the inner Ionian Sea are the most suitable environments for common dolphins' distribution.

Keywords: habitat modeling, *Delphinus delphis,* GIS, Generalized Additive Models, Eastern Mediterranean basin

1. Introduction

The short-beaked common dolphin (*Delphinus delphis*, Linnaeus, 1758; hereafter referred to as 'common dolphin') is a cosmopolitan species, which is found mainly in temperate and tropical waters worldwide. In the Mediterranean, it usually occurs over the continental shelf, in coastal waters and often follows the aggregations of small pelagic fishes such as sardine and anchovy (Bearzi et al. 2003; Frantzis 2009). Anchovies and sardines are key prey prey for common dolphins in the coastal waters of the eastern Ionian Sea, however the foraging ecology of common dolphins in the Mediterranean indicates relatively flexible feeding habits, with a preference for small pelagics and mesopelagic fish as well as eurybathic cephalopod and crustacean species (e.g. Bearzi et al., 2003 and references therein). The Mediterranean sub-population of common dolphin has severely declined in recent years and is listed as endangered in the IUCN Red List of Threatened Species (Notarbartolo di Sciara & Birkun, 2010). As an important significant proportion of the Mediterranean common dolphin' population is assumed to exist in Greece (Frantzis et al., 2003), we focused our research on the Aegean and Ionian Seas (Fig. 1).

The current study aims to develop for the first time in the Greek Seas, cetacean-habitat modeling using a presence / absence approach to assess the summertime suitable habitat for common dolphin using sardine probability of presence (as probability of prey). This info was available at an adequate spatial and temporal resolution for the entire Aegean and Ionian Seas from a published habitat suitability model (Tugores et al., 2011) thus supporting our modeling approach.

2. Materials and methods

Common dolphin' sightings (Table 1), were obtained from three different sources a) dedicated cetacean surveys of the Pelagos Cetacean Research Institute in the period 1994-2014 (Frantzis 2009; unpublished data) and IFAW/MCR Song of the Whale Research Team in 2013 (Ryan et al., 2014), b) opportunistic data during the MEDIAS surveys carried out on board R/V Philia (HCMR unpublished data) and c) published data (Angelici & Marini, 1992). In all surveys, cetaceans were identified by experienced observers on board, while questionable observations were discarded from the dataset.

Common dolphin' sightings in the Gulf of Corinth were also eliminated from the analysis, since the respective local population forms mixed-species groups with striped dolphin and present very peculiar behavior showing preference to pelagic habitats and deep water (Frantzis & Herzing 2002; Bearzi et al., 2011).

Most cetaceans are highly mobile and spend a substantial amount of time below the surface, making detection and group size estimation inherently difficult and often unreliable. Hence, the geographic location of each sighting was used without taking into consideration the quantitative estimation of the group size. Data covered the summertime period 1990-2014, split in early summer (May, June, July) and late summer (August, September) observations. This ensured a substantial number of observations to examine a seasonal effect in the potential habitat of common dolphins.

Table 1. Sightings of common dolphin used for analysis.

Source	Period covered	Month	Sightings
Surveys by Pelagos Cetacean Research Institute and IFAW/MCR	1990-1999	05-09	41
Song of the whale Research Team; Published references	2000-2014	05-09	61
MEDIAS research surveys	2006-2013	05-09	10

Generalized additive models (GAMs) (Hastie & Tibshirani, 1990) were applied to define the relationship between sardine probability of presence and common dolphin's spatial distribution during early and late summer for the period 2000-2013. However, GAMs application required presence / absence data. Thus for modeling purposes, survey locations at depths >400m [although marine mammals surveys are scarce at deep waters, common dolphin distribution in the Greek Seas is known not to exceed the 250 m isobaths (Frantzis, 2009)] where available sightings only referred to the striped dolphin (*Stenella coeruleoalba*; Meyen, 1833), were considered as absence locations for common dolphins. Sardine probability of presence at the geographical coordinates of the respective marine mammals' presence/absence records was retrieved from the available annual maps of the entire Greek Seas as estimated from a published habitat suitability model (Tugores et al., 2011). The selection of the smoothing predictors was done using the MGCV library in R statistical software (R Development Core Team, 2012). The final model was tested and evaluated for its predictive performance using the initial data in addition to records which were not included in model selection a) year 2014 and b) period 1990-1999. Due to a lack of adequate satellite data for the period 1990-1999, sardine probability of presence was estimated based on the respective available information for June and September 2003. For validation purposes, we estimated the receiver operating characteristic curve and the area under the curve. Sensitivity (proportion of observed positives that are correctly predicted) and specificity (proportion of observed negatives that are correctly predicted) indices were also used for model evaluation (Guisan & Zimmermann, 2000).

The final model was applied in a predictive mode to obtain annual habitat suitability maps over a grid at a GIS resolution of 4 km, covering the entire Ionian and Aegean Seas (i.e. practically indicating areas with suitable conditions to support common dolphins' presence) but limited for the period 2003-2008 (period that coincides with the best available sardine data). Subsequently, the mean average probability estimates and the respective standard deviation were estimated by means of GIS techniques at each grid point, and were the basis for defining preferential and occasional common dolphins' habitat (limits used for occasional: mean>0.25, standard deviation>0.05 and for preferential: mean>0.75, standard deviation<0.05) (*sensu* Bellier et al., 2007).

3. Results

Modelling results indicated higher probability of common dolphins' presence in areas with high probability of sardine presence. The season effect was also found significant. This model explained 67.5% of the total variation, while the model validation generally showed good model fit (Table 2). Habitat allocation maps showed summertime favorable areas that largely coincide with the areas of known records for the period 2000-2014 and for the period 1990-2000 (Fig. 1).

Table 2. Mean values of Area Under Curve (AUC), sensitivity and specificity accuracy measures ± standard error for the threshold criterion that maximizes the specificity–sensitivity sum.

Model	AUC	Sensitivity	Specificity
Modelled data	0.987 ± 0.011	0.878 ± 0.044	0.982 ± 0.013
Non-modelled data	0.889 ± 0.034	0.830 ± 0.055	0.877 ± 0.037

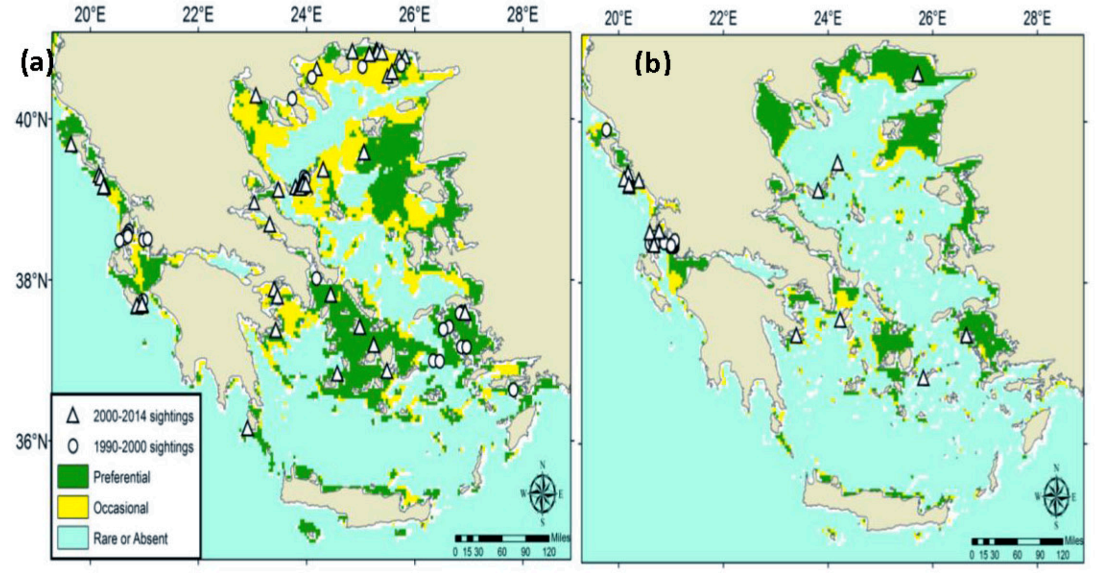

Fig. 1. *Delphinus delphis*: Habitat allocation maps for (a) early and (b) late summer in the period 2003-2008. Sightings for the periods 1990 - 2000 and 2000 - 2014 are also shown.

4. Conclusions/Discussion

Cetacean–habitat modeling represents a promising tool for predicting cetacean distributions and understanding the ecological processes that determine these distributions (Redfern et al., 2006). Bearzi et al. (2006) mention that prey availability and season are the primary factors controlling common dolphins' habitat and our approach also verified that sardines' presence along with the seasonal effect largely determine common dolphin's potential habitat. In both seasons, the North Aegean Sea and the inner Ionian Sea seem to be the most suitable environments for common dolphins' distribution. The Cyclades plateau and Dodecanese Islands also present extended persistent coastal areas. Our analysis showed that preferential and occasional habitats of common dolphin tend to change in size between early summer (expanding) and late summer (reducing in size). Common dolphin's known range in the Aegean Sea is considered to be delimited by an imaginary line that crosses Greece from south Zakynthos Island to south Cyclades and to north of Rodos Island (Frantzis et al., 2003; Frantzis, 2009). However, our results showed suitable habitat areas in the north part of Crete and Patraikos Gulf, where the species is known to be absent. Potential and realized habitat do not coincide in this case, most likely due to other reasons like biogeography. Thus additional data with emphasis on the true absences of the species would improve the model accuracy as well as additional data from Aegean Sea during late summer.

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