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Cetacean monitoring in Northeastern Atlantic Ocean: Occurrence and distribution of cetacean species in the Canary Basin

Ana Mafalda Tomás Correia

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Cetacean monitoring in Northeastern Atlantic Ocean: Occurrence and distribution of cetacean species in the Canary Basin

Ana Mafalda Tomás Correia

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Cetacean monitoring in Northeastern Atlantic Ocean: Occurrence and distribution of cetacean species in the Canary Basin

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Todas as correções determinadas pelo júri, e só essas, foram efetuadas.

O Presidente do Júri,

Porto, ______/______/_________

“The very basic core of a man's living spirit is his passion for adventure. The joy of life comes from our encounters with new experiences, and hence there is no greater joy than to have an endlessly changing horizon, for each day to have a new and different sun.”

Christopher McCandless

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RESUMO

Os cetáceos são ecologicamente importantes na reserva e transporte de energia nos ecossistemas marinhos e, como predadores de topo, exercem uma influência nas espécies de níveis inferiores das cadeias tróficas, mantendo o equilíbrio nestes ambientes complexos e dinâmicos. Assim, o conhecimento da distribuição e preferências de habitat dos cetáceos é assunto prioritário e fundamental nos planos de conservação e gestão marinha. No NE do Oceano Atlântico, o esforço de investigação em cetáceos está limitado a algumas áreas regionais (p.ex., Açores e Madeira) e a poucas milhas da costa. O conhecimento actual é por isso muito localizado e não representativo da área. Assim, há uma necessidade de monitorizar as águas *offshore*, especialmente considerando as prioridades identificadas pela Comunidade Europeia, ACCOBAMS/ASCOBAMS e ICES. Neste projecto, navios de carga foram usados como plataformas de oportunidade para monitorização de cetáceos, de Julho a Outubro de 2012, nas rotas de Portugal Continental (Lisboa e Porto) para a Madeira (Caniçal). As variáveis topográficas e oceanográficas da área foram analisadas e usadas como *drivers* na distribuição dos cetáceos. Recorreu-se a técnicas de modelação exploratória (Envelopes Ambientais e *Generalized Additive Models*) e análise espacial para estudar a distribuição e preferências de habitat dos grupos/espécies. Registaram-se 131 avistamentos, *on-effort* e oportunísticos, e identificaram-se 7 espécies: *Tursiops truncatus, Delphinus delphis, Balaenoptera acutorostrata, Ziphius cavirostris, Physeter catodon, Stenella frontalis* e *Globicephala macrorhynchus*. Os golfinhos foram os mais avistados (63% dos avistamentos), seguidos pelas baleias de dentes e de barbas (16% dos avistamentos). Houve 106 avistamentos *on-effort*, resultando numa taxa de avistamentos total (por 100 milhas náuticas) de 1.85 em 5737 milhas náuticas de esforço. Os resultados indicam uma clara segregação de habitat entre grupos. Provou-se que as variáveis topográficas e oceanográficas influenciam a distribuição dos grupos/espécies na área de estudo. Conclui-se que há provavelmente vários hotspots para cetáceos nesta região e que manter estas amostragens é importante no conhecimento da distribuição de cetáceos na Bacia das Canárias. As plataformas de oportunidade são um meio eficaz e de baixo custo para o estudo de áreas pouco estudadas permitindo uma amostragem sistemática ao longo de diferentes habitats e a aplicação de técnicas de modelação para determinar a distribuição de cetáceos em áreas mais abrangentes como como o NE do Oceano Atlântico.

Palavras-chave

Cetáceos, Monitorização, Distribuição, Oceanografia, Topografia, Modelação, Bacia das Canárias.

ABSTRACT

Cetaceans are ecologically important as storers and transporters of energy in marine ecosystems. As top-down regulators, they maintain the prey-predator balance in complex and dynamic environments. Therefore, the understanding of cetaceans' distribution and habitat preferences represents a priority issue in marine conservation being a key support for management plans. In the NE Atlantic Ocean, research effort in cetacean distribution is limited to some regional areas (e.g., Azores and Madeira) and to a few miles from the coast. The present knowledge is thus very localized and not representative of the area. Therefore, there is a need to monitor offshore waters in this region, especially considering the priorities identified by the European Community, ACCOBAMS/ASCOBAMS and ICES. In this project, cargo ships were used as platforms of opportunity to collect data on cetaceans' occurrence, from July to October, 2012, along the route from continental Portugal (Lisbon and Oporto) to Madeira Island (Caniçal). Topographic and oceanographic features of the area were studied and used as predictors in cetacean distribution. Exploratory modelling techniques (Environmental Envelope techniques and Generalized Additive Models) and spatial analysis were performed to analyze the distribution and habitat preferences of the groups/species. A total of 131 sightings were recorded, considering on-effort and opportunistic records. Seven species were identified: *Tursiops truncatus, Delphinus delphis, Balaenoptera acutorostrata, Ziphius cavirostris, Physeter catodon, Stenella frontalis* and *Globicephala macrorhynchus*. Dolphin species were the most sighted (63% of the sightings), followed by toothed and baleen whales (16% of the sightings). 106 sightings were registered on-effort with an overall encounter rate (sightings/100 nautical miles) of 1.85 on 5737 nm. Results show a clear habitat partitioning among groups. The topographic and oceanographic features were proved to be influencing the distribution of the groups/species within the study area. In conclusion, there are probably several hotspots for cetaceans within this area and, therefore, maintaining these surveys is an important step to improve the knowledge on cetaceans' presence and distribution in the Canary Basin. Platforms of opportunity are a cost-effective way to study an unknown area and perform a systematic sampling along different habitats, allowing the use of modelling techniques to understand the distribution in wider areas, like the NE Atlantic Ocean.

Key-words

Cetaceans, Monitoring, Distribution, Oceanography, Topography, Modelling, Canary Basin.

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LIST OF ABBREVIATIONS

ABR – Azores-Biscay Rise

ACCOBAMS – Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area

AVISO – Archiving, Validation and Interpretation of Satellite Oceanographic data

ASCOBAMS – Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas

AZC – Azores Current

BODC – British Oceanographic Data Centre

CC – Canary Current

CCA – Canonical Correspondence Analysis

CHL – Chlorophyll

CP – Continental Portugal

Dist.coast – Distance to coast

Dist.sm – Distance to seamounts

e.d.f – Effective degrees of freedom

EEZ – Economical Exclusive Zone

ENFA – Ecological Niche Factor Analysis

ENM – Environmental Niche Model

ER – Encounter Rate

FC – Flemish Cape

GAM – Generalized Additive Model

GARP – Genetic Algorithm for Rule-set Prediction

GCV – Generalized Cross-Validation

GEBCO – General Bathymetric Chart of the Oceans

GLM – Generalized Linear Model

HSC – Horseshoe Seamount Chain

ICNF – Instituto para a Conservação da Natureza e das Florestas

IWC – International Whaling Commission

Lat – Latitude

MADT – Maps of Absolute Dynamic Topography

MAP – Madeira Abyssal Plain

MAR – Mid-Atlantic Ridge

MARS – Multivariate Adaptive Regression Splines

Maxent – Maximum Entropy

MC – Mauritania Current

MEDDIES – Mediterranean eddies

MGET – Marine Geospatial Ecology Tools

MI – Madeira Island

MMO – Marine Mammal Observer

MODIS – Moderate Resolution Imaging Spectrometer

MPA – Marine Protected Area

n – Number of sample units

NA – Not Available (referring to data)

NACW – North Atlantic Central Water

NASA – National Aeronautics and Space Administration

NEA – NorthEastern Atlantic

NEC – North Equatorial Current

NECC – North Equatorial Counter-Current

nm – Nautical miles

NTW – Northeasterly Trade Winds

OPO – Observation Platforms of Opportunity

OSPAR – Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic

PC – Portugal Current

PCA – Principal Component Analysis

RSF – Resource Selection Function

SAC – Special Area of Conservation

SAWC – South Atlantic Central Water

s.e. – Standard error

SSH – Sea-Surface Height

SSS – Sea-Surface Salinity

SST – Sea-Surface Temperature

1 INTRODUCTION

1.1 CETACEAN CONSERVATION

Marine ecosystems are complex and dynamic environments where conservation and management of biodiversity represents a major challenge to science and policy drivers (Evans *et al.*, 2012; Thompson *et al.*, 2013). It is suggested that these particularities are responsible for the delayed advance in the conservation of the seas compared to the terrestrial habitats. However, with a growing threatening to marine ecosystems health, it is, more than ever, urgent to take actions and preserve marine biodiversity (McIntyre, 1999).

Cetaceans play an important role in marine ecosystems. They move and store energy and, as top-predators, have a controlling influence on lower levels of the trophic ladder (Morissette *et al.*, 2012; Sergio *et al.*, 2006). Sergio *et al.* (2006) suggests that protecting top-predators is a good strategy, as actions that protect them tend to have conservation effects for other species. In fact, his work proved that, most of the times, top-predators are keystone species that select sites with high biodiversity and abundances and have big area requirements, therefore acting as umbrella species.

Cetaceans have an important status as flagships for awareness campaigns not only for their importance in the marine ecosystems and sensibility to habitat changes, but also for their historical and present values. Cetaceans were culturally and economically valuable for their products (teeth, bones, oil and meat), but in the late 20th century, products from the cetacean hunting have been replaced for more available and accessible alternatives. Since then, and due to great conservational efforts, harvesting has reduced significantly and cetaceans gained an ecological value and the economic interest was reduced mainly to the touristic industry (Department of Environment, Water, Heritage and the Arts, Australian Government, 2008; Marine Board, European Science Foundation, 2008; Sergio *et al.*, 2006).

We can list a few natural causes threatening cetaceans (mass strandings, ice entrapments in the Artic and Antarctic regions and diseases outbreaks), but the anthropogenic impacts represent the biggest concern. The direct killing through hunting and commercial whaling was the main cause for the depletion of several populations (Baird, 2002; Department of Environment, Water, Heritage and the Arts, Australian Government, 2008). Despite the moratorium in high seas whaling of 1986, leaded by the International Whaling Commission (IWC), due to the aboriginal, Japan, Iceland and Norway exceptions and illegal whaling, culling is still a reality (Herrera&Hoagland, 2006; Sheiber, 1998). Accidental deaths are also very common: from entanglements in nets and by-catches to ship strikes (Baird, 2002;

Morizur *et al.*, 1999). Over-fishing is a growing problem in cetaceans' conservation, not only for the accidental entrapments, but also due to the competition for food resources and because it leads to a depletion of species from lower trophic levels that cetaceans depend on (McIntyre, 1999; Morissette *et al.*, 2012). Moreover, vessel traffic and other anthropogenic activities generate noise disturbances responsible for numerous consequences, among them, physical traumas and behavioural changes (Marine Board, European Science Foundation, 2008). Even the approach of a vessel can cause short-term and possible long-term effects, for example, causing spatial movement of the group from that area or inducing stressing behaviours (Papale *et al.*, 2012). These reactions create a dilemma for the growing touristic attraction: the whale-watching. IWC has considered this activity important as an environmental education tool and a sustainable way to improve the local economy. However, if not well regulated (for example, number of vessels allowed and minimum approach distances), it can be negative for cetaceans' conservation (Baird, 2002; Orams, 2000; Papale *et al.*, 2012). Another threat to consider is the increasing pollution and coastal development causing habitat loss and degradation and diseases. Consequences of pollution are aggravated because of the bioaccumulation on these top-predators. Cetaceans are very sensitive to ecological disturbances, so climate changes can have strong impacts on populations and scientists should address this issue, in order to predict the true consequences and support policy drivers to act as soon as possible, following the Precautionary Principle (Baird, 2002; Marine Board, European Science Foundation, 2008).

Recognizing their conservational value, the European Commission considers cetaceans in their policies, for example in the Habitats Directive (European Union Habitats Directive, 1992) and the Marine Strategy Framework Directive (European Union Marine Strategy Framework Directive, 2008). There are also important international organizations that are dedicated to implement policies, monitoring their success and update them when necessary in order to protect cetaceans, such as the "Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas" and the "Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area" (ASCOBANS and ACCOBAMS) and the IWC (Evans *et al.*, 2012; The International Whaling Comission, 2013). Groups that act more locally are also relevant, as they tend to specialize in protecting local populations (Projecto Delfim, 2013). All these groups use many different techniques to protect marine biodiversity, and more specifically cetaceans. The development, implementation and monitoring of threat and pressure mitigation tools is an issue that requires particular attention. An important measure is the delimitation of Marine Protected Areas (MPAs), according to species richness, patterns of distribution and habitat requirements of the species (Hoyt, 2011). Defining appropriate management units and finding new methodologies and tools for data collection and analysis to support conservation and management actions is essential. Therefore, scientists play an important role in providing the background knowledge to support conservational measures (Evans *et al.*, 2012; Reeves, 2000; Silva *et al.*, 2012).

Monitoring is the most effective way to collect relevant data and assure that threat mitigation and spatial (MPAs) measures are efficient. It allows scientists to find the status and spatio-temporal trends of the populations. Abundance, distribution, movements and migrations, occupancy, habitat-use and site fidelity can be monitored either by dedicated or opportunistic surveys, with visual (on-board observers or camera systems), acoustic (for example with autonomous acoustic data loggers such as T-PODs), photo-ID, strandings (possibly allied with biopsy) and tagging monitoring. Other information can be assessed with these methods: ecological data, life history, health status, behavioural and threats to the species. Together with environmental data and appropriate analytical and statistical tools, it can even be possible to make spatial and temporal predictions for the species through modelling, a powerful technique in a changing environment (Evans *et al.*, 2012; Redfern *et al.*, 2006).

1.2 Cetacean Distribution

Global maps of cetaceans' distribution and abundance are a reflection of the research effort and, therefore, tend to have gaps of data and over or underestimate abundances (Brito&Sousa*,* 2011; Kaschner *et al.*, 2010; Kaschner *et al.*, 2012). Kaschner *et al.* (2012) presented the results of distribution and abundance maps of line-transect surveys (aerial or ship-based). According to this analysis, total effort km surveyed cover two-thirds of the ocean surface area, but they are concentrated in 25% of the ocean, meaning the effort is not well distributed around the globe. In fact, it is shown that 44% of global line-transect effort is restricted to Eastern Tropical Pacific which corresponds to only 6% of the ocean surface area. Also, only 6% of the areas were surveyed frequently enough to allow a trend analysis. Moreover, most of the surveys are not year-round, focusing in summer season. Therefore, inter-annual and seasonal variation analysis from the existing line-transect surveys is conditioned.

To achieve a homogeneous global coverage of data in distribution and abundance of cetaceans represents a major challenge. There are several technical and logistic issues to overcome. Even in well-surveyed areas, the species inventories are not complete given the difficulties in detecting some of them (e.g. beaked whales) and the challenging conditions in sea-surveys, for example, the ability to identify the species and the sea-state bias (Kaschner *et al.*, 2010; Kaschner *et al.*, 2012; Redfern *et al.*, 2006). For these reasons, it is suggested the improvement in monitoring networks and the development of suitable environmental models to predict the distribution and abundance of cetaceans, particularly to be applied in less-surveyed areas, inter-annual and seasonal trends and future scenarios (e.g. climate changes) (Lambert *et al.*, 2011; Kaschner *et al.*, 2010; Kaschner *et al.*, 2012).

In the Atlantic Ocean there are, at least, 30 cetacean species, however their distribution is poorly understood (Rice, 1998). In the Northeast Atlantic Ocean (NEA), data comes from few regional hotspots (e.g. Azores and Madeira), where research effort limits data collection to a few miles from the coast or to certain species (e.g. *Tursiops truncatus*) (Augusto, 2007; Silva *et al.*, 2003; Moura *et al.*, 2012; Ribeiro *et al.*, 2009; Visser *et al.*, 2011). Therefore, the knowledge about cetaceans' distribution in this area has to be considered very localized and not representative of the area. Improved baseline data on distribution and habitat preferences is needed in this region and the development of models is essential to generate critical habitat maps for conservation purposes.

1.3 Oceanography and Topography variables shaping Cetacean Distribution

Research in species-habitat relationships constitutes an essential issue in the ecology of an organism. Therefore, in marine ecosystems, the understanding of the distribution and abundance patterns of any marine organism cannot be complete without understanding the oceanographic and topographic characteristics that define their environment (Ballance *et al.* 2006). Many recent studies found important oceanographic and topographic variables shaping cetaceans' distribution or abundance within the sampled area in order to study habitat preferences and niche partitioning (Cañadas *et al.*, 2012; Stocking *et al.*, 2008; Weir *et al.,* 2012). Many studies focused on these organism-habitat relations through modelling techniques, frequently with conservational purposes (see Table 1). Oceanographic features were found to be important factors also in the genetic structure of short-beaked common dolphin (Genus: *Delphinus*) rather than geographical distance alone (Amaral *et al.*, 2012). The power of these habitat variables in shaping cetaceans' distribution, abundance or even genetic structure, are an indirect consequence of the relation between cetaceans and their prey. Several topographic features are related with upwelling systems, turbulence and aggregation of prey species. Benthic or demersal species are strongly affected by depth, slope and substract type. Oceanographic structures, such as persistent fronts or eddies, are likely to affect prey distribution through physical-biological interactions and trophic relationships between plankton and prey species (Cañadas *et al.*, 2012; Moulins *et al.*, 2008; Stocking *et al.*, 2008). Analysing these species-habitat interactions is complex in marine environments due to their dynamics and variations. Oceanographic and topographic variables are linked with each other and with prey availability, and their influence in cetaceans' distribution and abundance patterns is a result of a combination of several factors. Moreover, these factors vary considerably in time and space (Weir *et al.*, 2012). Temporal scales can vary from daily to decadal, while spatially, the scales can vary from meters to thousands of kilometres. The smallest the scale, the biggest rate of change and lowest predictability. At small-scales, movements and behaviour of individual foragers should be studied while at mesoscales, water column and surface data as well as oceanographic features should be used as proxies for prey abundance and distribution, because these variables are responsible for the aggregation of preys (plankton and schools or swarms) in mesoscales patches. Prey species can then be aggregated in larger patches due to water masses and circulation systems, and these features should be used to define species ranges of cetaceans, considering variables relative either to ocean basin characteristics or to long-term changes (seasonal, inter-annual or decadal variations) (Redfern *et al.*, 2006).

Cañadas *et al.* (2002) studied the influence of slope and depth in the distribution of 7 species in Mediterranean waters off Southern Spain. This work was able to segregate species mainly according to depth: preference for deep waters (striped dolphins, Risso's dolphins, pilot whales, beaked whales and sperm whales) versus preference for shallow waters (common and bottlenose dolphins). This segregation was found to be related with feeding habits, since different preys inhabit different habitats (small fishes in shallow waters due to the high productivity and squids in deeper waters). Slope played a structuring role too, yet it was less important than depth. Therefore, physiographic characteristics were found to be influencing cetaceans' distribution, as they were responsible for prey availability and aggregation.

A revision paper from Ballance *et al.* (2006) on oceanographic influences in cetaceans and seabirds of the Eastern Pacific Ocean relates the presence of oceanographic structures (such as fronts, gyres and eddies, surface currents and countercurrents, upwelling systems) with particular characteristics (sea surface temperature (SST), sea surface salinity (SSS), chlorophyll (CHL), thermocline depth and strength and prey availability) to cetaceans' distribution, reported in several studies at different spatio-temporal scales. An illustrative example of the influence of the oceanographic variables in different species is shown in Figure 1.

It has been shown that coupling topographic with oceanographic variables may have better results in explaining habitat preferences and distribution patterns (UNEP-CMS, 2008) and many recent habitat models have been developed within this frame (see Table 1). These habitat variables can be assessed in several different ways: during cetacean sea-surveys or tagging studies, from remotely sensed data or from oceanographic models (Redfern *et al.*, 2006).

Eddies and upwelling processes, as well as large number of topographic structures (namely, seamounts chains), characterize the oceanography and topography of the NEA. However no comprehensive study correlating cetacean distribution with mesoscale (10-100km) features has been done in this area. This area is under the influence of Azores and Canary Currents and two upwelling systems (African and Iberian), mediated by the northeasterly trade winds and influenced by the Mediterranean outflow (Caldeira *et al.*, 2002). The topography is diverse as it encompasses two major canyons (Portimão and Agadir canyons) and seamounts (e.g. Horseshoe Seamount chain) which play an important role on the formation of Mediterranean Eddies (MEDDIES) (Caldeira *et al.*, 2002; Mason, 2009). Furthermore, this area can provide information on cetacean migratory patterns in and out the Mediterranean and from higher to lower latitudes or vice versa (Lockyer&Brown, 1981). The need to understand cetacean distribution better together with the *sui generis* oceanographic and topographic characteristics and habitat variability make the NEA an area appealing for studies in cetacean habitat preferences and modelling.

Relation between cetaceans and Environment in the Eastern Tropical Pacific

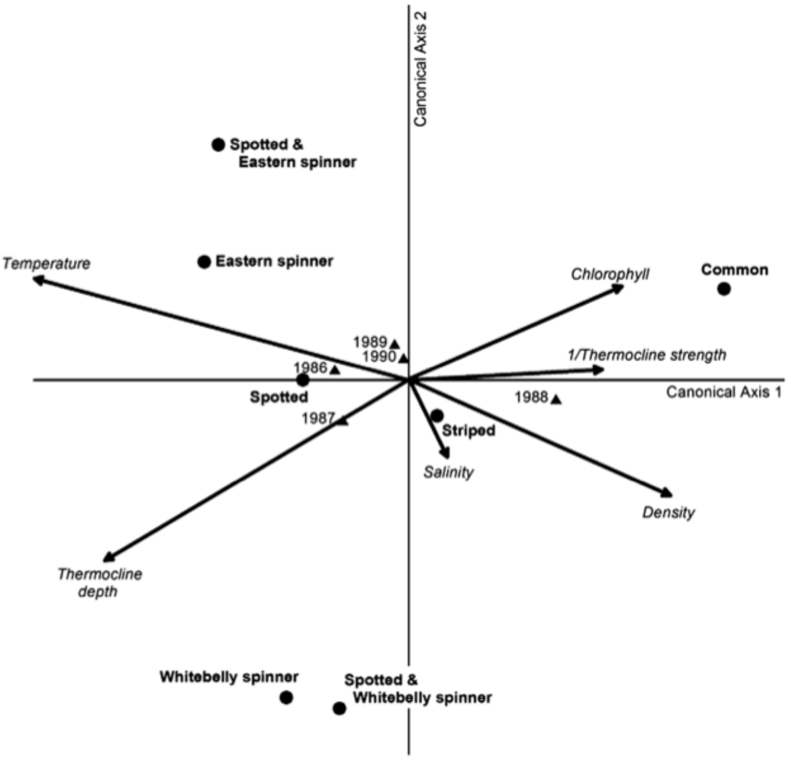


Figure 1. Ordination results from Canonical Correspondence Analysis of cetacean species/sub-species and environmental conditions in the Eastern Tropical Pacific. Canonical Axes represent those combinations of environmental characteristics that explain the greatest proportion of variance in density of seven dolphin species or school types. The direction and degree of influence of six oceanographic variables on the Canonical Axes are illustrated by the arrows. Centroids for each of five years are shown and clearly indicate interannual variation in the system. Integral image and adapted description from Balance *et al.* (2006). Original data and image in Reilly&Fiedler (1994).

1.4 HABITAT MODELLING

For effective conservation and management actions, knowledge on spatio-temporal distribution of cetaceans is needed. When dealing with this highly mobile, deep-water and hard to detect animals, modelling is a solution to predict where they are more likely to occur and how this relates to the environmental conditions (McLeod *et al.*, 2008).

Additionally, in such a dynamic environment and in a perspective of environmental changes (climate changes) being able to predict distribution patterns has major ecological significance. It is the tool needed for the identification of critical habitats and areas that need increased protection and conservational efforts and for mitigation or prevention of anthropogenic threats (Azzellino *et al.*, 2012; Gilles *et al.*, 2011; Praca *et al.*, 2009). If the model is "good" and predicts animal presence and/or abundance with high reliability and if robustness is achieved, models can predict distribution patterns in different areas and time, giving sound information on the impacts of environmental changes on populations (Boyce *et al.*, 2002).

Habitat selection is a hierarchical process involving a series of innate/learned behavioural decisions based on species requirements (for food, mating, etc.) and their ability to move between habitat patches. All these behavioural choices constitute habitat preferences and are defined as the degree to which such habitats are chosen over the others if offered on an equal basis, including innate preferences for resources not actually available (Johnson, 1980; Valcroze, 2008). The prey distribution is linked with the oceanographic processes through physical-biological interactions and trophic relationships between plankton and cetaceans' prey species (Moulins *et al.*, 2008; Weir *et al.* 2012). In fact, several studies in cetacean habitat have focused their attention in relating the cetaceans' presence with oceanographic and topographic features, either static (e.g. bathymetry) or dynamic (e.g. sea surface temperature, chlorophyll, eddy structures) (among others: Fergunson *et al.*, 2006; Moulins *et al.*, 2007; Moulins *et al.*, 2008; Panigada *et al.*, 2008; Torres *et al.*, 2008; see Table 1 for more recent habitat modelling studies). Moreover, it has been shown that better habitat models are obtained coupling topographic with oceanographic variables (UNEP-CMS, 2008).

As a first overview on the relation habitat-marine mammals, several correlation analysis can be performed to measure in which degree the variables affect the distribution. These are descriptive techniques used for hypothesis testing (Goodness-of-fitness techniques, Analysis of variance and Ordination methods such as Principal Components Analysis (PCA), Redundancy Analysis, Correspondence Analysis and Canonical Correspondence Analysis (CCA, see Figure 1 as an example)) (Redfern *et al.* 2006). Environmental Envelope techniques (an envelope defines the minimums and maximums in the environmental variables to fit an area that encompasses a percentage of occurrences) and quantiles analysis are also useful to define the range of habitat of the animals and to understand the distribution on the sampled area (Austin, 2007; Elith&Leathwick, 2009; Kiszka *et al.*, 2007; Pearce&Boyce, 2006).

Model development is a process. The first step is to choose the spatial and temporal scale and to define the sampling strategy accordingly. The unit of observation has to be decided based on the available data, purpose of the model and the scale at which the question of interest can be analysed. It is also possible to conduct a multi-scale model to find the change in the explanatory power of the habitat variables in relation to the unit of observation (Boyce *et al.*, 2002; Redfern *et al.*, 2006). There are several modelling techniques that fit into different modelling approaches: from Environmental Envelopes to Tree-based models (empirical method to resolve relationships in a complex dataset) (see Redfern *et al.* 2006). Among them, Research Selection Functions (RSF) have been frequently used in cetacean habitat modelling (see Table 1). A RSF is defined as a function proportional to the probability of use by an organism. These functions are regression methods such as Generalized Linear Models (GLM) and Generalized Additive Models (GAM) (Boyce *et al.*, 2002; Redfern *et al.*, 2006).

The choice of the model technique is also highly dependent on the biological data available. MacLeod *et al.* (2008) compared different modelling approaches on marine animals, either presence-absence or only-presence techniques. Presence-absence techniques were more accurate in predicting animal's distribution. On the other hand, presence-only models performed significantly better than random models and both techniques gave similar spatial distribution results. Therefore, both of the model approaches can be used and the choice depends on the reliability of the absence data.

Due to errors in the sampling process (ecological stochastic processes) and model selections, the final model will not perfectly predict the cetaceans' occurrence and the uncertainty associated with the predictions has to be determined. After model fitting is achieved, the accuracy and applicability of the model needs to be addressed. The model can have explanatory purposes or be aimed to have predictive power. In the last case, reliability of the predictions has to be evaluated (Elith&Leathwick, 2009). The evaluation is the comparison between predictions and real values of occurrence, with an independent dataset or dividing the original one into two (one for fitting and other for evaluation) (Redfern *et al.*, 2006).

Due to the increase in the computational capabilities and developed statistical tools, modelling techniques have diversified and adapted to different purposes and needs in the conservation and management areas (Praca *et al.*, 2009). Thus, many studies have focused in habitat modelling. Table 1 presents some of the most recent works in cetacean habitat modelling in different geographical areas and shows the variety of techniques used for different final purposes. Redfern *et al.* (2006) suggests that future developments in this area should use the actual modelling techniques, but focus in geographical areas, species and habitat conditions not yet studied.

Table 1. Examples of recent works in cetacean habitat modelling. OPO – Observation Platforms of Opportunity. SSH – Sea-surface height. ENMs – Environmental Niche Models; Maxent – Maximum Entropy; ENFA – Ecological Niche Factor Analysis; GARP – Genetic Algorithm for Rule-set Prediction; MARS – Multivariate Adaptive Regression Splines. Some works used standard deviation, means or other variants of the predictors.

Reference	Geographical Area	Target Species	Sampling	Predictors	Modelling techniques	Aims
Azzellino *et al.*, 2012	Pelagos Sanctuary, Mediterranean Sea	*Balaenoptera physalus* *Physeter catodon* *Grampus griseus* *Stenella coeruleoalba* *Tursiops truncatus* *Ziphius cavirostris*	Research vessel observations	Depth, Slope	Binary Logistic Regression Analysis	Model distribution and habitat preferences
Peltier *et al.*, 2012	French Atlantic Coast	*Delphinus delphis* *Phocoena phocoena*	Stranding data	Bathymetry, Tides, Atmospheric data, Water velocity, Drift predictors	Drift model (MOTHY, Météo-France)	Improve ecological significance of cetacean stranding data by a better understanding of drifting of small cetaceans at sea
Pendleton *et al.*, 2012	Gulf of Maine, East coast of North America	*Eubalaena glacialis*	Research vessels observations	*Calanus* model, Bathymetry, CHL, SST	Maxent	Model right whale habitat on a weekly time scale with sensitive to intra and inter-annual variability in environmental conditions
Moura *et al.*, 2012	Portuguese Coast	*Delphinus delphis*	OPO	Depth, CHL, SST	ENMs, Maxent	Model common dolphin habitat preferences and compare models obtained from two different OPO
Azzellino *et al.*, 2011	Mediterranean Sea (Alboran and Ligurian)	*Ziphius cavirostris*	Research vessels (visual sightings and acoustic detection)	Depth, Slope, CHL	Binary Logistic Regression Analysis	Evaluate model transferability
Corkeron *et al.*, 2011	Arabian Sea, Oman Coast	*Megaptera novaeangliae* *Balaenoptera sp.*	Research vessels and shore-based observations	Depth, Slope, Distance to coast	GLM	Identify areas with greatest relative abundance for humpback whales
Friedlaender *et al.*, 2011	Marguerita Bay, Western Antartic Peninsula	*Balaenoptera bonaerensis* other krill predators	OPO	Depth, Slope, Distance to coast, Distance to ice, Deep temperature, Prey	ENMs	Assess distribution of sympatric krill predators and niche overlap, relating to environmental variability

Gilles *et al.*, 2011	SE North Sea	*Phocoena phocoena*	Aerial surveys (visual sightings)	Depth, Slope, Distance to coast, Salinity, SST, CHL, Residual current, Silicate, Nitrogen	GAM	Validate model with independent dataset; estimate seasonal abundances for 3 special areas of conservation in German Bight
Pirotta *et al.*, 2011	Balearic Islands, Mediterranean Sea	*Physeter catodon*	Research vessels (visual sightings and acoustic detection)	Depth, Slope, SST, SSH, Surface wind direction, CHL, Year, Latitude, Longitude	GAM, GLM	Use of multi-scale approach to investigate the pattern distribution and the difference between single and groups of sperm whales
Embling *et al.*, 2010	Souther Inner Hebrides, West Coast of Scotland	*Phocoena phocoena*	Research vessel observations	Depth, Slope, Type of sediment, Tide, Spring-neap cycle, Survey effects	GAM	Predict high-use areas
Viddi *et al.*, 2010	Fjords of Southern Chile	Mysticetes, Odontocetes, *Lagenorhynchus australis, Cephalorhynchus eutropia*	OPO	Latitude, Channel with, Distance to coast, Depth, Coast complexity	GAM	Examine spatial and temporal distribution of cetaceans
McLeod *et al.*, 2008	Souther Inner Hebrides, West Coast of Scotland	*Phocoena phocoena*	OPO	Depth, Slope, Aspect, Distance to coast	GLM, PCA, ENFA, GARP	Compare the ability of the different modelling techniques to predict occurrence of harbour porpoise; test the efficacy of presence-only techniques in the marine environment
Praca *et al.*, 2009	NE Mediterranean Sea	*Physeter catodon*	Research vessels (visual sightings and acoustic detection)	Depth, Thermal fronts, Distance to 200m contour, Salinity, CHL	ENFA, PCA, GLM, MARS	Model critical habitat for sperm whales

1.5 Study Area

The study area is in the NEA, and is a part of the ACCOBAMS area and the Portugal Economical Exclusive Zone (EEZ) (Figure 2). Considering the planned EEZ extension, the whole area will be within the Portuguese EEZ limits (Estrutura de Missão para a Extensão da Plataforma Continental – EMEPC, 2013). Within the study area, Josephine seamount is a MPA (Figure 2) since 2010, designated by the Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) (Protected Planet, 2012). In the area, there are small and coastal areas of protection that include cetacean species: “Madeiran Marine Mammal Sanctuary”, “Sado Estuary Natural Reserve” and “Arrábida Natural Park” (Hoyt, 2011).

Geographic limits in the Study Area

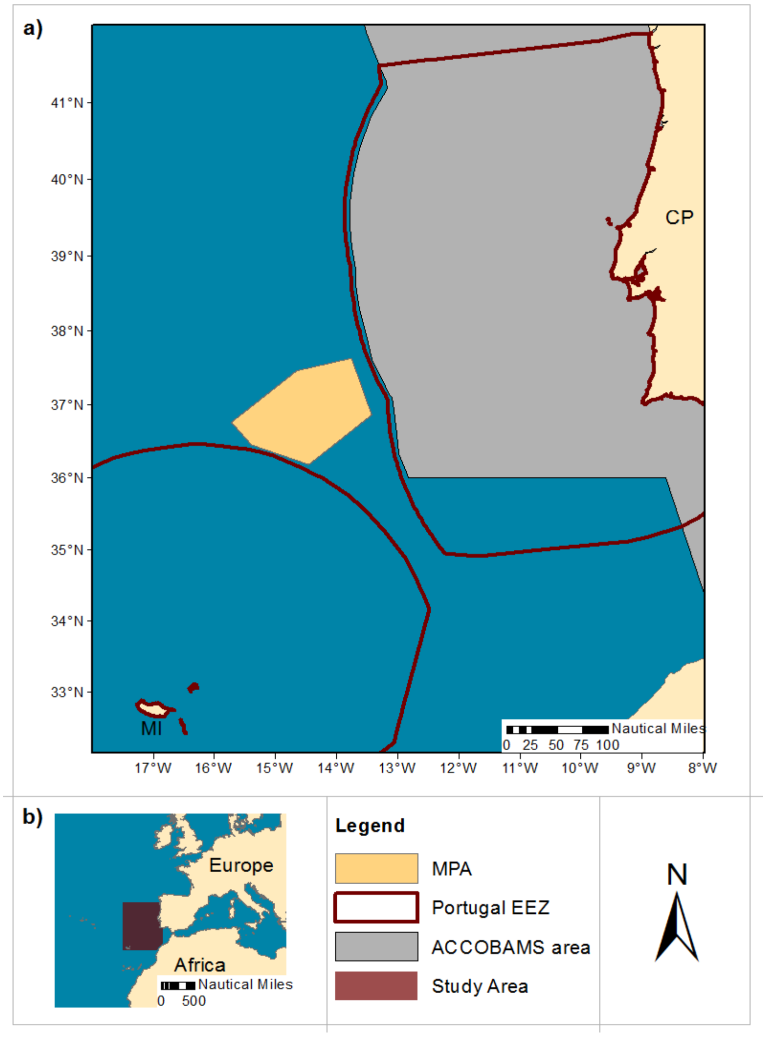


Figure 2. Study area with the Marine Protected Area (MPA), Portugal Economic Exclusive Zone (EEZ) limits and in the “Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area” (ACCOBAMS) area. a) Study area (CP – Continental Portugal; MI – Madeira Island); b) Geographical context of the study area.

Studies developed on cetaceans within this area are restricted to near shore areas. Beside the Josephine seamount MPA, that has no management plan so far and, to our knowledge, very little information on cetaceans' occurrence and distribution (OSPAR, 2011), and the proposed MPA for the Gorringe seamount, also, to our knowledge, with no published data on cetaceans (Oceana, 2013), there is only two continental and coastal Marine Natural Reserves (Sado Estuary Natural Reserve and Arrabida Natural Park) and the Madeiran "Marine Mammal Sanctuary" (Hoyt, 2011), within the EEZ limit of Madeira.

Brito&Sousa (2011) reported the results of ten centuries of records in cetaceans in Portugal. It is shown that increasing in the investigation and areas of interest in cetaceans over the years has resulted in a better knowledge and the identification of more species. However, according to the "Instituto para a Conservação da Natureza e das Florestas" (ICNF, 2013), only 6 of these species are resident in the continent: *Tursiops truncates, Stenella coeruleoalba, Delphinus delphis, Grampus griseus, Phocoena phocoena* and *Balaenoptera acutorostrata* (Table 2).

The "Museu da Baleia" (2013) confirmed 24 species in Madeira Archipelago. The most common species are *Tursiops truncatus*, which is present all year round, *Delphinus delphis* present seasonally, in Spring and Winter, and *Stenella frontalis* present seasonally, during Summer. Other common species are: *Physeter catodon* and *Globicephala macrorhynchus* (all year round), *Stenella coeruleoalba* (end of Spring and Winter and during Summer) and *Balaenoptera physalus* (Spring and Summer) (Museu da Baleia, 2013). An overview of the species known in the study area is presented in the table below (Table 2).

Table 2. Cetacean species known in the study area. Res – resident; Oc – occasional; Vis – visitor. Data from Brito&Sousa (2011), Museu da Baleia (2013) and ICNF (2013).

Species	Continental Portugal (CP)	Madeira Island (MI)	Occurrence CP	Occurrence MI
Tursiops truncatus	✓	✓	Res[a]	Res[a]
Steno bredanensis	✗	✓	-	Rare[b]
Phocoena phocoena	✓	✗	Res[a]	-
Delphinus delphis	✓	✓	Res[a]	Res[a]
Stenella frontalis	✗	✓	-	Res[a]
Stenella coeruleoalba	✓	✓	Res[a]	Common[b]
Grampus griseus	✓	✓	Res[a]	Oc[a]
Pseudorca crassidens	✓	✓	Oc[a]	Oc[a]
Feresa attenuata	✗	✓	-	Rare[b]
Orcinus orca	✓	✓	?	Oc[a]
Globicephala macrorhynchus	Globicephala sp.	✓	?	Res[a]

Mesoplodon europaeus	Mesoplodon sp.	✓	?	Oc[a]
Mesoplodon densirostris		✓		Oc[a]
Mesoplodon bidens		✓		Oc[a]
Ziphius cavirostris	✓	✓	?	Oc[a]
Kogia simus	✗	✓	-	Rare[b]
Kogia breviceps	✓	✓	?	Oc[a]
Physeter catodon	✓	✓	Oc[a]	Res[a]
Balaenoptera acutorostrata	✓	✓	Res[a]	Oc[a]
Balaenoptera edeni	✗	✓	-	Oc[a]
Balaenoptera borealis	✓	✓	Oc[a]	Oc[a]
Balaenoptera physalus	✓	✓	Vis[a]	Vis[a]
Balaenoptera musculus	✓	✓	Oc[a]	Oc[a]
Megaptera novaeangliae	✓	✓	Oc[a]	Oc[a]
Eubalaena glacialis	✗	✓	Oc[a]	Oc[a]

[a] Whenever IUCN standard data on occurrence was available, either in ICNF (2013) or Museu da Baleia (2013), these were used.

[b] Information on occurrence non standardized taken from Museu da Baleia (2013).

In the Continental Portuguese coast, distribution of small cetaceans has been related with oceanographic and topographic variables, and studies with linear transects were suggested to provide new insights on this matter (Brito *et al.*, 2009; Moura *et al.*, 2012). In Madeira Archipelago, the Museu da Baleia (2013) has on-going projects that aim the study of cetacean habitat and influences of oceanographic and topographic variables.

The study area is within the Canary Basin, a very dynamic and diverse area concerning oceanographic and topographic structures as shown by Mason (2009) (Figure 3).

Canary Basin

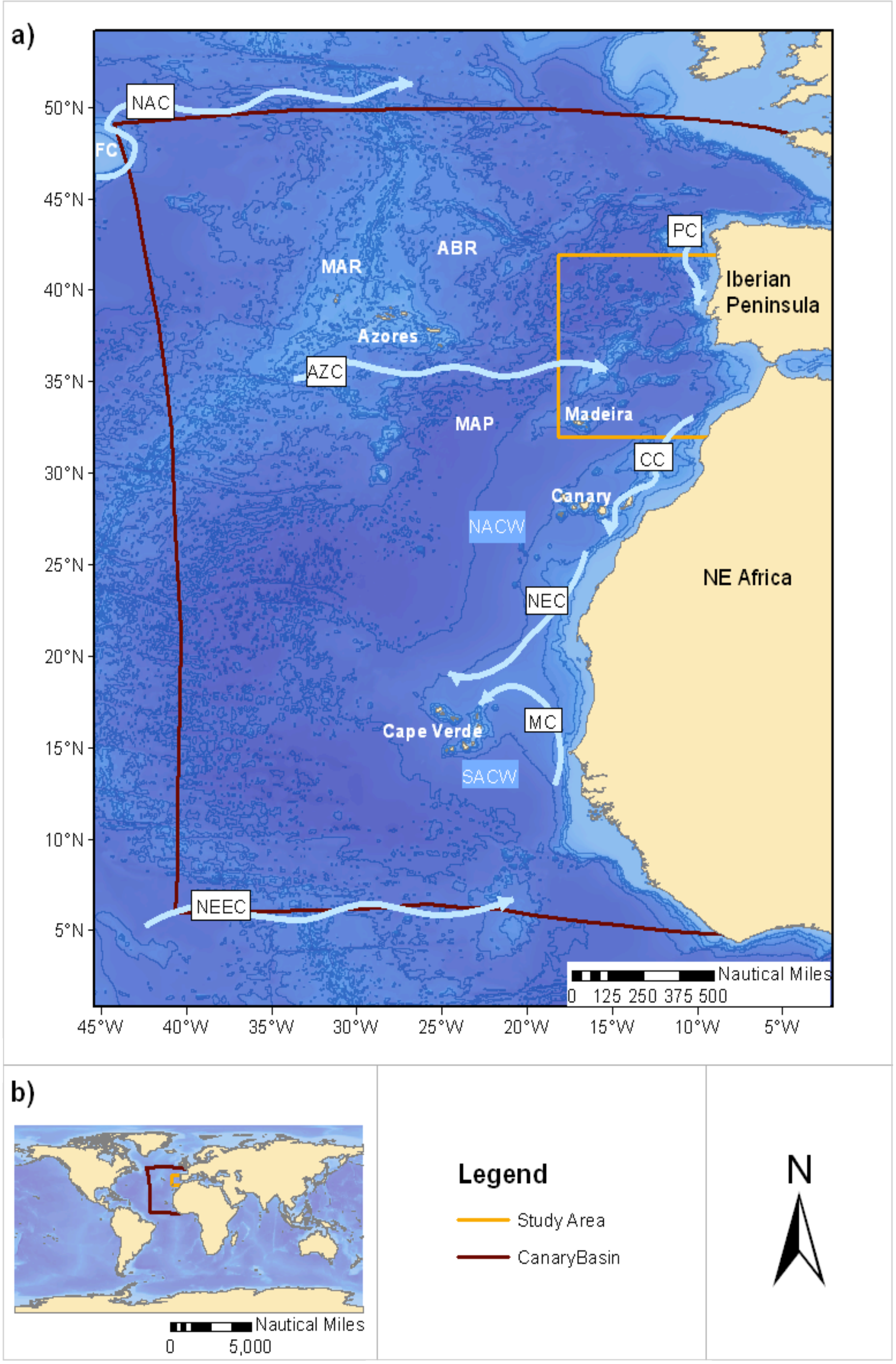


Figure 3. Principal oceanographic and topographic features of the Canary Basin in the NEA. Limits of the Basin in red line. a) Canary Basin; b) Geographical context of the Canary basin. Labels: AZC - Azores Current, PC – Portugal Current; CC - Canary Current, MC - Mauritania Current, NEC - North Equatorial Current, NECC - North Equatorial Counter-Current; ABR - Azores-Biscay Rise, FC - Flemish Cap, HSC - Horseshoe Seamount Chain, MAP - Madeira Abyssal Plain, MAR - Mid-Atlantic Ridge, NACW - North Atlantic Central Water, SACW - South Atlantic Central Water. Image and description adapted from Mason (2009).

Canary Basin region is characterized by numerous topographic structures (canyons and seamounts), associated with the occurrence of eddies. For example, the Portimão Canyon situated in Gulf of Cadiz is associated with the occurrence of MEDDIES. Several surface currents can be identified in this area. At the surface, the predominant northeasterly trade winds (NTW) interact with atmospheric high-pressure (Azores High), and the latitudinal changes of these features are responsible for seasonal variation of mesoscale oceanic eddies. The NTW are also linked with the formation of upwelling systems occurring along the African and Portuguese coasts. Moreover, the Azores High and annual cycles of insulation are responsible for seasonal variation in the mixed layer (Mason, 2009).

1.6 Research Objectives

In this project, OPO (cargo ships) were used to monitor within the study area (Figures 2 and 3) to obtain data on cetacean occurrence and relate to major oceanographic and topographic structures. The main goal of this project is to provide new insights into cetacean species inhabiting Canary Basin waters in order to address priorities identified by the European Community (UNEP-CMS, 2008) and international bodies such as ACCOBAMS/ASCOBAMS and ICES (ICES AGISC, 2005.).

The primary objectives of this work are:

• To study the area dynamics and understand the oceanographic and topographic structures that characterize it. Also, analyse topographic variability along transects as well as the dynamic of the oceanographic variables and identify major mesoscale oceanographic features (persistent fronts, eddies, upwelling filaments, etc.).

• To characterize the habitat of cetacean species. Assess groups/species habitat range and provide preliminary information required for habitat modelling, through descriptive techniques such as Environmental Envelopes. Moreover, investigate the habitat partitioning among species sharing a similar ecological role (e.g. beaked whales and sperm whales).

• To identify the topographic and oceanographic features having a major role in structuring cetacean habitat, to use as proxy for their presence and distribution patterns.

• To find adequate habitat models in order to map, explore and predict cetaceans' distribution in the area. In particular, fit habitat models with more explanatory power (e.g. GAMs) (Elith&Leathwick, 2009).

• To identify possible hotspots for cetacean species (or guilds), considering both oceanographic and topographic structures, in order to map areas which would need more conservation efforts. For this purpose, a spatial representation of model's results was done.

1.7 Challenges and Limitations

When projecting this work, some difficulties were predicted. This is a study that involves 3 distinctive parts: biological sampling (collection of sightings data), habitat sampling (collection of oceanographic and topographic data) and data analysis. Several challenges and limitations were expected in each of the parts and they are presented below.

Cetacean distribution sampling

• Dependence on the OPO schedules and conditions. By using OPO, sampling had to be adjusted to the schedules of the company. Moreover, the use of OPO limits the spatial coverage of the study area (Kiszka *et al.*, 2007; Viddi *et al.*, 2010).
• Marine Mammal Observers (MMOs) visual capacity. Every MMO has a different visual capacity and in this sampling, one of the MMO changed every month. Moreover, volunteers had no previous experience and, therefore, they gained experience with the sampling improving their visual capacity.
• Perception bias. Sea-survey is always conditioned to swell-height, wind force and visibility conditions for monitoring purposes this factor is even more relevant since it affects cetaceans' detection and identification. Also, when animals are at the surface, they can be missed since they are often discrete when emerged (Embling *et al.*, 2010; Redfern *et al.*, 2006).

Oceanographic and topographic sampling

• Choice of the predictors to consider in the analysis. This has to be a consequence of the environmental analysis and the understanding of the dynamics of the study area.
• Choice of reliable and adequate sources of data;
• Choice of the proper resolution of the data. A temporal and spatial resolution has to be chosen considering the balance between the adequate scale to use with the biological data collected and the availability of data (Embling *et al.*, 2010; Redfern *et al.*, 2006).

Data analysis

• Effort consideration. Since not all the segments of the routes were equally sampled and the determined use and non-use habitat can depend on the amount of effort (Boyce *et al.*, 2002), measures of effort are advised.

• Choice of the possible spatial and temporal scale to use.

• Temporal or spatial lag between the oceanographic conditions and cetaceans' presence. This can happen due to three things: available data does not have enough resolution, the analysis is being done in an inappropriate scale or the influence of oceanographic processes is not direct because of all the process oceanographic variables – oceanographic structure – prey – cetacean (Ballance *et al.*, 2006);

• Choice of an appropriate method for modelling according to the available data: presence/absence, presence/pseudo-absences, only presences or used/available habitat (Brotons *et al.*, 2004; Elith&Leathwick, 2009; MacLeod *et al.*, 2008; Pearce&Boyce, 2006).

2 Materials and Methods

2.1 Sampled Area

A systematic sampling design was carried out from Continental Portugal to Madeira (and vice versa), more specifically from Lisbon to Caniçal and vice versa (approximately 38h) and Caniçal to Oporto (approximately 48h), and a single survey from Oporto to Lisbon (approximately 12h), during summer season (July-October, 2012). A survey was considered a one-way travel from one port to another.

These transects were chosen because they intersect areas with predicted different cetacean species profiles (e.g. coastal and oceanic species) and cross a diversity of oceanographic and topographic features (Figure 4). Transects pass in coastal and deep-sea areas and in seamounts, covering different topographic profiles. Oceanographically, tracks covered are under the influence of two major currents (Portugal and Azores currents). Thus, transects surveyed are assumed to be representative of the studied area.

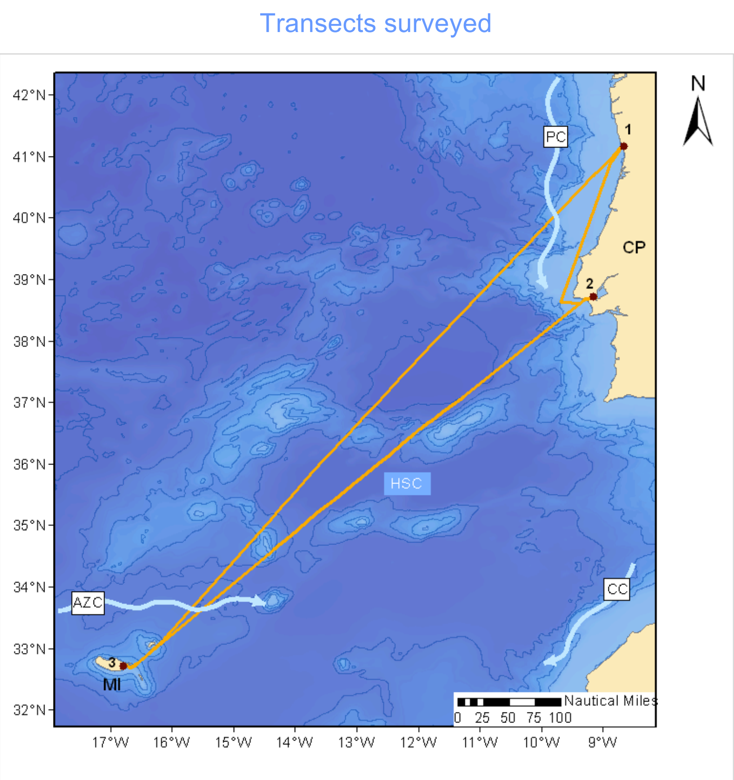


Figure 4. Transects surveyed with the main oceanographic and topographic structures crossed. Labels: CP – Continental Portugal; MI – Madeira Island; CC – Canary Current; AZC – Azores Current; PC – Portugal Current; HSC – Horseshoe Seamounts Chain. The cargo ships routes that will be sampled are indicated by the orange lines (draft configuration). The main ports of call are represented in red (1 – Oporto; 2 – Lisbon; 3 – Caniçal). Structures data from Mason (2009).

For maps creation and analysis purposes, the study area was defined as a box with the following boundaries: 18ºW 32ºN 8ºW 42ºN.

2.2 COLLECTION OF SIGHTINGS DATA

Two tween cargo ships from Transinsular Company ("n/m Monte da Guia" and "n/m Monte Brasil") were used as OPOs.

Ships were 127m long and 20m wide and the cruise speed varied from 14 knots to 16 knots. Observers were placed at 19.4m height in the navigation bridge and wings of the bridge. Since platform of observation height affects the detectability of cetaceans, survey conditions were accessed in relation to the height of the platform used (Stocking *et al.*, 2008). Sampling effort stopped with sea state above 5 (Douglas scale) or whenever the visibility was lower than 500m with poor sea-state conditions (above 3 in Douglas scale) and when the monitoring team could not stay in the navigation bridge.

The sampling protocol adopted was the one usually followed during line-transect sampling (Moulins *et al.*, 2007) and was performed by two trained observers: each observer stood on one side of the vessel checking cetaceans' presence in an area of 90° around him with and without binoculars (Paralux Nemo deep Sea 7x50mm). Observers switched sides every 60 minutes to avoid fatigue and to reduce the observer detection capacity bias. Once detected, species name, distance and angle from the boat were recorded as well as some distinct surface behaviours or other relevant information (group size, direction of the animal/group, swimming speed). For dolphin species, a minimum, maximum and best estimate was registered for group size when the exact number of animals could not be accessed. The best estimate was then used in the descriptive analysis. Groups were defined as individuals having the same activity, being in close proximity and coming and going in the same direction. A GPS (Garmin GPSmap 60C) recorded the whole effort transect and was used to check the coordinates of the sightings. Weather conditions (sea state on Douglas scale, wind force on Beaufort scale, wind direction, visibility, sky cover and rainfall) were recorded at the beginning and the at end of the surveys or whenever they changed. Vessel traffic was accessed every hour and whenever a sighting was recorded.

The crews of the ships provided some sightings they recorded during the sampling season (crew records from July to September, 2012) on non-sampled trips or sections of the trips. They registered date and time, coordinates, animals (group) sighted, approximate number of the group and main characteristics of the animals.

Data collected in data sheets was logged into an Excel database and prepared for subsequent analysis after each survey.

2.3 Collection and Computing of the Habitat Variables

Bathymetric data was obtained from the "General Bathymetric Chart of the Oceans" (GEBCO) one arc-minute (for general maps) and 30 arc-second (for data analysis) Digital Atlas (GEBCO, 2012) and converted to ESRI compatible format (ASCII) with the "Grid display software", downloaded from the British Oceanographic Data Centre website (BODC, 2013). ArcGIS 10 (ESRI, 2011) was then used to generate the static variables used in the analysis. Slope was computed from bathymetry with Surface Analysis tools. The topographic structures, namely the seamounts to compute the distance to seamounts variable, were obtained from GEBCO and from EarthRef (2013). A polygon shapefile was created to define the seamounts as the polygons limited by their base (whenever contour lines, created every 50m, started to be denser) and surrounding all the structure. Therefore, the distance to seamounts is the distance from the base of the seamount to the point sampled. For the Environmental Envelope (described on Data Analysis section), distance to coast was computed for each sighting point with the Spatial Join tool. However, for the habitat modelling (described on Data Analysis section), a distance raster was created for distance variables (distance to coast and distance to seamounts) with Spatial Analyst tools, with the same resolution (cell size) of the bathymetric raster.

Three dynamic variables were collected with remotely sensed data: chlorophyll-*a* (as a proxy to primary production), sea-surface temperature and absolute dynamic topography. Chlorophyll-*a* and sea-surface temperature (measured at night) were obtained from the "Moderate Resolution Imaging Spectrometer" (MODIS) instrument on the Aqua satellite from the "National Aeronautics and Space Administration" agency (NASA). Data was visualized and downloaded from Giovanni platform (NASA (a), 2013) and Ocean Color Data - MODIS Aqua archives (NASA (b), 2013), from global datasets, with 4km resolution.

Finally, Maps of Absolute Dynamic Topography were collected from global products of the "Archiving, Validation and Interpretation of Satellite Oceanographic data" agency (AVISO) (from satellites Jason-Envisat and Topex/Poseidon-ERS) (AVISO, 2013), with 25km of resolution. All remotely sensed data was analysed in MatLab R2012a (MATLAB version 7.14.0, 2012) and converted to ESRI compatible format (ASCII) for ArcGIS analysis.

All raster data was sampled with the pack Marine Geospatial Ecology Tools (MGET) (Roberts *et al,* 2010) for ArcGIS (Spatial and Temporal Analysis tools).

In Table 3 are the variables used for analysis and their characteristics.

Table 3. Habitat variables used in data analysis.

Variables	Name used	Source	Unit	Type	Spatial Resolution	Temporal Resolution
Depth	Depth	GEBCO	m	Static	30 arc-second	-
Slope	Slope	GEBCO	% and º	Static	30 arc-second	-
Distance to coast	Dist.coast	-	Nautical miles (nm)	Static	30 arc-second	-
Distance to seamounts	Dist.sm	GEBCO	Nautical miles (nm)	Static	30 arc-second	-
Latitude	Lat	GPS	Decimal and UTM Northing (m)	Static	-	-
Chlorophyll - a	CHL	MODIS	mg/m**3	Dynamic	4km	Monthly
Sea surface temperature	SST	MODIS	ºC	Dynamic	4km	Monthly
Maps of absolute dynamic topography	MADT	AVISO	cm	Dynamic	25km	Monthly

All the data, rasters and shapefiles, were referenced with the coordinate system GCS_WGS_1984 (EPSG: 4326) and projected with World_Mercator (EPSG:3395).

2.4 DATA ANALYSIS

Descriptive analysis

A deeper analysis of the study area dynamics and characterization of the sampling year (2012) was performed. Monthly averages for the study area (area-averaged values) were plotted to create a 10-year time-series (2003-2012) for CHL and SST to check their seasonality. 10-year climatology (2003-2002) was analysed for these variables, both the time-series and the spatial maps of the climatological year. Climatological year was used as a reference to compare with the sampling year and the presence of anomalies in the latest was verified. For the MADT data, monthly averaged maps for the sampling months were computed. For all maps, the presence of mesoscale processes was investigated.
Data from the sea-surveys was analysed. Crew sightings as well as sightings recorded off-effort by the monitoring team were considered opportunistic sightings. These were only used for descriptive purposes and presence-only analysis.
Total number of sightings (on-effort and opportunistic sightings) was used to determine the range of the group sizes of the species and create the sightings distribution map with

ArcGIS. For encounter rates (ER), only on-effort sightings were considered in relation to the distance sampled on-effort. Total ER was defined as follows:

ER = (n/D) x 100,

where n is the total number of sightings on-effort and D the distance sampled on-effort in nautical miles. ER was computed for all species, for groups (defined as dolphins, baleen and toothed whales) and for all species pulled together (overall ER).

Environmental Envelope

To define the habitat range, the species were grouped as follows: dolphins, baleen whales, beaked whales and sperm whales. Toothed whales were divided in beaked and sperm whales to better understand the habitat segregation between them. For this analysis, *Globicephala macrorhynchus* (2 sightings) and non-identified Cetacea (6 sightings) were left out. Presence-only data of the total sightings (on-effort and opportunistic) was used. The following variables were sampled for the sightings points: depth, slope, SST, MADT, Lat and Dist.coast (see Table 3 for details on variables). Habitat range was accessed through quantiles analysis (Austin, 2007; Elith&Leathwick, 2009; Kiszka *et al.*, 2007; Pearce&Boyce, 2006) and boxplot graphs were created with ArcGIS. Kruskall-Wallis was performed to determine the difference between the habitat ranges for the four groups, while Mann-Whitney-Wilcoxon tests were used for pairwise comparisons. Differences were assumed to be statistically significant whenever $p\text{-value}<0.05$, considering a level of significance of 0.05. Statistical tests were computed in R 2.15.0 Software (R Development Core Team, 2012).

Habitat modelling

Considering the sampling data, a used/available habitat was chosen (Brotons *et al.*, 2004; Elith&Leathwick, 2009; MacLeod *et al.*, 2008; Pearce&Boyce, 2006). To define the available habitat, sampled sections of transects were selected based on weather conditions to consider only a reliable sampled habitat. For these purpose, bar graphs were created with weather records for sea state (Douglas scale), wind force (Beaufort scale) and visibility to analyse the distribution of the registers and cut the worst weather conditions. With the sampled habitat selected, a set of points equally distanced (2.5nm) was created along the line with the pack MGET for ArcGIS (Spatial and Temporal Analysis tools), and these points were considered to represent the available habitat. For used habitat, only on-effort records were used, and models were developed for the following groups: baleen and beaked whales.

Dolphins were proven to have a very wide range (see Environmental Envelope results) since all the dolphin species, with different habitats (e.g. coastal and oceanic species), were grouped. Therefore, the most sighted dolphin species (bottlenose and common dolphins) were selected to develop species-specific models. Sperm whales had very few sightings and were excluded from the habitat modelling process. The 8 variables (see Table 3) were considered for the modelling. For CHL, the monthly average of March, 2012 was used since it was shown to be the bloom month by the oceanographic analysis (see Descriptive Analysis results). SST and MADT monthly averages were sampled considering the month of the used/available points.

GAM model techniques were chosen (Brotons *et al.*, 2004; MacLeod *et al.*, 2008; Pearce&Boyce, 2006; Torres et al., 2008; Viddi *et al.*, 2010) and performed with R (mgcv package). A quasibinomial distribution (used/available) and logit link function were used. The model fitting process followed the one used in Viddi *et al.* (2010). All variables were considered for the first fitting, followed by a backward selection to obtain the best-fitting models based on the generalized cross-validation (GCV) scores. The process consisted in taking the variable with the least significant p-value from the saturated first fitted model. If this leaded to a model with lower GCV, this last model was retained. Otherwise, the variable was maintained and the next less significant variable was taken. The process was repeated until the best GCV score was obtained. Scale parameter was set to -1, gamma to 1.4 and knots to a maximum of 5 to prevent overdispersed data and an overfitted model.

For baleen and beaked whales, a weight parameter was included in models, corresponding to the number of animals sighted. Since number for dolphin species was not always certain and estimations could lead to erroneous conclusions, no weight was used in species-specific models, and the all group was considered as one point of used habitat.

From GAM plots, zero line was used to define the positive or negative effect of the predictors with statistical significance in the model ($p\text{-value}<0.05$). Threshold cutoffs were applied in ArcGIS on the explanatory variables rasters to define habitat (positive effect on GAM plot) in a process called *GAMvelope* by Torres *et al.*, 2010. Areas were divided in “Unsuitable”, “Suitable” and “Highly suitable” habitat according to the number of the variables favourable to the animal presence. Monthly maps of habitat suitability were computed to assess the influence of the dynamic variables of the four months (SST and MADT).

3 Results

3.1 Descriptive Analysis

Study area oceanography

Chlorophyll-*a*

10-year time-series (2003-2012) for CHL (Figure 5) showed a clear seasonal pattern, usually reaching the peak in March, signal of a spring phytoplankton bloom. After this month the mean value of CHL decreases significantly. The year of 2009 had an abnormal peak of CHL.

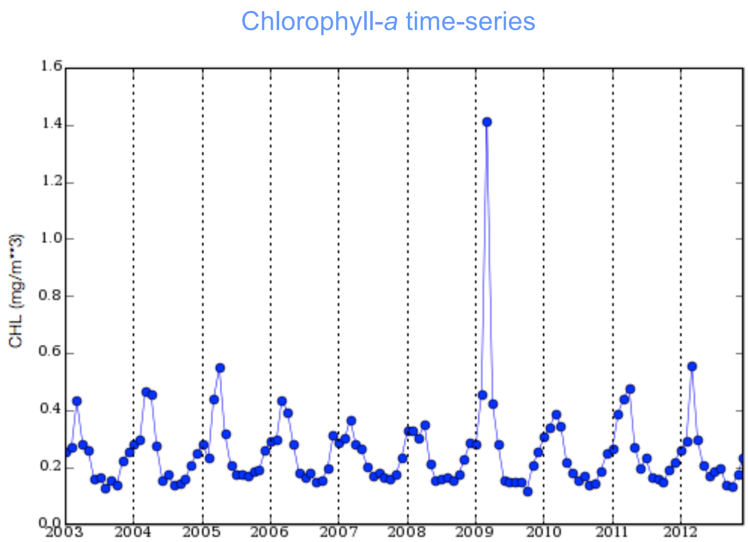


Figure 5. 10-year time-series of chlorophyll-*a* of the study area (area-averaged values) with monthly averages from 2003 to 2012.

Analysing the climatological year time-series and the monthly averages for the year of 2012 (Figure 6), it was possible to verify that 2012 area-averaged values are representative of the study area since the curve follows the pattern of the climatological year curve, with minor variations.

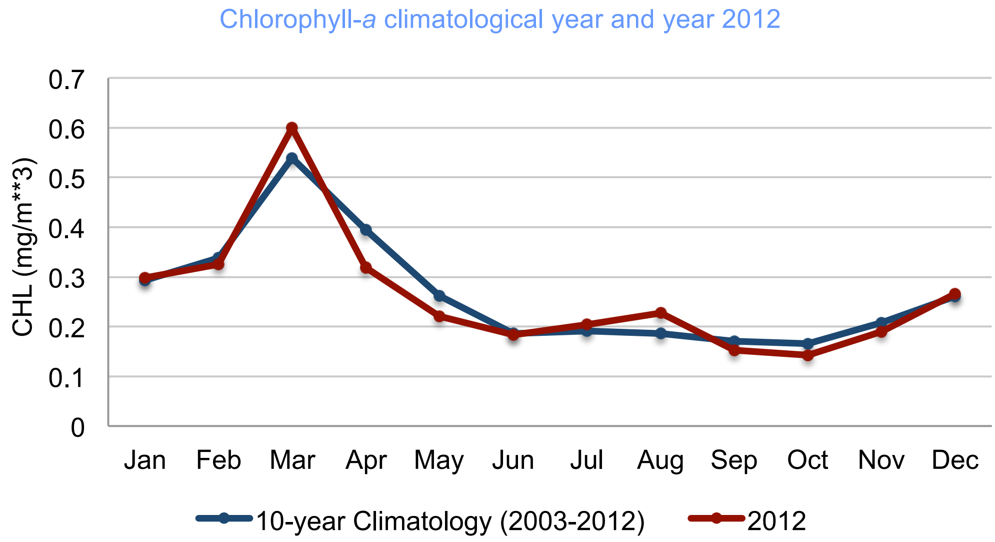


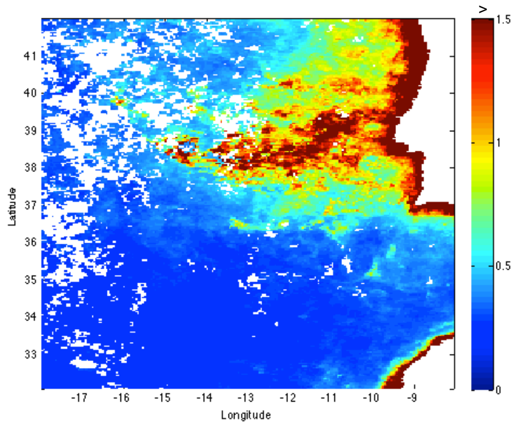
Figure 6. 10-year climatological year (2003-2012) and 2012 time-series (area-averaged values) with monthly averages of chlorophyll-*a*.

Spatially it was possible to detect the phytoplankton bloom in the climatological March map (Figure 7(a)). The core of the bloom is between 37.5ºN and 39.5ºN, with higher values in the Continental Portuguese coast and extending towards open-ocean (roughly until 15ºW). There is a year-round section of high concentrations of chlorophyll-*a* in the Continental Portuguese coast, result of the river drainage and upwelling.

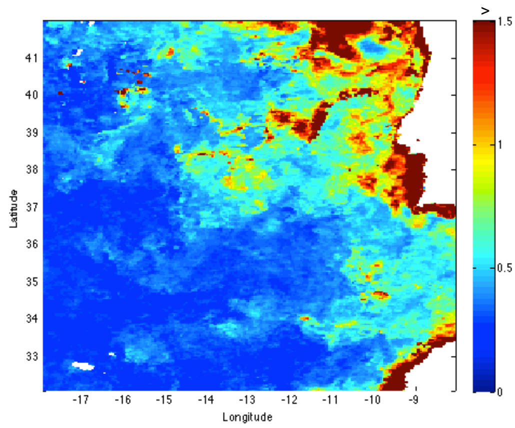
It was possible to observe that the year of 2012 had lower concentration of CHL in the core of the phytoplankton (Figure 7(b)). In fact, negative anomalies were evident along the core of the bloom and also in the north costal region (Figure 7(c)). However, positive anomalies were present in south coastal region and in the open-ocean.

Chlorophyll-*a* maps

a) Climatological March



b) March of 2012



c) March of 2012 anomalies

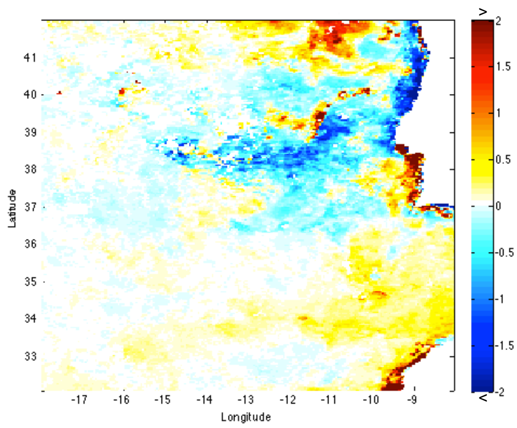


Figure 7. Chlorophyll-*a* (mg/m**3) in March in the study area. a) Climatological March; b) March of 2012; c) March of 2012 anomalies. Anomalies were computed as the difference between March of 2012 and climatological March.

Sea-surface temperature

10-year time-series (2003-2012) of SST (Figure 8) allowed the identification of different periods during the year according to this variable. It is possible to say the "winter" is between January and April with lower SST that starts to increase between May and June ("spring"). The peak of temperatures is between July and October ("summer"). The decreasing of temperatures happens in November and December ("fall").

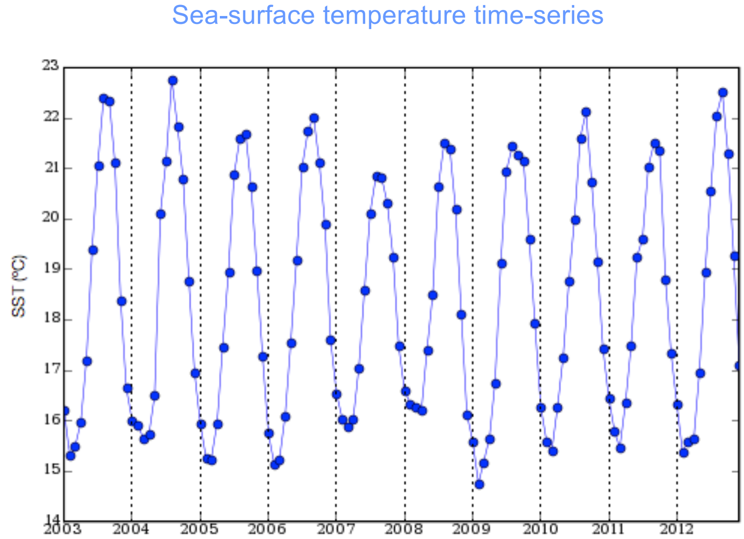


Figure 8. 10-year time-series of sea-surface temperature of the study area (area-averaged values) with monthly averages from 2003 to 2012.

As in CHL, the area-averaged values of SST of 2012 seem to be representative of the study area, since the 2012 curve of monthly averaged values follows the one from the climatological year (Figure 9).

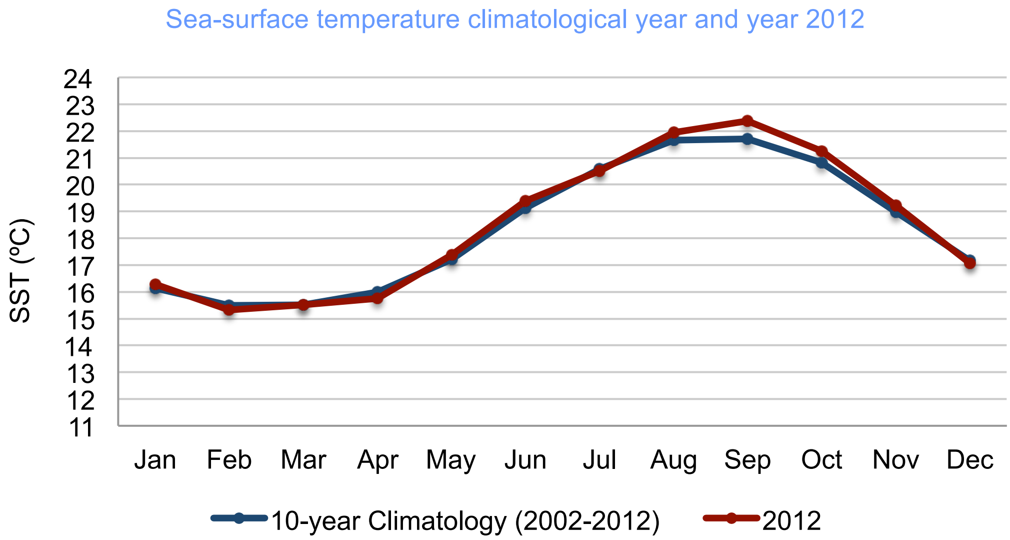


Figure 9. 10-year climatological year (2003-2012) and 2012 time-series (area-averaged values) with monthly averages of sea-surface temperature.

Spatially, maps of the climatological months showed a clear gradient of higher to lower temperatures from Madeira Island to Continental Portugal, where a year-round and all along the coast upwelling filament is observed (Figure 10(a)).

The SST peak months were warmer in 2012 compared to the climatological ones, especially during the month of September that was the month with higher temperatures in 2012 (Figure

10(b)). In fact, positive anomalies were present in the entire study area, and a stronger one in the southwest coast of Continental Portugal is visible in the map (Figure 10(c)).

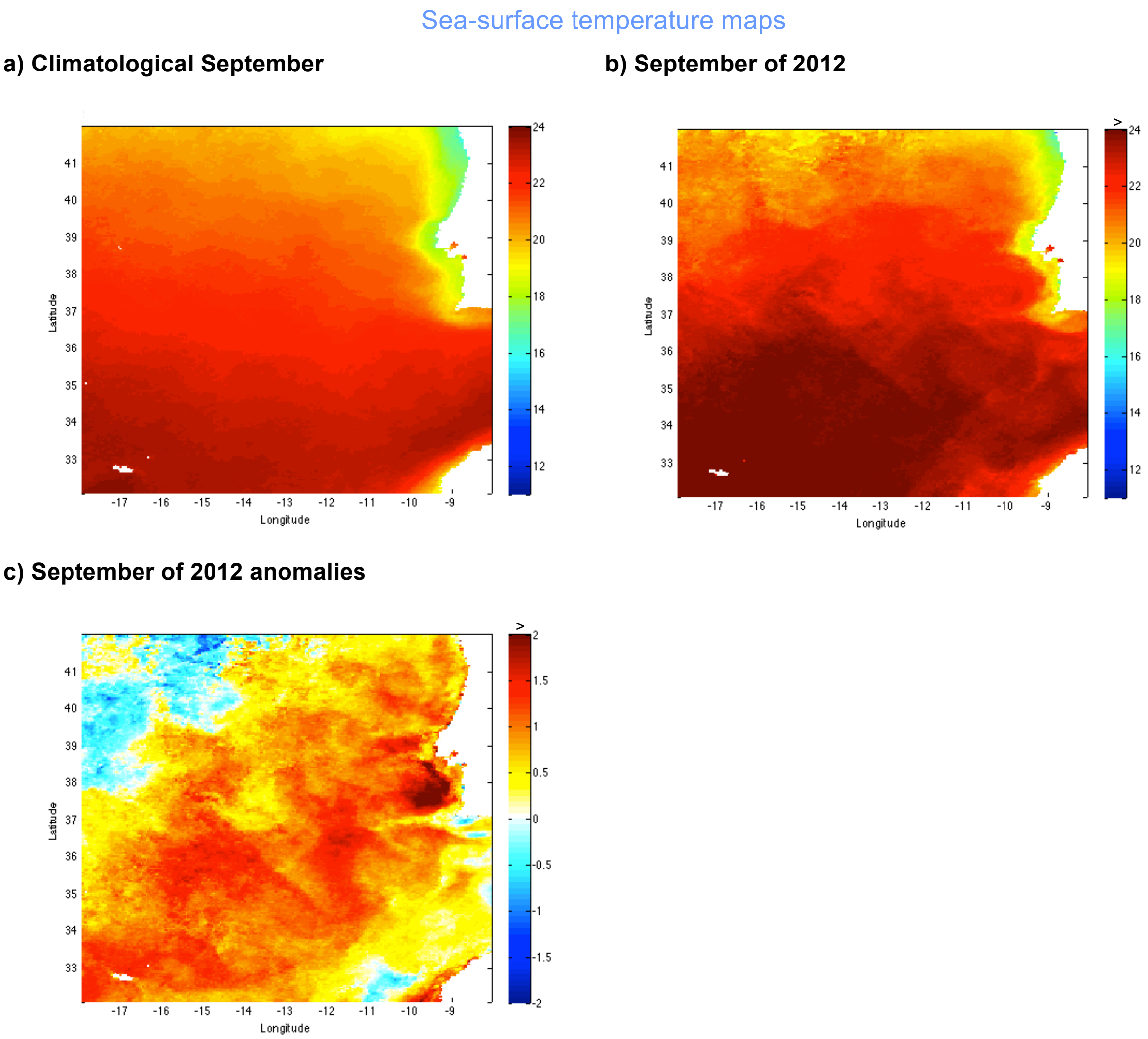


Figure 10. Sea-surface temperature (ºC) in September in the study area. a) Climatological September; b) September of 2012; c) September of 2012 anomalies. Anomalies were computed as the difference between September of 2012 and climatological September.

Absolute dynamic topography

The MADT seemed to increase from July to October in the study area (Figure 11). During these months, a pattern of higher values is seen roughly between 34ºN to 36ºN and 16ºW to 14ºW. It is possible to see its variation in size and position and that the higher values (approximately between 25cm and 35cm) are surrounded with lower values (approximately between 5cm and 15cm).

Absolute Dynamic Topography Maps

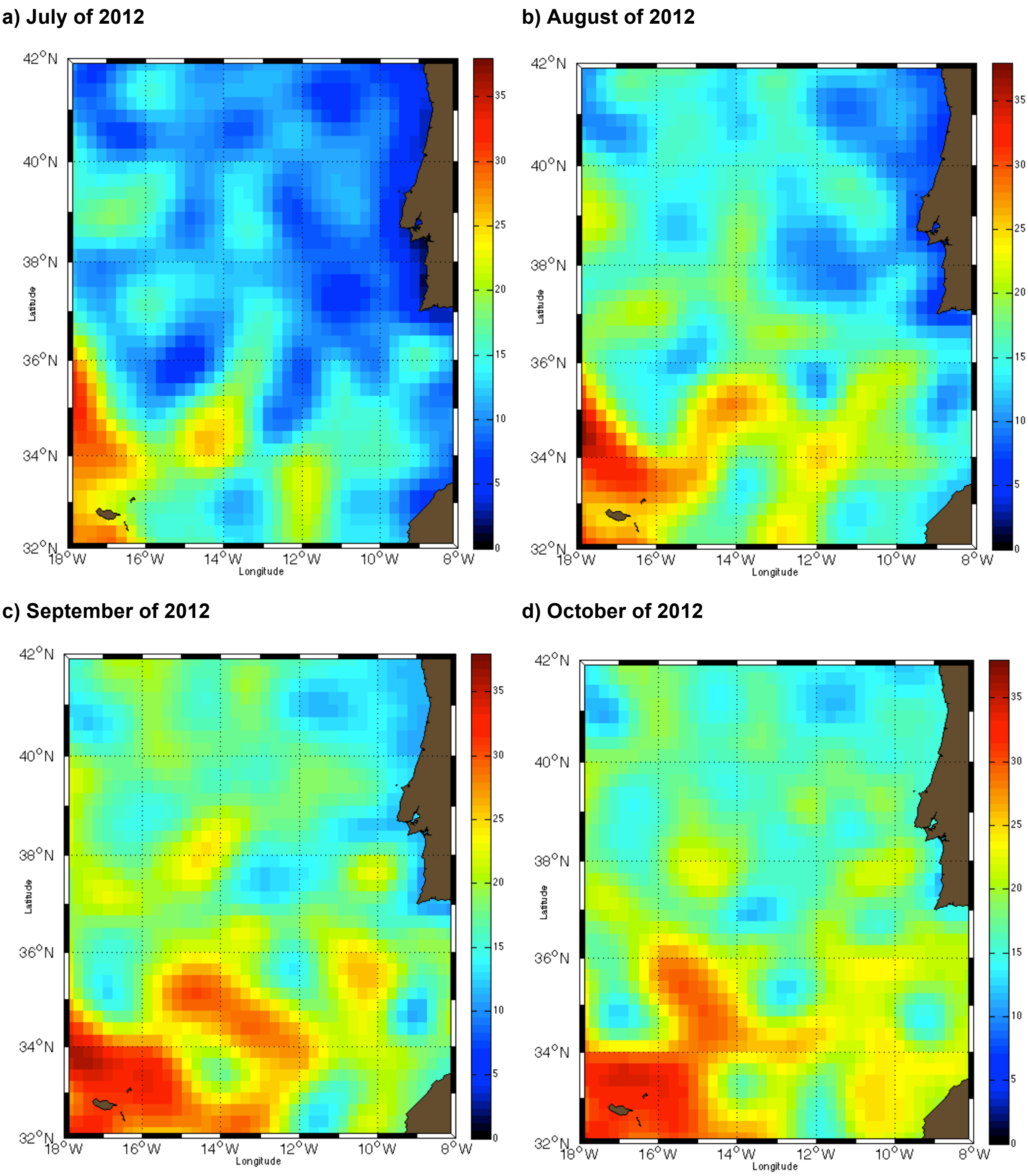


Figure 11. Monthly averages of absolute dynamic topography (cm). a) July of 2012; b) August of 2012; c) September of 2012; d) October of 2012.

Sea-survey

Effort

Three different transects were covered in this study. The surveys and the distance sampled are presented in Table 4.

Table 4. Transects surveyed and the distance sampled.

Transects	Number of surveys	Total distance (nm)	Total distance on effort (nm)	Mean distance (nm)	Mean distance on effort (nm)
Oporto – Lisbon	1	245.61	42.98	-	-
Lisbon – Caniçal (and vice-versa)	11	7039.93	2900.35	639.99	263.66
Caniçal – Oporto	7	5651.70	2793.83	807.39	399.12
TOTAL	19	12937.24	5737.17		

A map of the transects and total effort is presented in Figure 12 showing that, with the exception of Oporto-Lisbon, surveyed only once and with a short distance covered on-effort (as shown in Table 3), the transects were almost fully covered on-effort at least once.

Sightings

The Table 5 shows the general information of the dataset. A total of 131 sightings were recorded, considering on-effort and opportunistic sightings. 7 species were identified: *Tursiops truncatus, Delphinus delphis, Balaenoptera acutorostrata, Ziphius cavirostris, Physeter catodon, Stenella frontalis* and *Globicephala macrorhynchus*. Considering total number of sightings, dolphins species were the most sighted with 63% of the sightings, followed by toothed and baleen whales with 16% of the sightings. 106 sightings were registered on-effort with an overall encounter rate of 1.85 on 5737 nm on-effort. Weighting sightings with the ER, dolphins are the most encountered group (ER=1.10), followed by toothed (ER=0.35) and baleen whales (ER=0.31).

Table 5. Description of the dataset of total sightings.

Species	Sightings on-effort	Opportunistic sightings	Total sightings	Percentage[a]	Group size Mean (±σ, range)[a]	Total ER[b] (sightings/100nm)
Tursiops truncatus	21	3	24	18.32	9.38 (±7.36, 2-35)	0.37
Delphinus delphis	15	2	17	12.98	12.41 (±9.91, 1-40)	0.26
Balaenoptera acutorostrata	15	2	17	12.98	1.94 (±1.25, 1-5)	0.26
Ziphius cavirostris	9	0	9	6.87	2.67 (±1.66, 1-5)	0.16
Physeter catodon	7	1	8	6.11	1.38 (±0.74, 1-3)	0.12
Stenella frontalis	5	0	5	3.82	11 (±4.95, 3-15)	0.09
Globicephala macrorhynchus	2	0	2	1.53	- (1,5)	0.03
Delphinidae sp.	22	15	37	28.24	11.19 (±14.42, 1-70)	0.38
Balaenoptera sp.	3	1	4	3.05	1.25 (±0.5, 1-2)	0.05
Ziphidae sp.	2	0	2	1.53	- (1,5)	0.03
Non-identified	5	1	6	4.58	1.5 (±0.55, 1-2)	0.09
TOTAL	106	25	131	100	7.63 (±10.00, 1-70)	1.85

[a] Considered total number of sightings (on-effort and opportunistic).

[b] Considered only sightings recorded on-effort.

The following map (Figure 12) shows the distribution of the total sightings. There is a higher concentration of sightings at a middle distance between departure and arrival ports (roughly around seamounts region) where effort was also higher.

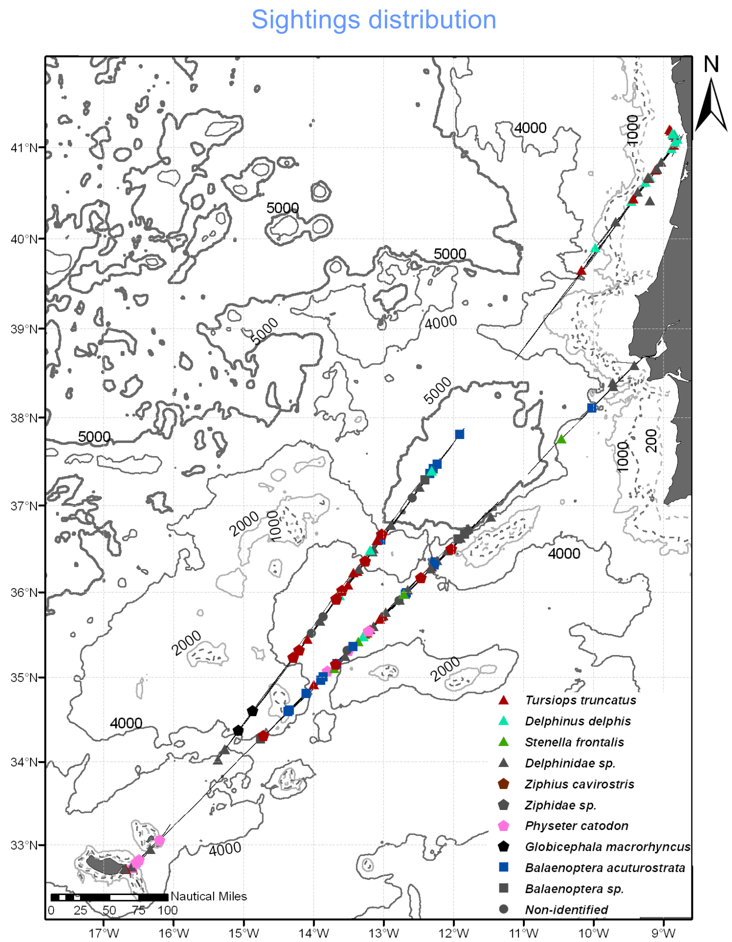


Figure 12. Distribution map of the total sightings recorded (on-effort and opportunistic). Effort transects are represent by black lines.

3.2 Environmental Envelope

Figure 13 represents the distribution considering the groups used for the Environmental Envelope. It is possible to observe that dolphins were encountered all along the effort tracks but were the only group found in the north of Continental Portugal. Baleen and beaked whales were more frequent in the middle of the transects, and sperm whales were especially frequent near Madeira shore.

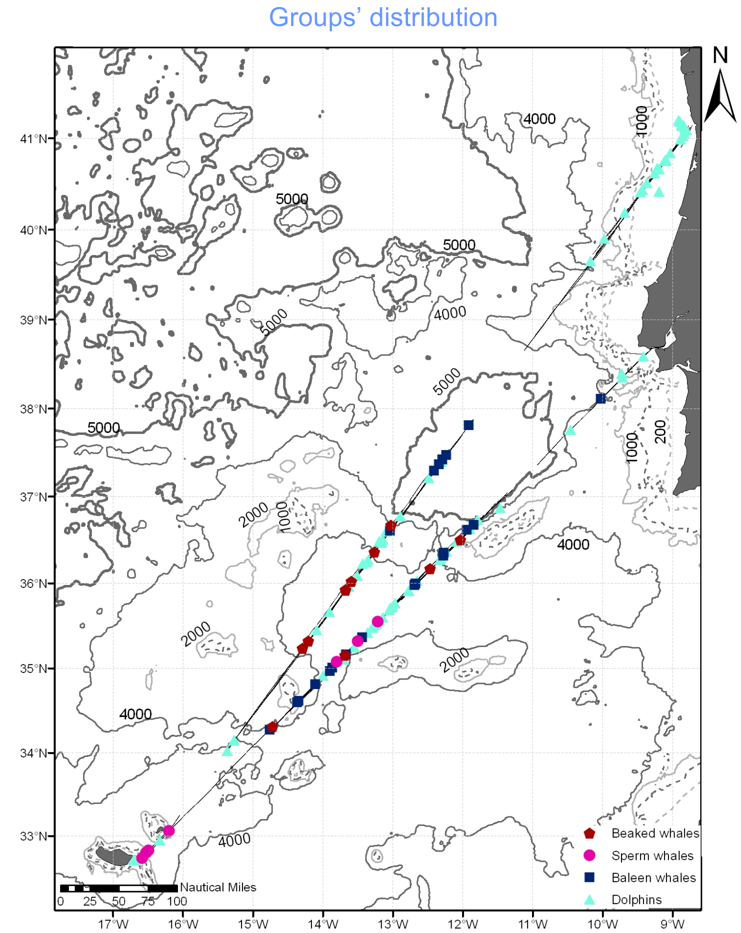


Figure 13. Distribution map of the total sightings recorded (on-effort and opportunistic) representing the groups' segregation. Effort transects are represented by black lines.

Quantiles analysis results for habitat range assessment are presented in Table 6.

Table 6. Habitat range considering the variables selected for the Environmental Envelope. In each group, n represents the total number of sightings for that group.

Groups	Lat (Decimal)	Dist.coast (nm)	Depth (m)	Slope (%)	SST	MADT
Dolphins (n=83)	Min = 32.71 1st quartile = 35.70 Median = 36.51 3rd quartile = 40.64 Max = 41.19	Min = 2.37 1st quartile = 21.74 Median = 169.01 3rd quartile = 245.47 Max = 273.17	Min = 34 1st quartile = 112.5 Median = 3651 3rd quartile = 4814.5 Max =5122	Min = 0.05 1st quartile = 0.23 Median = 0.75 3rd quartile =3.72 Max =21.87	Min = 18.01 1st quartile = 19.16 Median = 21.93 3rd quartile =23.20 Max =24.10	Min = 7.34 1st quartile =11.46 Median = 17.14 3rd quartile = 20.29 Max = 31.18
Baleen whales (n=21)	Min = 34.27 1st quartile = 35.01 Median = 36.31 3rd quartile =37.29 Max = 38.11	Min = 52.73 1st quartile = 172.91 Median = 196.59 3rd quartile = 205.49 Max = 244.72	Min = 2125 1st quartile = 3744 Median = 4179 3rd quartile = 4862 Max = 5118	Min = 0.04 1st quartile = 0.57 Median = 2.25 3rd quartile = 7.66 Max = 23.49	Min = 20.17 1st quartile = 22.21 Median = 22.67 3rd quartile = 23.31 Max = 23.92	Min = 9.11 1st quartile = 12.92 Median = 20.30 3rd quartile = 24.68 Max = 28.37
Beaked whales (n=11)	Min = 34.31 1st quartile = 35.28 Median = 35.92 3rd quartile = 36.26 Max = 36.67	Min = 128.10 1st quartile = 199.30 Median = 217.67 3rd quartile = 257.68 Max = 266.74	Min = 3036 1st quartile = 4011.5 Median = 4296 3rd quartile = 4685.5 Max = 4847	Min = 0.05 1st quartile = 0.79 Median = 1.19 3rd quartile = 3.32 Max = 9.12	Min = 20.70 1st quartile = 21.64 Median = 21.98 3rd quartile =22.96 Max = 24.11	Min = 9.53 1st quartile = 18.07 Median = 21.05 3rd quartile = 23.67 Max = 26.75
Sperm whales (n=8)	Min = 32.73 1st quartile = 32.80 Median = 32.94 3rd quartile = 35.14 Max = 35.54	Min = 4.38 1st quartile = 8.09 Median = 10.63 3rd quartile = 212.70 Max = 255.69	Min = 171 1st quartile = 2060.5 Median = 2313 3rd quartile = 4407 Max = 4864	Min = 0.05 1st quartile = 2.14 Median = 8.90 3rd quartile = 15.15 Max = 20.53	Min = 21.05 1st quartile = 21.57 Median = 22.86 3rd quartile = 24.42 Max = 24.51	Min = 17.53 1st quartile = 18.78 Median = 19.91 3rd quartile = 31.23 Max = 31.23

Figure 14 is a representation of the distribution of the groups along the Lat. Dolphins have the highest (northern) median (36.5) followed by baleen (36.31) and beaked (35.92) whales and finally sperm whales that have the southern habitat range with a median latitude of 32.94 (Table 6). Statistical differences were found among groups, being the baleen and beaked whales the only groups that did not differ with statistical significance between them (Table 7).

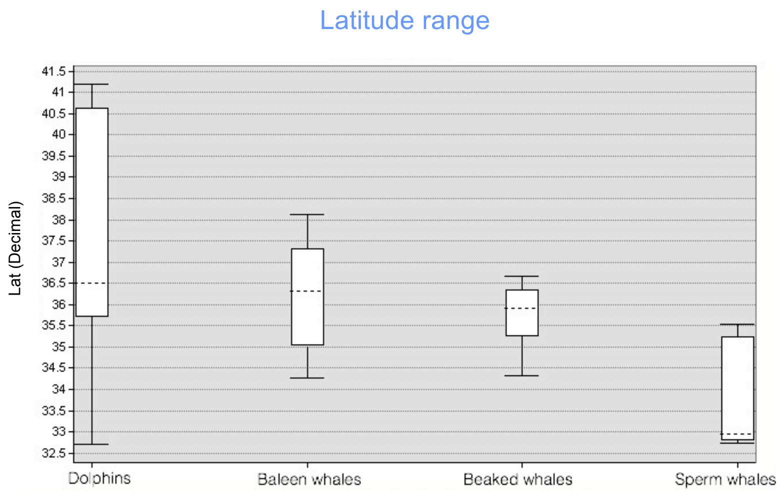


Figure 14. Habitat range regarding latitude for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum, and the dashed line is the median (50% quartile). The box includes 50% of the occurrences.

Sperm whales were seen closer to the coast (median = 10.63nm) followed by dolphins (median = 169.01nm) and baleen whales (median = 196.59nm) (Table 6). These three groups were significantly different from beaked whales (Table 7). This group had the sightings more distant from the coast (median = 217.67nm) than all the others (Table 6). The partitioning between groups according to Dist.coast can be seen in Figure 15.

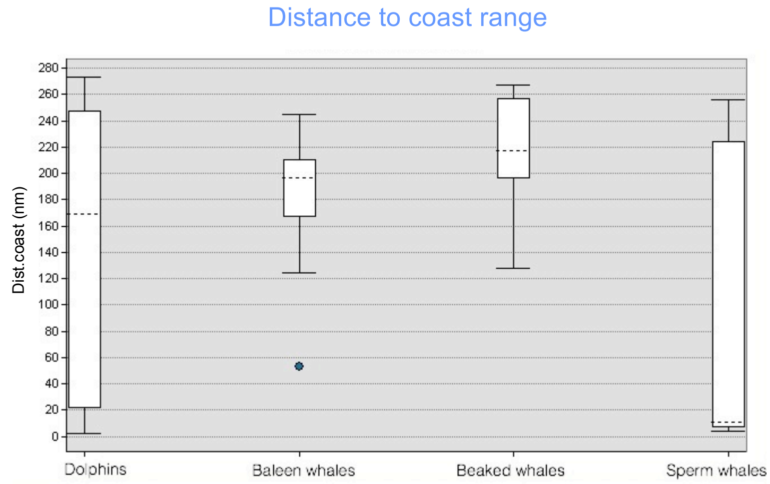


Figure 15. Habitat range regarding distance to coast for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum, and the dashed line is the median (50% quartile). The box includes 50% of the occurrences.

Considering depth, baleen and beaked whales were sighted in deeper waters, having higher medians (4179m and 4296m, respectively) compared to the other two groups (Table 6). Figure 16 represents the habitat ranges of the four groups, considering the depth. Pairwise comparisons enhanced the difference between dolphins and baleen whales (Table 7).

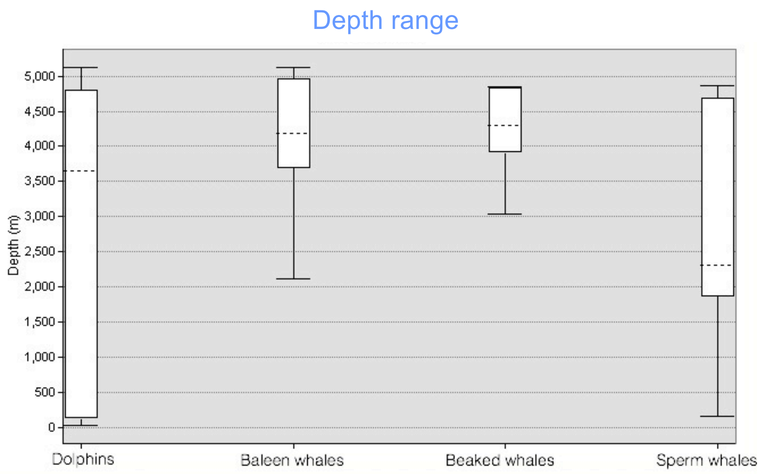


Figure 16. Habitat range regarding depth for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum, and the dashed line is the median (50% quartile). The box includes 50% of the occurrences.

Slope was the only variable with no statistically significant differences among groups, and therefore no pairwise comparisons were computed (Table 7). Figure 17 represents habitat range considering slope for the four groups.

Figure 17. Habitat range regarding slope for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum, and the dashed line is the median (50% quartile). The box includes 50% of the occurrences.

Regarding SST, dolphins had the lowest median (21.93ºC) contrasting with sperm whales, whose median was the highest of the groups (22.86ºC) (Table 6). Figure 18 shows the distribution of the groups along a temperature gradient. Although statistically significant differences among groups were found, only dolphins differ with statistical significance from baleen and sperm whales (Table 7).

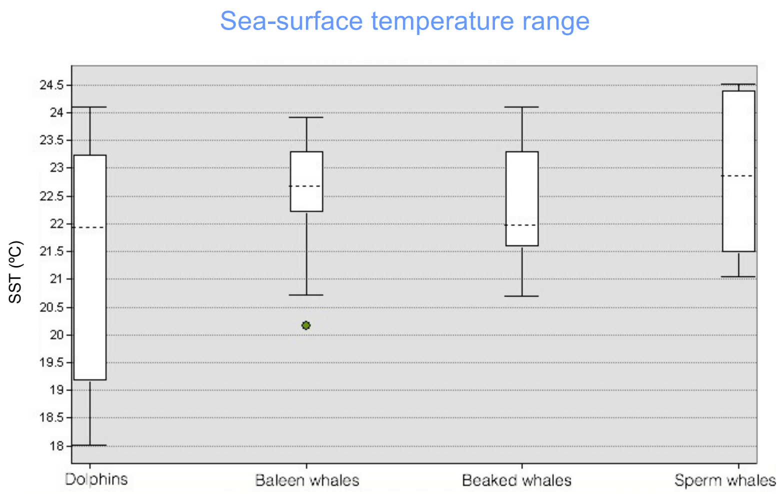


Figure 18. Habitat range regarding sea-surface temperature for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum, and the dashed line is the median (50% quartile). The box includes 50% of the occurrences.

Considering MADT, beaked whales have the highest median (21.05cm), followed close by baleen (20.30cm) and sperm (19.91cm) whales (Table 6). Dolphins presented the lowest median (17.14cm). This pattern is well demonstrated by Figure 19. Regarding the statistical test, only dolphins were different from all the other groups with statistical significance (Table 7).

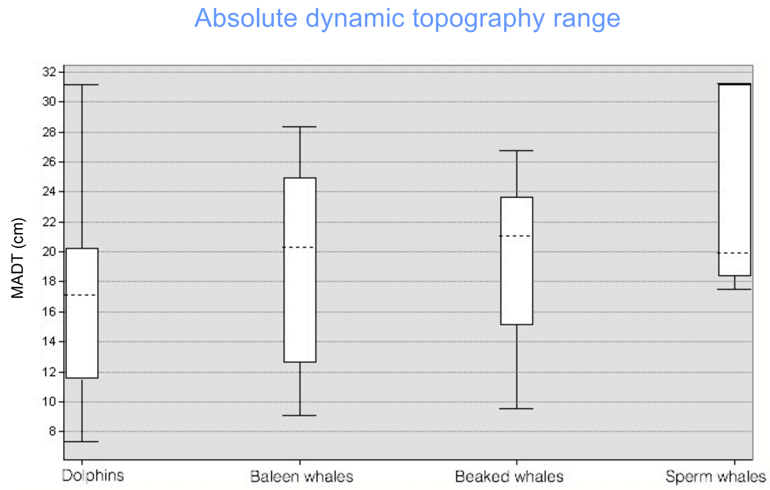


Figure 19. Habitat range regarding absolute dynamic topography for the 4 groups. Whiskers represent the lower and upper 25% of the occurrences delimited by minimum and maximum and the dashed line is the median (50% quartil). The box includes 50% of the occurrences.

Table 7 presents the results of all the statistical tests performed for the Environmental Envelope analysis.

Table 7. Statistical results of the Environmental Envelope. Kruskal-Wallis tests were used to test the differences among groups, while Mann-Whitney-Wilcoxon tests were computed for pairwise comparisons. In bold are the p-values<0.05, indicating statistically significant differences.

Comparison among groups: Kruskal-Wallis test	
Lat	K=22.626, **p<0.001**
Dist.coast	K=8.998, **p=0.029**
Depth	K=9.1573, **p=0.027**
Slope	K=6.8043, p=0.078
SST	K=10.1229, **p=0.018**
MADT	K=12.7228, **p=0.005**

Pairwise comparisons – Mann-Whitney-Wilcoxon test

	Baleen whales	**Beaked whales**	**Sperm whales**
Dolphins	Lat: U=1127, **p=0.039** Dist.coast: U=746, p= 0.311 Depth: U=543.5, **p=0.008** SST: U=569, **p=0.0145** MADT: U=627.5, **p=0.049**	Lat: U=648, **p=0.025** Dist.coast: U=266, **p= 0.035** Depth: U=318, p=0.105 SST: U=343, p=0.184 MADT: U=263.5, **p=0.023**	Lat: U=614, **p<0.001** Dist.coast: U=447, p= 0.109 Depth: U=314, p=0.806 SST: U=180, **p=0.034** MADT: U=147, **p=0.010**
Baleen whales		Lat: U=135, p=0.457 Dist.coast: U=60, **p= 0.027** Depth: U=118, p=0.937 SST: U=137, p=0.405 MADT: U=106, p=0.721	Lat: U=147, **p=0.001** Dist.coast: U=114, p= 0.153 Depth: U=123, p=0.059 SST: U=74, p=0.643 MADT: U=56, p=0.179
Beaked whales			Lat: U=80, **p=0.002** Dist.coast: U=71, **p= 0.026** Depth: U=61, p=0.173 SST: U=35, p=0.482 MADT: U=40, p=0.772

3.3 HABITAT MODELLING

Available habitat

Figure 20 represents the distribution of frequencies of the weather conditions (129 records). For the sampled habitat, sections with sea state and wind force above 4 were cut as well as visibility below 1nm, resulting in a sampled habitat of 5034.05nm. Available habitat is represented by 2029 points, equally distanced (2.5nm), along the sampled habitat.

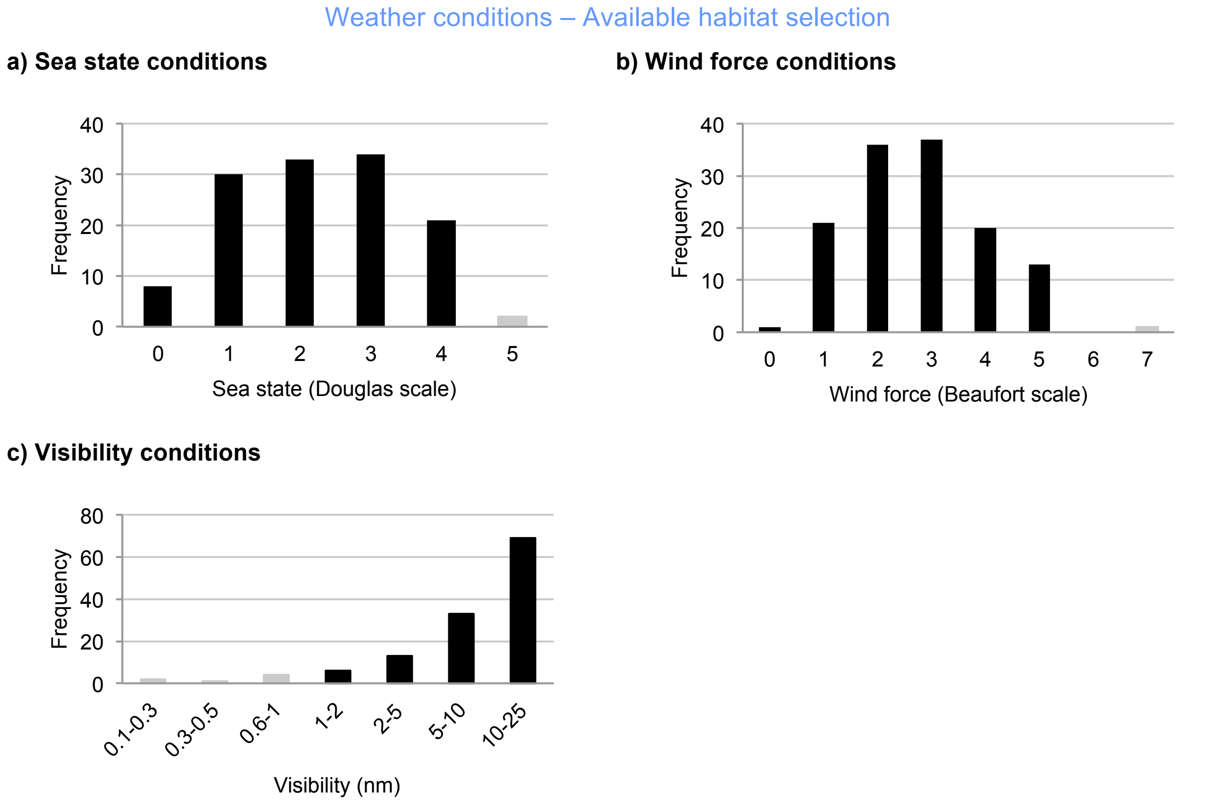


Figure 20. Frequency distribution of the weather conditions during effort sampling (n=129). In grey bars are the conditions of the transects that were cut for the sampled habitat.

Model results

Table 8 presents the best GAM models results. Model performed worst for baleen whales (GCV score of 0.111) and the deviance explained was lower in bottlenose dolphins (24.8%). Beaked whales had the higher deviance explained (44.8%), but common dolphins had the best GCV score (0.071).

Some variables with no statistically significant p-value or with no smoothed function fitted had to be kept in the models as their removal leaded to a model with a worse GCV score.

Table 8. Best GAM model results obtained. NA value in the p-value indicates that it was not possible to calculate p-value and the smoothed function was not fitted. e.d.f. – effective degrees of freedom; s.e. – standard error; n – total number of points (available/used) considered in the model fitting.

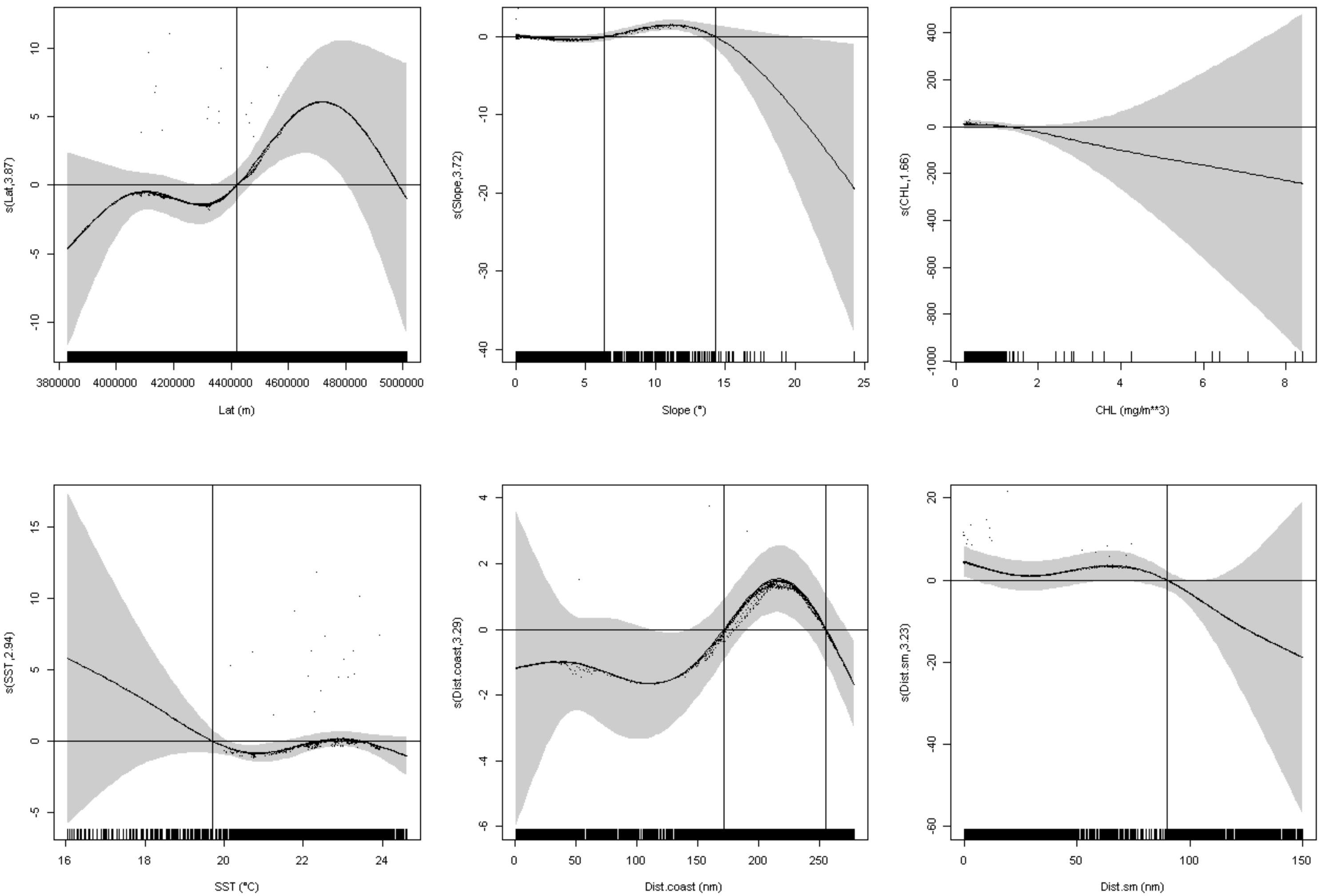
Taxon and parameter	Estimate	e.d.f.	s.e.	t-value	F-value	p-value	Deviance explained (%)	r^2	GCV score	n
BALEEN WHALES										
Intercept	-14.37		8.13	-1.77		0.08				
Smoother terms										
Lat		3.87			4.70	<0.001				
Slope		3.72			9.70	<0.001				
CHL		1.66			0.67	0.506				
SST		2.94			2.91	0.028				
Dist.coast		3.29			6.17	<0.001				
Dist.sm		3.23			10.39	<0.001				
Best final model: BL~s(Lat)+s(Slope)+s(CHL)+s(SST)+s(Dist.coast)+s(Dist.sm)							25.2	0.126	0.111	2047
BEAKED WHALES										
Intercept	-150.47		29.95	-5.02		<0.001				
Smoother terms										
Lat		3.30			49.23	<0.001				
Slope		3.97			19.33	<0.001				
SST		4.00			67.19	<0.001				
MADT		4.00			78.48	<0.001				
Dist.sm		3.30			13.03	<0.001				
Depth		3.79			26.06	<0.001				
Best final model:BK~s(Lat)+s(Slope)+s(SST)+s(MADT)+s(Dist.sm)+s(Depth)							44.8	0.428	0.088	2040

BOTTLENOSE DOLPHINS										
Intercept	-8.48		0.43	-19.49		<0.001				
Smoother terms										
Lat		4.00			15.22	<0.001				
Slope		0.00			0.02	NA				
CHL		2.93			2.29	0.069				
SST		4.00			18.80	<0.001				
MADT		3.91			16.08	<0.001				
Dist.coast		2.57			18.48	<0.001				
Dist.sm		3.82			9.06	<0.001				
Depth		2.48			10.39	<0.001				
Best final model:BD~s(Lat)+s(Slope)+s(CHL)+s(SST)+s(MADT)+s(Dist.coast)+s(Dist.sm)+s(Depth)							24.8	0.057	0.089	2050
COMMON DOLPHINS										
Intercept	-31.33		4.31	-7.28		<0.001				
Smoother terms										
Lat		3.96			9.51	<0.001				
CHL		3.92			31.32	<0.001				
MADT		3.93			7.25	<0.001				
Dist.coast		4.00			19.41	<0.001				
Dist.sm		3.91			26.54	<0.001				
Depth		3.92			11.81	<0.001				
Linear terms										
Slope	0.16			-3.66		<0.001				
Best final model:CD~s(Lat)+s(CHL)+s(MADT)+s(Dist.coast)+s(Dist.sm)+s(Depth)+Slope							44.3	0.32	0.071	2044

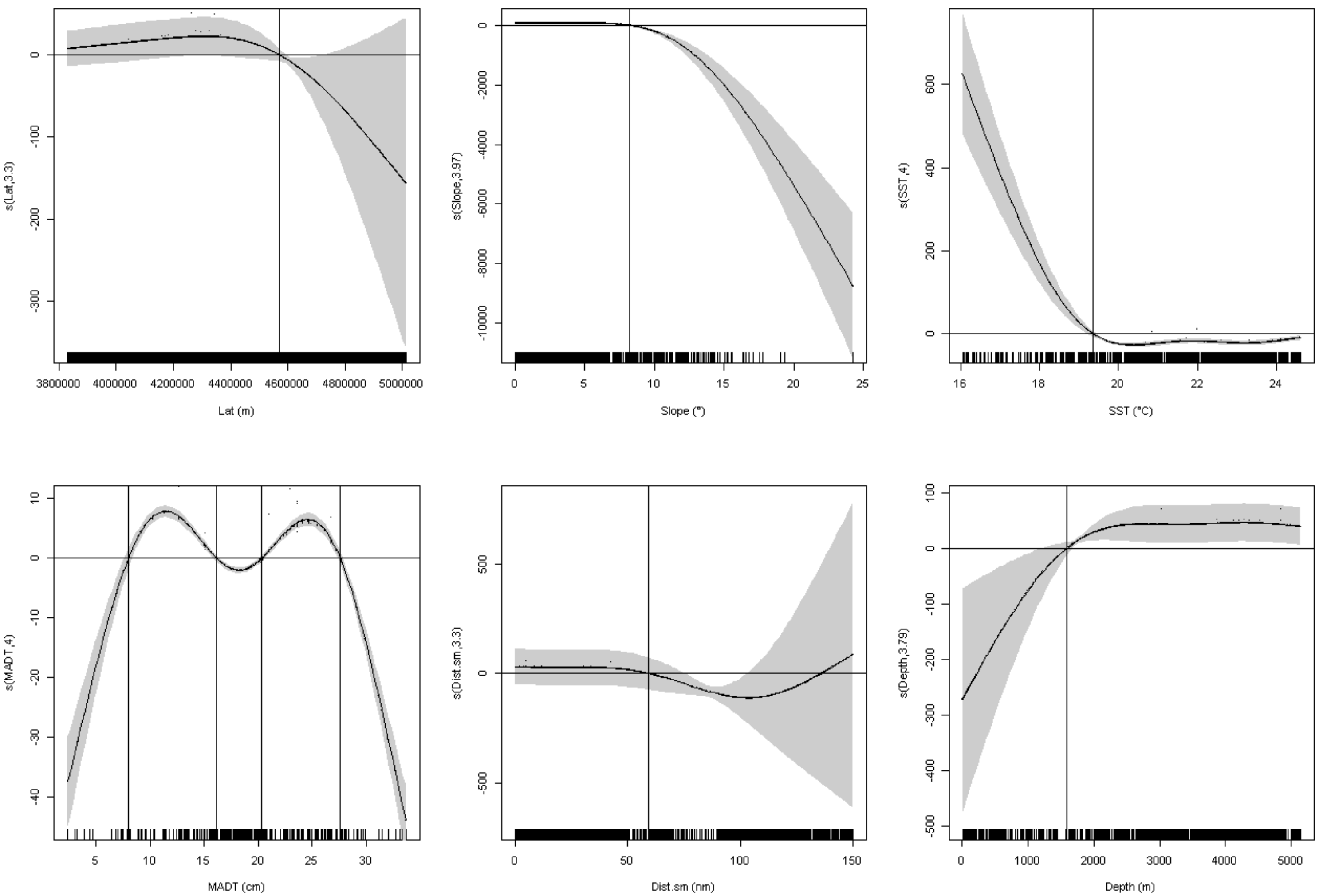
GAM plots are presented in Figure 21 for the four models computed with the threshold cuttofs used for the *GAMvelope* (values presented in Table 9).

GAM plots

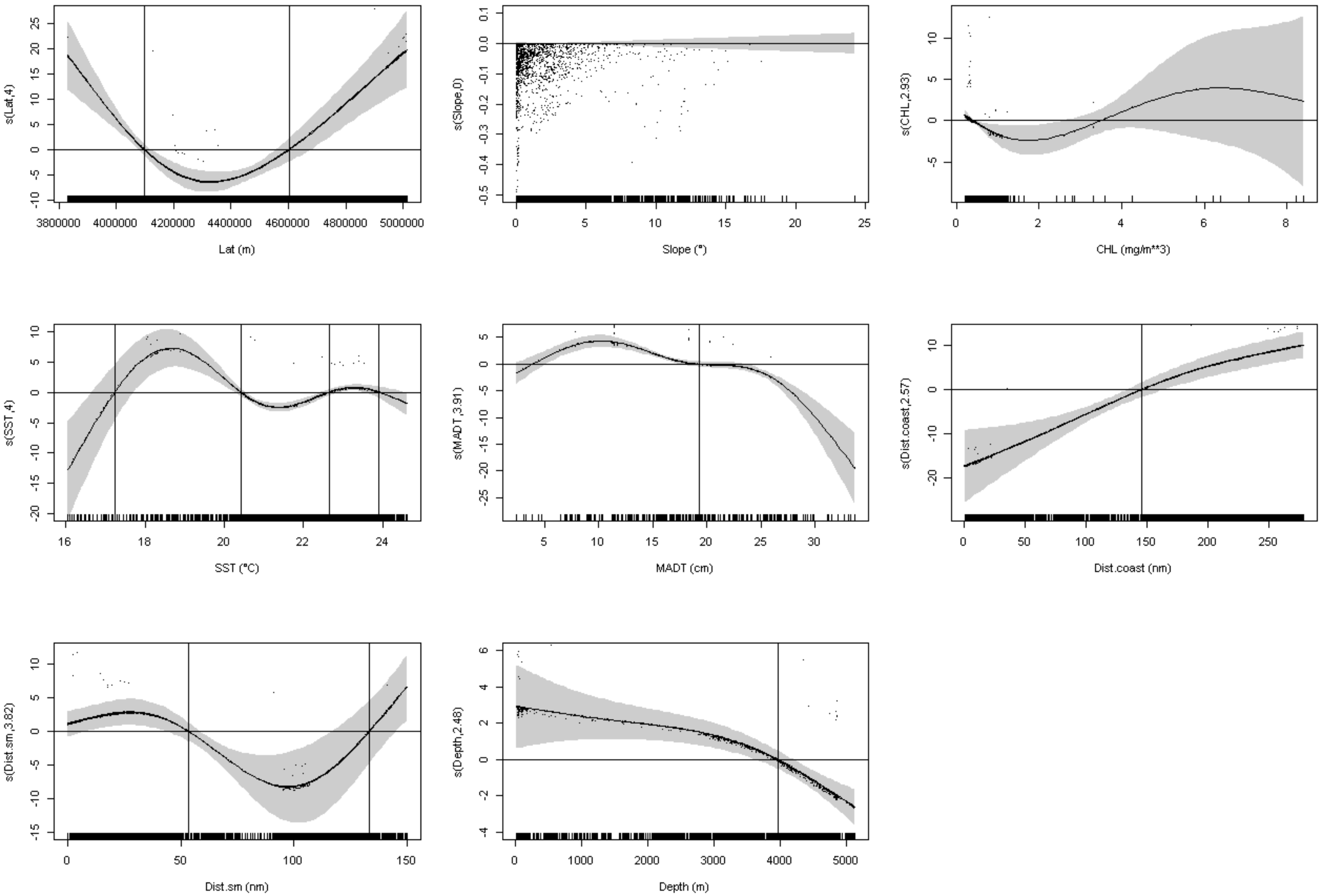
a) Baleen whales



b) Beaked whales



b) Bottlenose dolphins



d) Common dolphins

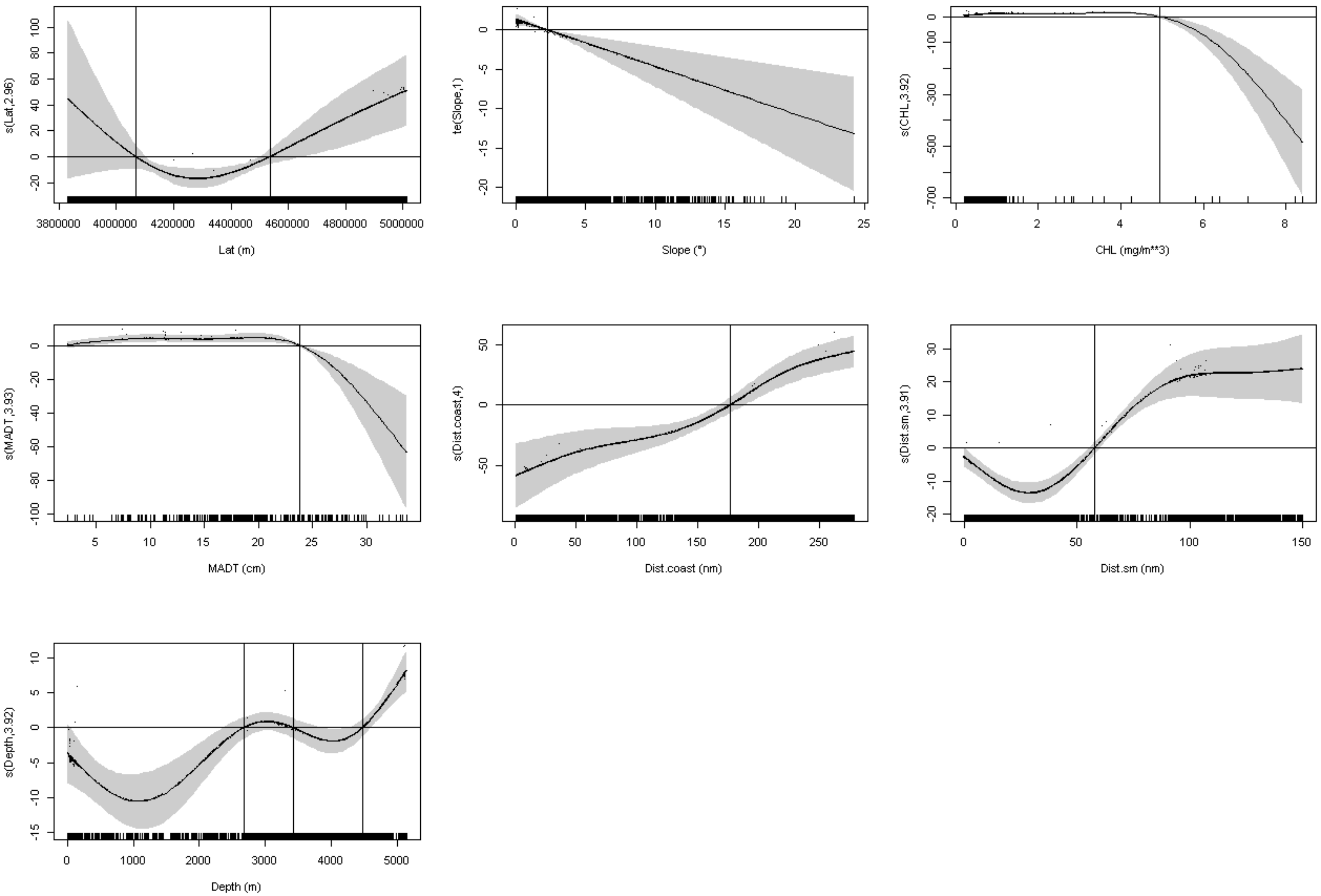


Figure 21. Generalized Additive Models (GAM) predicted smooth splines of the response variable available/used of the animals as a function of the explanatory variables. The effective degrees of freedom are in parenthesis on the y-axis. Shadings represents the 95% confidence intervals and the tick marks above the x-axis indicate the distribution of points (available and used). Vertical lines represent the threshold cutoffs applied for the *GAMvelope* (see Table 9). a) Baleen whales; b) Beaked whales; c) Bottlenose dolphins; d) Common dolphins.

GAMvelope

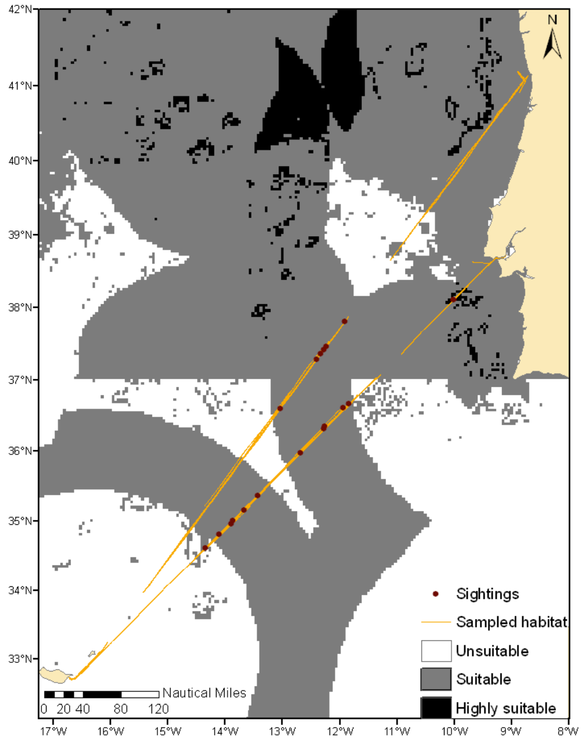
The thresholds cutoffs and the suitability classification used for *GAMvelope* are presented in Table 9 and the suitability habitat maps are shown in Figure 22.

Table 9. Threshold cutoffs and suitability classification used for *GAMvelope.*

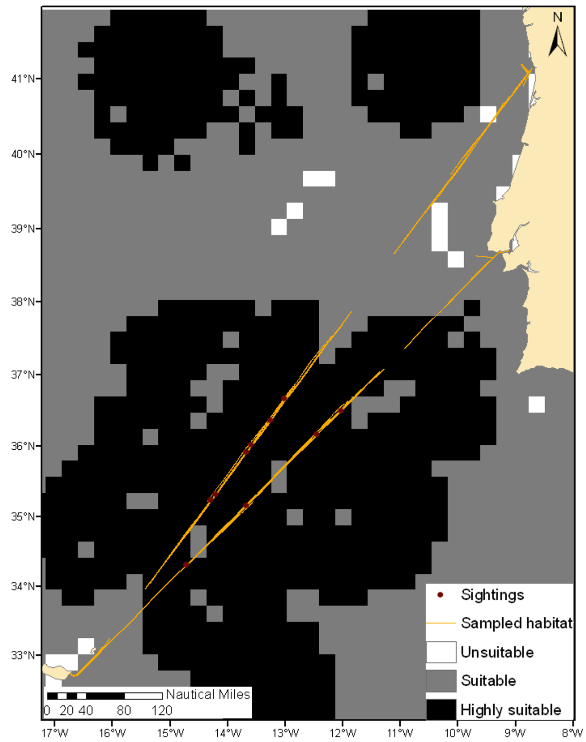
Taxon and parameter	Cutoffs	Suitability classification
BALEEN WHALES		
Lat	4419500	**Total: 5 variables**
Slope	6.3; 14.3	**Unsuitable:** 0-1 variables
SST	19.7	**Suitable:** 2-3 variables
Dist.coast	171; 255.5	**Highly suitable:** 4-5 variables
Dist.sm	90	
BEAKED WHALES		
Lat	4572000	**Total: 6 variables**
Slope	8.22	**Unsuitable:** 0-2 variables
SST	19.35	**Suitable:** 3-4 variables
MADT	8; 16.15; 20.3; 27.6	**Highly suitable:** 5-6 variables
Dist.sm	59.2	
Depth	1590	
BOTTLENOSE DOLPHINS		
Lat	4098000; 4605000	**Total: 6 variables**
SST	17.23; 20.43; 22.65; 23.9	**Unsuitable:** 0-2 variables
MADT	19.3	**Suitable:** 3-4 variables
Dist.coast	146	**Highly suitable:** 5-6 variables
Dist.sm	53.5; 133.5	
Depth	3980	
COMMON DOLPHINS		
Lat	4069000; 4538000	
Slope	2.25	**Total: 7 variables**
CHL	4.95	**Unsuitable:** 0-2 variables
MADT	23.85	**Suitable:** 3-4 variables
Dist.coast	177	**Highly suitable:** 5-7 variables
Dist.sm	58	
Depth	2680; 3425; 4480	

GAMvelope maps

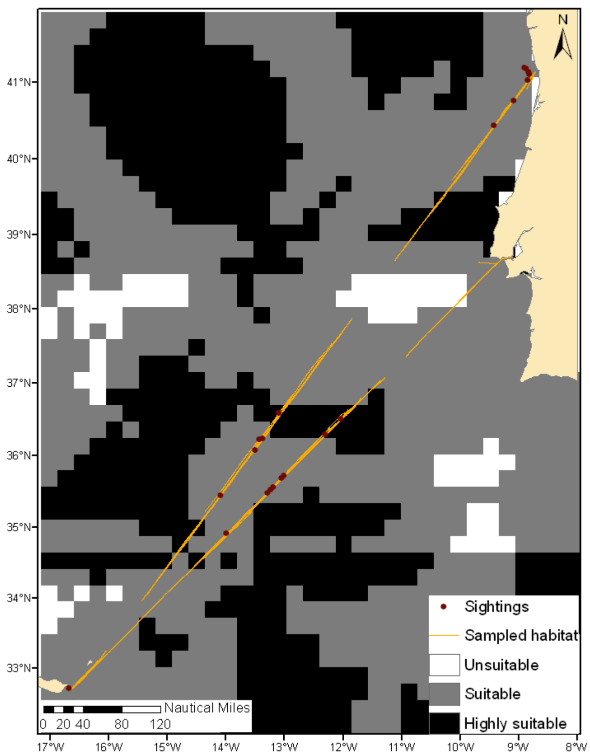
a) Baleen whales



b) Beaked whales



c) Bottlenose dolphins



d) Common dolphins

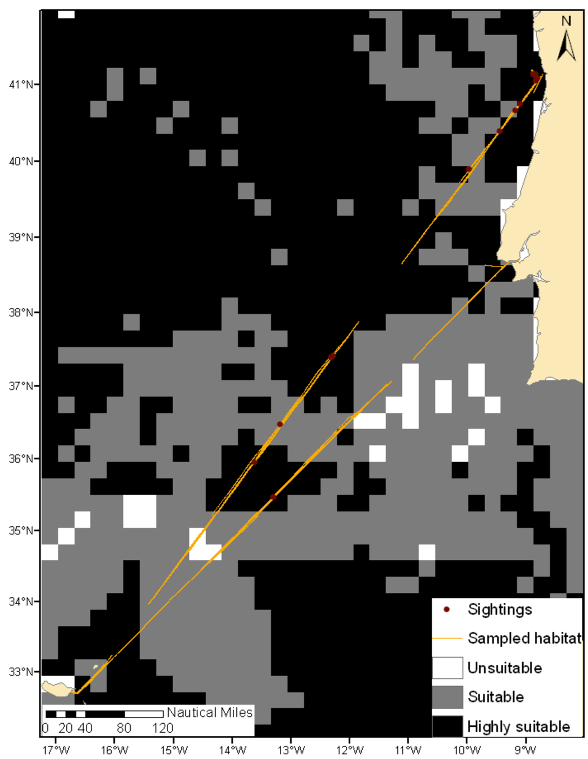


Figure 22. *GAMvelope* spatial maps. a) Baleen whales; b) Beaked whales; c) Bottlenose dolphins; d) Common dolphins.

All sightings were within the “Suitable” to “Highly suitable” predicted areas.

In the monthly maps of habitat suitability, only MADT seemed to be correlated with the “Highly suitable” habitat of beaked whales, that apparently follows the patterns of MADT variations (Figure 23).

Monthly MADT maps with monthly “Highly suitable” habitat for Beaked whales

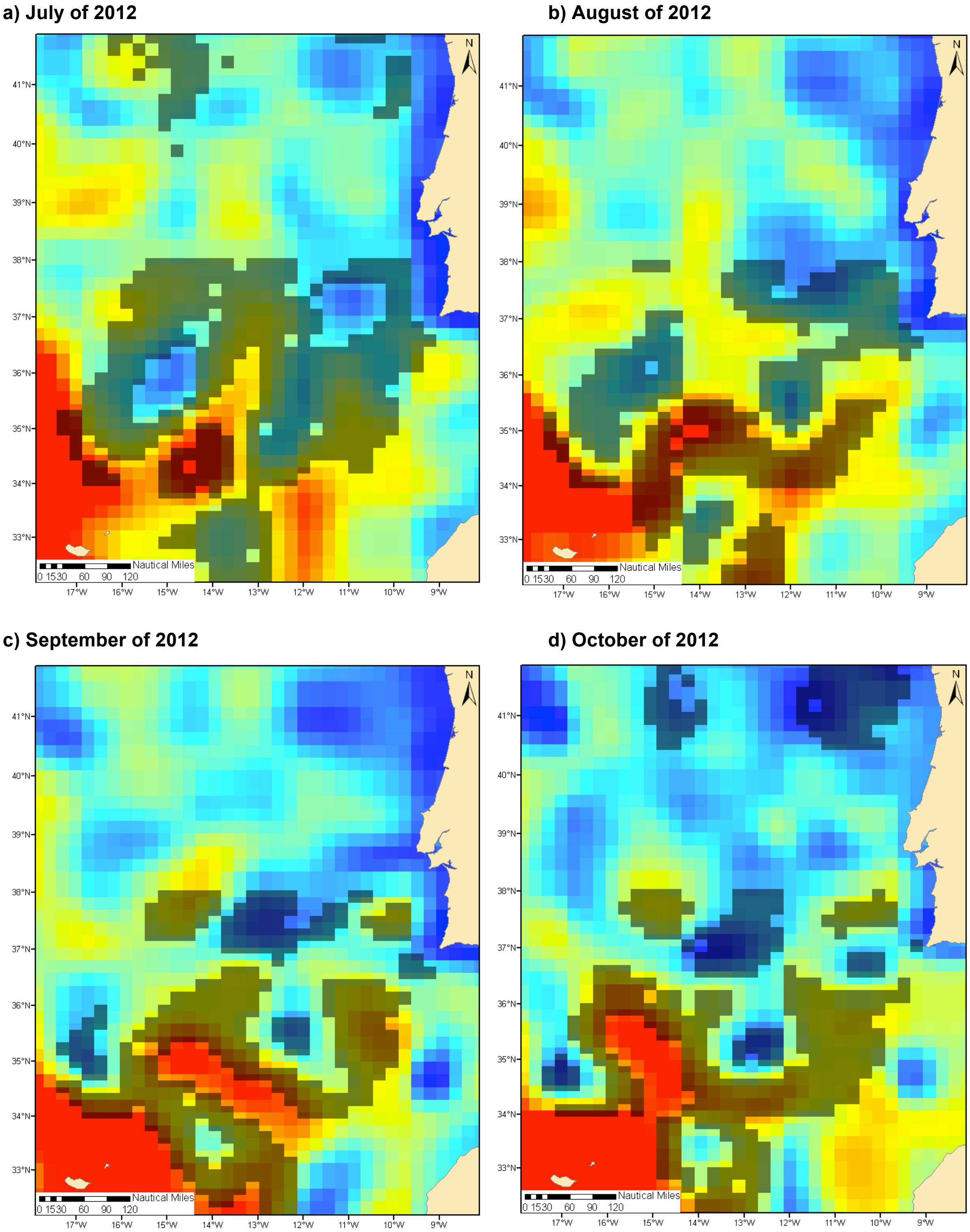


Figure 23. Correlation between monthly “Highly suitable” habitat for beaked whales (shadow areas) and monthly Maps of Absolute Dynamic Topography (MADT). a) July of 2012; b) August of 2012; c) September of 2012; d) October of 2012.

4 DISCUSSION

4.1 METHODOLOGICAL CONSIDERATIONS

Using OPOs

Several studies have successfully used ships of opportunity to collect scientific data, namely cetaceans' distribution (Kiszka *et al.*, 2007; MacLeod *et al.*, 2008; Moulins *et al.*, 2007; Moura *et al.*, 2012; Viddi *et al.*, 2010) and oceanographic data (Lüger *et al.*, 2006). Some international successful projects can also be identified, such as Volunteer Observing Ship (VOS) (National Oceanic and Atmosferic Administration, 2012). In this project, the use of cargo ships as OPO proved to be a very efficient way to gather data on cetaceans' occurrence. Though it limits the area coverage, conditioning the modelling techniques (Kiszka *et al.*, 2007), OPOs assure a large dataset of observations and allow a regular sampling, spatially and temporally (Redfern *et al.*, 2006). Cargo ships from Transinsular had weekly transects (Continental Portugal-Madeira-Continental Portugal), and therefore, temporal coverage was not a problem. Moreover, transects crossed a spatially large area and several habitats were sampled. However, due to different times of departure and part of the transect being covered during night, spatial effort coverage was not homogenous, so effort and weather conditions had to be considered in the modelling process, as suggested by Redfern *et al.* (2006). Another issue with OPO, and particularly with merchant ships, is that the containers are transported in the front of the ships, and consequently, in front of the MMOs monitored area. Though it was a rare situation, when a lot of containers were piled up, the front line of the monitored area was difficult to sample, and some animals may have been missed. For this reason, it is not appropriate to perform techniques such as distance sampling with this type of OPOs.

Though the use of OPOs limits the analysis possible to perform, in poorly sampled areas, such as the Canary Basin, this approach is a cost-effective way to improve the knowledge in cetaceans' occurrence and distribution (Moura *et al.*, 2012). If the monitoring network improves and survey coverage extends, it would result in better habitat preferences analysis and habitat models with predictive power (Kiszka *et al.*, 2007).

Sampling process

In the sampling, the MMOs were volunteering students with very little experience of sea-surveys and in cetacean monitoring. In all campaigns, one of these students was always accompanied by a more trained MMO (present in all surveys). Though students were very efficient and professional throughout the campaigns and learned the protocol very fast, the experience in detecting animals is still very important in cetacean monitoring. Moreover, every month, there was a new student as MMO. Therefore, we assume there might be an underrepresentation of the sightings. In fact, it was possible to observe that the experienced MMO had more sightings than the less trained students and that sightings from the students increased with days at the sea. All analysis had these facts in consideration by using presence-only analysis or accounting for the effort. Also, the protocol and the experienced MMO was always the same in the campaigns and so the results are comparable. This sampling method had the advantage of training several students as MMOs, which can be useful for future campaigns. One of the students used this work as his internship for his under graduation report. For the other students, it was a good experience, giving them curriculum in fieldwork in marine environments, which is quite difficult to get in the university courses. Therefore, we stand for this sampling method, as it was an important part in several students' formation.

We are aware that we were very permissive in the survey conditions (sea and wind state) comparing to most of the works in cetacean monitoring (see, for example, survey conditions in the papers from Table 1). However, the study was not species-specific, it represents (to our knowledge) the first records of cetaceans in deep-sea for this area and the platform of observations was high, so we considered important to gather all the data possible, even with worse conditions. Then, we were cautious by doing presence-only analysis and define an available habitat, "cleaning" the sampling according to survey conditions, for the habitat modelling.

Data analysis

The variables used as drivers for cetaceans' distribution were chosen according to the state of the art in habitat preferences and modelling (Table 1), availability of data (satellite data) (Robinson, 2010) and analysis of the area. Since transects cross deep-sea and coastal sections, distance to coast was included in the analysis. Also, taking into account the topographic characteristics of the region, more than depth and slope, distance to seamounts was considered, as these features are so unique and have been proved to be important for several species, namely cetaceans (Schlacher *et al.*, 2010). Latitude was used as a geographical variable, because species distribution is a combination of environmental and geographical factors (Elith&Leathwick, 2009). Study area has a big gradient of SST Figure 10), so this was considered to be an interesting variable for habitat partitioning. Moreover, SST is an indicator of upwelling systems, with cooler, nutrient and rich waters (Robinson, 2010), in this case occurring along the Continental coast. CHL acts as proxy for productive waters, and coastal blooms are also indicators of upwelling systems and river drainage (Figure 7) (Robinson, 2010). All three oceanographic variables chosen act as proxies for mesoscale eddies, but the MADT is an especially important variable to understand the dynamics and patterns of circulation, allowing the identification of sea-surface anomalies (Robinson, 2010) and has already been directly linked to one tagged beaked whale movements (Baird *et al.*, 2011).

Transects cross especially deep-sea, oligotrophic waters and therefore CHL was very low, being the March bloom the month to analyse for productivity proxy. Since the bloom was temporally far from the sampling season, sometimes the correlation of CHL with cetaceans' distribution was not clear (Table 8 – baleen whales, bottlenose and common dolphins models), as circulation patterns and lag on data may influence and spatially "move" the more productive area. Another problem with the oceanographic data was the spatial resolution of the MADT (25km) that was very low, even considering that only mesoscale and more permanent structures were analysed. *GAMvelope* maps (Figure 22) show that models using the MADT had a very low resolution and large cells.

We chose monthly resolution for the oceanographic variables as only two surveys per month were done. Moreover, these records are the first results on cetacean occurrence, distribution, habitat preferences and modelling in deep-sea for the area (to our knowledge), so we were aiming for a descriptive and exploratory analysis, that considered more permanent, mesoscale structures. Therefore, the spatial and temporal scale for analysis was a combination of the objectives of the study and available data (Redfern *et al.*, 2006).

Environmental envelopes have been defended as methods to understand habitat preferences with presence-only data (Elith&Leathwick, 2009; Pearce&Boyce, 2006) and quantiles analysis used by several authors (Austin, 2007), namely for bathymetric preferences of cetaceans (Kiszka *et al.*, 2007). In this study, it was fundamental in the analysis of the cetacean habitats along the route and habitat partitioning among groups.

RSF models were chosen as they are recommended to determine animals' distribution in function of a variable, allowing to distinguish between "available" and "used" habitat (Elith&Leathwick, 2009). As the extent of the study included a big variability of habitats, this was considered to be a good approach for habitat modelling in the area. Moreover, RSF techniques have been used successfully in cetacean habitat modelling by several authors (Table 1). As the scope of the study was not predictability, GAM was used, since it is more flexible than GLM (Elith&Leathwick, 2009; Torres *et al.*, 2008), for example, the accuracy of the model is less affected by low prevalence of animals (Barbet-Massin *et al.*, 2012).

We were very cautious with the modelling approach. Several authors defend the presence/absence approach whenever possible (Brotons *et al.*, 2004; MacLeod *et al.*, 2008; Pearce&Boyce, 2006), however, we did not have true absences due to the sampling technique and all the bias inherent to the sea-surveys, especially from an OPO (Redfern *et al.*, 2006). But since we were aiming a used/available approach and transects crossed a big habitat diversity, it was possible to create pseudo-absences along transects to represent the available habitat. These points had 2.5 miles distance so they would not fall in a cell with the same oceanographic value (higher resolution of oceanographic variables of 4km). By creating these points in all transects, effort was being considered, as sections more sampled had more available points. This resulted in a high number of pseudo-absence points, weighted equally with the presences, as recommended by Barbet-Massin *et al.* (2012). Although we followed the parameters and model protocol used in Viddi *et al.* (2010), a limit on the number of splines was defined (Quian, 2009), so we would be modelling and not just fitting the data. This becomes more important with a smaller number of presences, as GAM curves will adjust to the presence points. For example, with no limiting splines, common dolphins model was reaching the 94.4% of deviance explained, so we were fitting the data, but the model was not actually good, as it did not allow any assumption from the results.

No evaluation was carried out as the model had explanatory purposes only (Elith&Leathwick, 2009) and neither the analysis of residuals, documented as not appropriate for binary data (Quian, 2009). However, all the results and their limitations were analysed carefully. Quoting Pearce&Boyce (2006) the “researchers must be mindful of study design and the biases inherent in the presence data and be cautious in the interpretation of model predictions.”

4.2 Descriptive Analysis

Study area oceanography

CHL is mainly oligotrophic on the area, except in the Continental coast where there is high concentrations of CHL (Figure 7), indicating a strong upwelling phenomena and river drainage. Portuguese coastal upwelling has been reported several times (Dias *et al.,* 1992; Mason, 2009). Spring bloom occurs in central coast in March (Figure 6), and there is a characteristic CHL annual cycle (Figure 5). The year of 2009 had an extremely high bloom (Figure 5), but the year of sampling, 2012, can be considered representative of the area (Figure 6). However, some anomalies can be identified in 2012. The bloom was smaller in the central coast, which can be a result of a less pronounced upwelling as the SST anomalies confirm (Figure 10). However, in the southwest coast, there is a positive anomaly of CHL that may have been a result of atypical high river drainage. In fact, this area was much warmer than it usually is (Figure 10). Some positive anomalies of CHL along the transect may indicate the presence of small upwelling systems, result of eddies and the presence of abrupt seamounts and ridges (Figure 4). In fact, MADT analysis shows a very dynamic circulation (Figure 11), consistent with data presented by Caldeira *et al.* (2002) and Sala *et al.* (2013). The northeast of Madeira Island is under the influence of the island mass effect phenomena, the permanent Azores current and several seamounts and ridges (Caldeira *et al.*, 2002; Sala *et al.*, 2013) that may be causing permanent and dynamic cyclonic and anti-cyclonic eddies. The SST data are consistent with data presented in Dias *et al.* (1992) and Sala *et al.* (2013). The area around Madeira is very warm comparing to northern latitudes. Madeira's latitude has been suspected to be the sub-tropical front where cold waters from the north meet the warm waters from south (Caldeira *et al.*, 2002). However, even not visible in the figures presented (Figure 10) due to the scale and big area mapped, small upwelling systems were reported around the islands (Madeira, Porto Santo and Desertas) (Caldeira *et al.*, 2002). The year of 2012 had several positive anomalies, indicating a sea-surface warming. However, despite a slightly warmer summer (in study area average SST), the year of 2012 is representative of the area (Figure 9).

Sea-survey

The transect Oporto – Lisbon was sampled only once, as it was being done mainly during the night and therefore not useful for the monitoring. The transect Caniçal – Oporto is longer than Lisbon – Caniçal, however it was less sampled (Table 4). Both transects were important as they crossed different habitat profiles.

All the identified species, with exception of *Ziphius cavirostris*, were reported as resident either in Continental Portugal or in Madeira Island (Table 2). However, not all the resident species were identified, so these species may have been missed, spotted but not identified at the species level (dolphins like *Stenella coeruleoalba* registered as *Delphinidae sp*.), or the species are very coastal (like *Phocoena phocoena*) (Rice, 1998) and this region was less surveyed.

Bottlenose dolphins were more prevalent than common dolphins, which is not consistent with the results presented in Brito *et al.* (2009). However, most common dolphins were spotted near the Continental coast, as well as several unidentified *Delphinidae* (Figure 12). Moreover, bottlenose dolphins have been reported as the most common species in the waters of Madeira (Museu da Baleia, 2013). Bottlenose dolphins are an inshore and offshore species (Cawardine, 2000), and in the area there seems to be a coastal and an oceanic population, as there were coastal occurrences, but also several sightings in deep sea (Figure 12). This may be an effect of the low depth seamounts along transects. The chains of seamounts in the area have been characterized as highly productive with lots of schooling fish (WWF, 2003). In fact, bottlenose dolphins are known to be opportunistic feeders that take advantage of the local features that aggregate the preferable prey, which in Portugal has been reported as being fish (Cañadas *et al.*, 2002). Sperm whales were mainly spotted in the waters around Madeira, which is consistent with registers from "Museu da Baleia" (2013). Beaked whales were spotted in deep-sea (Figure 12) and are considered occasional in waters of Madeira (Table 4). This can mean they are common in the area, but have few registers as they occur mainly in offshore waters. No migratory species were identified even though migratory season was surveyed (in the month of October) (Cawardine, 2000). This may indicate that the migratory route is passing mainly on the west side of Madeira. The profile of species in deep-sea areas, near seamounts region, is more similar to the species reports in Madeira Island than in Continental Portugal (Figure 12 and Table 4). Therefore, animals sighted in deep-sea may be mainly from the populations sighted in Madeira Island. It can be a result of the topographic connectivity between Madeira and the seamounts chains (Figure 4), since there is an abyssal area between Continental coast and the seamounts region (mainly along the transect Caniçal – Oporto). All hypotheses presented need more sampling effort in the area to be confirmed.

4.3 ENVIRONMENTAL ENVELOPE

Results presented show a clear habitat partitioning among cetacean groups in the area (Figure 13). Moreover, this has been driven by habitat variables (Table 6). Statistical significant differences support the findings (Table 7).

Despite not being an environmental variable, latitude accounts for the geographic partitioning in the area. From this point of view, baleen and beaked whales seem to be sharing the middle latitudes and occupying a more restricted habitat than sperm whales and dolphin species (Figure 14). Dolphins are occupying a wide range because all dolphin species, known to have different habitat preferences (such as common and bottlenose dolphins) were grouped and species with very wide ranges (such as common dolphins) (Kiszka *et al.*, 2007) and unidentified species (*Delphinidae sp.*) were included in the group. The wide range for dolphins was observed also in the other predictors (Figure 14 – 19). Sperm whales were seen mainly in southern latitudes (lower median) (Figure 14 and Table 6), which is consistent with the reported resident status of sperm whales around Madeira (Museu da Baleia, 2013).

It seems there is habitat segregation among beaked and sperm whales (Figure 13). This has been suggested before in the Mediterranean Sea (Azzellino *et al.*, 2008). Both species share the same prey (cephalopod prey) and, therefore, this can be an indication of interspecific competition.

Despite the fact they are sharing the same middle latitudes, the distance to coast is different among beaked and baleen whales and it is statistically significant, with the latter closer to shore (Figure 15). This may be an effect of the seamounts, meaning both groups share the middle latitudes, but beaked whales move towards the seamounts and baleen whales stay in areas closer to coast. There are evidences supporting these findings, as seamounts and canyons were suggested to play an important role in beaked whales distribution (Azzellino *et al.*, 2012; Cañadas *et al.*, 2002; Moulins *et al.*, 2007) and proximity to coast an important factor to baleen whales (Friedlaender *et al.*, 2011). Regarding dolphins, they were mainly closer to coast (lower median), but were ubiquitous in the area (Figure 15 and Table 6), which is consistent with several studies (Azzellino *et al.*, 2008; Azzellino *et al.*, 2012; Cañadas *et al.*, 2002; Kiszka *et al.*, 2007; Moulins *et al.*, 2008). Sperm whale is considered to be an oceanic species, however it was sighted very close to coast (to Madeira Island) (Figure 13 and 15 and Table 6). There were only two offshore sightings in the seamount region and these were probably from the population resident in Madeira. We suggest that sperm whales have a high site-fidelity in the Madeira region. Even though there are few sightings in this study to support this hypothesis, the “Museu da Baleia” (2013) data enhance our supposition. Moreover, sperm whales have been reported closer to coast, mainly in the shelf edge, in other studies (Kiszka *et al.*, 2007; Pirotta *et al.*, 2011). It should be noted that shelf edge in Madeira is very close to the coast (abrupt slope) (Figure 4).

Regarding depth, medians and ranges are higher than in most studies (Table 6 and Figure 16) (see for example, Kiszka *et al.*, 2007, for quantiles comparison). This is a result of the diversity of habitat surveyed and the amount of effort in offshore waters. Moreover, with the presence of abrupt canyons and seamounts, an animal rapidly passes from shallow to deeper waters. Baleen and beaked whales are occupying deeper waters, with narrow ranges, comparing especially with dolphin species (statistically significant difference between dolphins and baleen whales) (Table 7). This is consistent with the knowledge on the groups (Cawardine, 2000), and in concrete, for the animals in the area (Museu da Baleia, 2013). Sperm whales had a very low median (Table 6), considering they have been described as having preferences for deeper waters (Cañadas *et al.*, 2002) but this is probably related to the hypothesis stated before on the high site-fidelity of sperm whales on the waters of Madeira and the abrupt slope in the Island.

Groups did not seem to be segregated according to slope. This may be a consequence of a complex bathymetry that presents abrupt variations on the slope within the same region.

Dolphins and beaked whales seemed to prefer colder waters compared to baleen and sperm whales (Figure 18, Table 6 and 7). This is probably due to the coastal upwelling system (in case of the dolphins) and in the deep-sea, where small upwelling phenomena can happen because of the seamounts (for both dolphins and beaked whales) and to the circulation dynamics, namely the presence of cyclonic (cold cores) or anti-cyclonic (cold margins) (in the case of beaked whales) (Robinson, 2010). In fact, MADT results show that beaked whales had a preference for higher values (Figure 19 and Table 6), that occur in the more dynamic region of the transects, where positive and negative anomalies, probably indicators of mesoscale eddies, are observed (Figure 11). On the other hand, dolphins seem to prefer lower MADT, characteristic of the Continental coastal region (Figure 11).

Values have to be interpreted within the sampled habitat and extent of the sampling (Weir *et al.*, 2012). For example, we cannot directly compare habitat results obtained in the Atlantic with the Mediterranean, or results obtained from OPOs covering large distances of line-transects with dedicated surveys covering areas with less habitat diversity.

Even with a wide diversity of habitats covered and clear habitat segregation and habitat preferences, to fully understand and define the realized niche of these groups or species, more sampling effort is needed.

4.4 HABITAT MODELLING

Models had a higher deviance explained in species with fewer, but more concentrated sightings (Table 8). Brotons *et al.* (2004) proved that models do perform better with more marginal and specialist species compared to the generalist ones. This means that models are more accurate when the available habitat limits are bigger than the used habitat, considering the environmental conditions. In Brotons *et al.* (2004), there was a positive effect of prevalence on models' accuracy, but was secondary and indirect, since the occurrence of species is highly dependent on the species ecological characteristics and relative sampling (a more marginal species with a restricted habitat will probably have less occurrences). However, GAM models used are robust techniques regarding the prevalence (Barbet-Massin *et al.*, 2012).

Latitude was a significant variable in all species models. It is a variable related with the geographical space and not environmental and, therefore, it is not ecologically explaining the species distribution but accounting for important predictors that were missing in the analysis, improving the models (Elith&Leathwick, 2009).

Baleen whales distribution was influenced by the CHL, even with no statistical significance (Table 8). This may be reflecting the indirect effect of CHL on the baleen whales' distribution.

Moreover, the March CHL (bloom month) was used as a proxy for productive areas, however, it may be temporally too distant to detect and explain the influence. Combining all the variables and representing them spatially, all sightings were within the suitable area (Figure 22). Northern latitudes (more than 37ºN), associated with the Continental area, had a positive influence in the habitat (Figure 21 and 22). This was expected, considering minke whales (corresponding to most of the baleen whales sightings) are reported as resident in the Continent and only occasional in Madeira Island (Table 2). Distance to coast had a peak of positive influence between the 171nm and 255.5nm (Table 9 and Figure 22). Positive slope areas were distributed on the continental slope and seamounts (from 6.3º to 14.3º) (Rable 9 and Figure 22). Cutting points on SST and distance to seamounts were 19.7ºC and 90nm, respectively (Table 9). Neither MADT nor depth were determinant in the models. Spatially, the north in offshore areas, where there are several seamounts, seems to be an area of potential interest regarding baleen whales habitat (Figure 22). There is also a potential hotspot in the southwest of Continental Portugal (along the positive slope areas) (Figure 22). It is interesting to note that it overlaps with the positive anomaly of CHL verified for the year of 2012 (Figure 7). It seems that baleen whales habitat is more driven by the distance to coast and prey availability, rather than depth, similar to results presented before (Friedlaender *et al.*, 2011; Viddi *et al.*, 2010)

Beaked whales suitable habitat was in southern, deeper and closer to seamounts waters (Table 9 and Figure 22). Geographically, it was expected the occurrence in southern waters compared to the northern, as the species are reported as occasional in the Madeira Island, but the occurrence in the Continent is unknown (suggesting very few sightings) (Table 2). There were two peaks of positive effect regarding MADT (Figure 21 and Table 9), indicating a preference for areas particularly active in terms of mesoscale eddies (causing downwellings and upwellings phenomena) (Robinson, 2010). Slope and SST cut-offs were at 8.22º and 19.35ºC, respectively (Table 9). Neither distance to coast nor CHL were determinant in the habitat modelling. When combining all the variables effects on a spatial representation, the seamount effect, reported before for beaked whales (Azzellino *et al.*, 2012; Cañadas *et al.*, 2002; Moulins *et al.*, 2007), is evident (Figure 22). All sightings were within the highly suitable habitat (Figure 22).

Bottlenose dolphins had two geographical suitable habitats, one in north and another in the south, probably corresponding to dolphins under the Continental coast or the Island shelf influence (Figure 21 and 22). This was also evident on the SST results (two positive peaks, one colder corresponding to the northern and Continental influenced waters and another warmer corresponding to southern and Island influenced waters). In fact, bottlenose dolphins are resident in both areas (Continent and Island) (Table 2). Moreover, models support the theory of a coastal and an oceanic (positively influenced by the seamounts) population suggested before (in the discussion on the Descriptive Analysis – Sea-survey), as there are two peaks (one close and another distant) of positive influence regarding distance to seamounts (Figure 21 and Table 9). As in the baleen whales model, CHL was not statistically significant but was important in the model, probably for the same reasons (Table 8 and Figure 21). MADT had a peak of positive effect around 10cm and decreased until starting to have a negative effect from the 19.3cm, suggesting bottlenose dolphins have a preference for negative anomalies, several times associated to cold and productive areas off eddies (Figure 21 and Table 9) (Robinson, 2010). There was a positive effect on habitat when distance to coast was superior to 146nm and depth inferior to 3980m (Figure 21 and Table 9). Slope was not an important variable for the bottlenose habitat (Table 8). By looking at the *GAMvelope*, it seems there is a highly suitable habitat following the CHL bloom pattern (Figure 7 and 22). All the sightings were within the suitable to highly suitable habitat (Figure 22).

In the common dolphins habitat, CHL was statistically significant (Table 8). In fact, Moura *et al.* (2012) reported a tight correlation between CHL and common dolphins. However, the explanation for the negative influence in CHL concentrations higher than 4.95mg/m**3 is not clear (Figure 21 and Table 9). This may be caused by the CHL lag (discussed before) or because concentrations higher than the CHL cut-off only occur very close to coast (upwelling and river drainage region) (Figure 7 and 22). Geographically, there was also a northern and southern habitat (Figure 21 and 22) and as in bottlenose dolphins, this was expected since the common dolphins are resident in the Continent and in the Island (Table 2). There was a preference for lower gradient slopes (2.25º) (Figure 21 and Table 9). This was in line with the results obtained for the distance to seamounts and to coast, since neither of the positive effects of these two variables coincides with the strong gradient slopes (continental slope or seamounts slope) (Figure 21 and Table 9). The cut-off for the MADT was high (23.85) and there were two suitable habitats regarding depth (between 2680m and 3425m and higher than 3425) (Figure 21 and Table 9). The variables limits result in a very wide suitable to highly suitable habitat, suggesting that common dolphins are a very generalist species in the region.

Regarding the temporal variability of highly suitable habitat for beaked whales considering MADT, this correlation has already been reported (Baird *et al.*, 2011). In the Figure 23 (especially in September and October), it seems that the highly suitable habitat is in the margins of very high MADT, possibly associated with anti-cyclonic eddies and located in a highly active area (Island influence, Azores current and seamounts region); and in very low MADT, possibly associated with cores of cyclonic eddies. The margins of anti-cyclonic eddies are colder than the cores and the opposite happens in cyclonic eddies, and both colder areas are associated with high productivity (Robinson, 2010). This relation is very important, as it can be a very good indicator for species movements, especially in such sensitive groups as beaked whales (Baird *et al.*, 2011).

The modelling techniques allowed explaining the distribution of the cetaceans in the area, extending and completing the results obtained with the Environmental Envelope, a fitting technique. However, considering the amount of data, all raised hypothesis should be confirmed with data from an extended monitoring program to determine the effective niche limits, correctly access species hotspots and possibly obtain models with predictive power.

4.5 Conservation Implications

There is a need for sound knowledge in occurrence and distribution of cetaceans, especially in high seas, to efficiently define critical habitats for the species and designate MPAs. In high seas the data is deficient and protected areas are lacking. The main problem is the authority in waters outside the EEZ (more than 200nm offshore) to create MPAs and management plans (Hoyt, 2011). International agreements are therefore essential for the biodiversity protection in high seas. In the study area, data in cetacean are not only restricted to the EEZ limits but also to coastal areas (Augusto, 2007; Moura *et al.*, 2012; Ribeiro *et al.*, 2009). In fact, the special areas of conservation (SACs) including cetacean species, designated by Natura 2000, in the area are in costal areas (“Madeiran Marine Mammal Sanctuary”; “Sado Estuary Natural Reserve” and “Arrábida Natural Park”) (Hoyt, 2011). Regarding offshore areas, ACCOBAMS has recently expanded the area to the Portuguese EEZ and needs data to define management plans (ACCOBAMS, 2013). Josephine seamount MPA (designated by OSPAR) and the Gorringe seamount proposed MPA have no management plans defined and, to our knowledge, no published data on cetaceans (Oceana, 2013; OSPAR, 2011).

Most cetaceans inhabit in offshore areas and depend on high seas, where they spend most of their lives or have critical habitat (breeding, calving, feeding and migrating). In offshore waters, there are several areas with favourable environmental conditions for cetacean habitats, such as seamounts, thermal fronts, upwellings and eddies (Hoyt, 2011). The preliminary results presented here show the potential of the area as habitat for cetaceans, given the environmental space. With the recent extension of the ACCOBAMS area and future extension of the Portuguese EEZ, data on cetacean occurrence and distribution is essential for management plans and conservation actions. A long-term monitoring network in the region is suggested to improve knowledge on the cetaceans habitat, and especially, to define hotspots areas, breeding and feeding grounds, migration pathways and movements patterns, to support efficient conservation measures (Ballance *et al.*, 2006; Hoyt, 2011; Schlacher *et al.*, 2010).

5 CONCLUSION

This thesis presents the preliminary results on occurrence and distribution of cetacean species in the Canary Basin, from the observation on the routes between Continental Portugal and Madeira Island. Habitat segregation and preferences of the groups/species were studied. The main conclusions are presented below:

- Routes cross an area very rich topographically and oceanographically, and therefore, a big extension concerning the environmental space and available habitat.
- There is a clearl habitat segregation among groups in the region, caused by habitat variables.
- Habitat variables are good indicators of the spatial distribution of the cetaceans in the area.
- Due to the available habitat sampled and clear habitat preferences of the groups/species, habitat modelling has a great potential for these routes.
- The area has, probably, several critical habitats for cetaceans.
- A possible critical habitat for beaked whales in the NEA was identified.
- OPOs were proved to be very useful to obtain preliminary data in poorly known areas.
- To our knowledge, these are the first published results for the offshore waters in the area.
- A long-term monitoring network in the region is suggested to improve knowledge on the cetaceans' habitat and support efficient conservation measures.

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