UNIVERSIDADE DE LISBOA
FACULDADE DE CIÊNCIAS
DEPARTAMENTO DE BIOLOGIA ANIMAL

Conservation of large cetaceans: Sperm whale maternity in the Azores

Beatriz Negrita da Silva

Mestrado em Ecologia Marinha

Dissertação orientada por:
Doutora Maria Adelaide Ferreira
Doutor José Nuno Gomes Pereira

2024

Acknowledgements

First, I would like to thank my supervisor, Professor Adelaide Ferreira, for all her support and availability to guide me through the thesis process, and for all her advice and suggestions, even though she was not with me from the start.

I would also like to thank José Nuno Gomes Pereira for his availability and patience throughout the thesis, for helping me to overcome some barriers concerning the data and for sharing lots of knowledge about cetaceans and especially sperm whales.

To Professor José Ângelo Guerreiro da Silva, who accompanied me at the beginning of this journey and who suggested this topic. To Professor Carlos Assis for his availability and kindness in guiding me from the moment I chose my thesis topic, as well as assisting me with several questions.

I would like to thank Naturalist and the whole team for welcoming me and for making it possible for me to learn so much about the sea and marine life.

Thanks to MONICET and specially to Terra Azul company, for sharing data.

To the friends that Naturalist gave me, Luana Gonçalves, Mafalda Albuquerque, Maria Ernesto and Nádia Jesus, I would like to thank you for all your support during the thesis and for all the incredible moments. My thanks to all my friends who supported me throughout this process.

Finally, I would like to thank my family and my boyfriend for always being there for me in the good times and in the difficult ones, for being understanding and for always encouraging me to do my best. Thank you for everything.

Resumo

O arquipélago dos Açores, localizado no Oceano Atlântico Norte, é um dos poucos locais do mundo onde os cachalotes (*Physeter macrocephalus* L., 1758) podem ser observados de forma fiável durante todo o ano, maioritariamente grupos compostos por fêmeas, crias e juvenis com visitas ocasionais de machos adultos. Esta espécie é atualmente designada a nível global como Vulnerável na Lista Vermelha de Espécies Ameaçadas da IUCN, o que torna muito importante avaliar a utilização de habitat pela espécie e a importância dos Açores como zona de maternidade.

Após o fim da baleação, a observação de cetáceos tornou-se uma das atividades no setor do turismo de maior importância para a região, permitindo também a recolha de dados para fins científicos a partir destas embarcações. O principal objetivo deste estudo é avaliar a importância dos Açores como área de maternidade de cachalotes, através da recolha de registos de nascimentos e da análise da presença de crias nos grupos avistados. Avalia também a influência da batimetria da região na utilização do habitat e na presença de crias no grupo, bem como a sua presença sazonal e anual. Com base numa análise das rotas dos navios em torno do Grupo Central e Oriental dos Açores, considerando a distribuição dos cachalotes na área, são propostas medidas de mitigação para a conservação da espécie.

Os dados de avistamentos foram obtidos de duas fontes: a base de dados da empresa Naturalist, com dados de 2016 a 2022, correspondendo a avistamentos no Grupo Central e a plataforma MONICET, da qual foram utilizados dados exclusivamente da empresa Terra Azul para a região de São Miguel, de 2009 a 2022. De forma a evitar parte do enviesamento de resultados, para cada data, foi considerado apenas um avistamento da espécie. Para avaliar o uso do habitat, considerando ambos os conjuntos de dados, foram realizadas duas análises de Kruskal-Wallis no RStudio. A primeira análise teve como objetivo verificar se existiam diferenças estatísticas significativas no uso de habitats entre o Grupo Central e a Ilha de São Miguel, onde apenas o declive e a distância à costa apresentaram tais diferenças, possivelmente associadas às próprias características do fundo marinho de cada região. O objetivo da segunda análise foi avaliar a preferência de habitat dos grupos de cachalotes com e sem crias de acordo com a influência das mesmas variáveis para cada região, em que apenas a profundidade para o Grupo Central apresentou diferenças estatísticas significativas.

Os dados de registos plurianuais de cachalotes em torno das ilhas de São Miguel, Faial e Pico, revelam que os grupos de cachalotes estão presentes durante todo o ano nos Açores. Para ambas as regiões, Grupo Central e São Miguel, é destacada a preferência por profundidades de 800-1100m. Através do software QGIS foi também possível analisar, de uma forma geral, a distribuição da espécie ao redor destes grupos de ilhas considerando, numa fase inicial, todos os avistamentos disponíveis da espécie e posteriormente apenas dos dados pertencentes às duas empresas selecionadas. Apesar de terem sido produzidos mapas apenas com avistamentos de crias, de forma a avaliar se existiriam áreas específicas onde estas seriam mais avistadas, não se encontraram diferenças relativamente à distribuição dos avistamentos na sua totalidade.

Para analisar a percentagem de crias presentes nos grupos para ambas as regiões dos Açores de acordo com a sazonalidade, foi totalizado o número de avistamentos para cada mês, ao longo dos vários anos do conjunto de dados. O número de saídas/dias de mar para cada mês, ao longo dos vários anos do conjunto de dados, foi também totalizado para ser utilizado como medida de esforço. No Grupo Central, as crias estão presentes durante praticamente todo o ano. Apesar de não se terem registado saídas entre novembro e fevereiro, possivelmente devido às más condições climatéricas, é expetável que a espécie permaneça na região. Em relação aos avistamentos em São Miguel, as crias encontram-se presentes na maioria dos meses, à exceção de fevereiro e dezembro. A presença de crias foi notória nos grupos, em 55,2% dos avistamentos do Grupo Central e em 22,5% dos avistamentos da Ilha de São Miguel. Registos de nascimentos de cachalotes nos Açores foram recolhidos de fontes

bibliográficas e dos registos de diferentes empresas, revelando uma maior incidência no final da primavera e nos meses de verão, sendo agosto o mês com mais registos. A maioria dos nascimentos foi descrita de forma muito semelhante, descrevendo-se a agregação de vários indivíduos na zona, em socialização e mostrando alguma agitação. Geralmente, é observada uma mancha de sangue na superfície em tons vermelho-escuro, distinguindo-se um recém-nascido através do seu pequeno tamanho em comparação aos restantes indivíduos, além de apresentar mais pregas/rugas na pele e ausência de marcas na mesma que normalmente são mais observadas em juvenis e adultos.

Os habitats dos cachalotes sobrepõem-se por vezes a zonas de elevado tráfego marítimo, nomeadamente as linhas de ferry que ligam o Faial, Pico e São Jorge, no caso do Grupo Central, e a zona a sul de São Miguel, no caso do Grupo Oriental, devido à localização dos principais portos. De modo a analisar possíveis zonas de risco para a espécie, foram analisadas as rotas de 3 tipos diferentes de embarcações: navios-petroleiros, navios de carga e navios de passageiros. Os dados referentes às rotas, correspondentes a 4 anos de registos, foram carregadas no QGIS de forma que fosse possível analisar a sua sobreposição com as zonas de maiores concentrações de avistamentos de cachalotes. Para os navios de carga, o número mais elevado de rotas por km^2 por ano, em zonas de avistamentos, foi de 177 rotas por km^2 por ano entre as ilhas do Pico e São Jorge e 438 para São Miguel. No que diz respeito aos navios-petroleiros, foram registadas 137 rotas por km^2 por ano na ilha de São Miguel e 88 na ilha do Faial junto aos principais portos. Os navios de passageiros entre as ilhas do Faial e do Pico representaram a densidade de tráfego marítimo mais elevada, com 4726 rotas por km^2 por ano e 180 rotas km^2 por ano para São Miguel. Estes quatro anos correspondem a 167 avistamentos de cachalotes registados para ambas as regiões. De uma forma geral, as áreas que aparentam ser mais preocupantes relativamente à sobreposição entre avistamentos e tráfego marítimo são, para o Grupo Central, a área entre as ilhas do Faial, Pico e São Jorge, e para o Grupo Oriental, a área a sul de São Miguel. Apesar de não existirem registos de colisões de embarcações com cachalotes disponíveis para a região dos Açores, foram feitas recomendações de medidas de mitigação para os possíveis impactos desta ameaça. São recomendadas medidas de conservação, incluindo observadores a bordo dos ferries, limites de velocidade nas zonas de avistamento de baleias e canais de comunicação entre embarcações e vigias em terra.

Além disso, este estudo acresce informação valiosa relativamente à distribuição e presença de crias de cachalotes na região que poderá ser importante para estabelecer futuras áreas marinhas protegidas, complementando a Rede de Áreas Marinhas Protegidas dos Açores, de forma a salvaguardar habitats críticos, como áreas de maternidade e reprodução, onde os cachalotes são maioritariamente avistados com crias. Esta abordagem centraria os esforços de conservação na proteção das populações vulneráveis durante os períodos críticos do seu ciclo de vida. Estes resultados podem também ajudar a delinear planos de gestão adequados e uma linha de base para estudos futuros, contabilizando a distribuição das crias de cachalote nos Açores. É, no entanto, essencial uma investigação e monitorização contínuas para avaliar a eficácia das medidas de conservação, além de adaptar e melhorar estratégias conforme necessário.

Palavras-chave: Açores, cachalotes, crias, colisões com embarcações, conservação

Abstract

Data from multi-year records of sperm whales around São Miguel, Faial and Pico islands, reveal that sperm whale groups are present year-round calving in the Azores. Data from 2009 to 2022 were collected from the Naturalist company database and the MONICET platform, focusing on Terra Azul company sightings.

To evaluate habitat use we used both datasets, carrying out a Kruskal-Wallis analysis in RStudio revealing that depth is a significant factor influencing sperm whale habitat, with a preference for depths of 800-1100m. There was a notable presence of calves in the groups found in the Azores, with 55.2% of Central Group sightings and 22.5% of São Miguel Island sightings. Sperm whale births are regularly reported in the late spring and summer months, with August being the month with more births recorded.

Sperm whale habitats overlap with maritime traffic areas, particularly the ferry lines connecting Faial, Pico and São Jorge, for the Central Group and the area south of São Miguel for the Eastern Group due to the location of the main harbours. Conservation measures are recommended, including onboard observers for ferries, speed limits in whale sighting areas and communication channels between vessels and onshore lookouts. Additionally, the data adds further conservation value to safeguard critical habitats, such as areas where sperm whales gather for breeding and calving. This approach would focus conservation efforts on protecting vulnerable populations during critical life cycle periods.

Key-words: Azores, sperm whales, calves, ship collisions, conservation

Table of Contents

Index of Figures

Index of Tables

List of Abbreviations and Acronyms

DOP - Departamento de Oceanografia e Pescas

EEZ – Economic Exclusive Zone

IMO – International Maritime Organization

IUCN - International Union for Conservation of Nature

IWC – International Whaling Commission

MPA – Marine Protected Area

POPA - Programa de Observação das Pescas dos Açores

RAMPA – Rede de Áreas Marinhas Protegidas dos Açores

1. Introduction

The Azores archipelago in the North Atlantic Ocean has a complex oceanographic dynamic, which combined with the numerous seamounts in the area creates a variety of prime habitats for megafauna (Afonso et al., 2020; Gomes-Pereira et al., 2017). It is known as a global hotspot for cetacean diversity, with 28 different species recorded (M. A. Silva et al., 2014). Notably, it is one of the few places worldwide where sperm whales can be reliably observed year-round (International Whaling Commission, 2023a).

Sperm whales *(Physeter macrocephalus* L., 1758) are the largest species of toothed whales (Suborder Odontocetes) and are the cetaceans that exhibit the greatest sexual dimorphism in length and body weight. While adult females reach about 12 m in length and 15 tons, a physically mature male can reach approximately 18 meters and 45 tons (Best et al., 1984; Gosho et al., 1984; Rice, 1989; Shirihai et al., 2006). They can be found in all the deep oceans, from the equator to the ice edge of the Arctic and Antarctic, with their distribution varying greatly according to the sex of the individual (Figure 1.1). Female sperm whales almost always inhabit waters deeper than 1000 m and at latitudes lower than 40° (Rice, 1989). Males leave their pod between the ages of 4 and 21, forming male-only groups with individuals of approximately the same age, usually referred to as "bachelor schools", at which point they begin to move to ice edges at higher latitudes, and to more solitary lives over time (Steiner et al., 2012; van der Linde & Eriksson, 2019; Whitehead, 2018). When they reach sexual maturity, at an unknown time, male sperm whales begin their migrations returning to the warm tropical waters, to the breeding grounds (Whitehead, 2018).

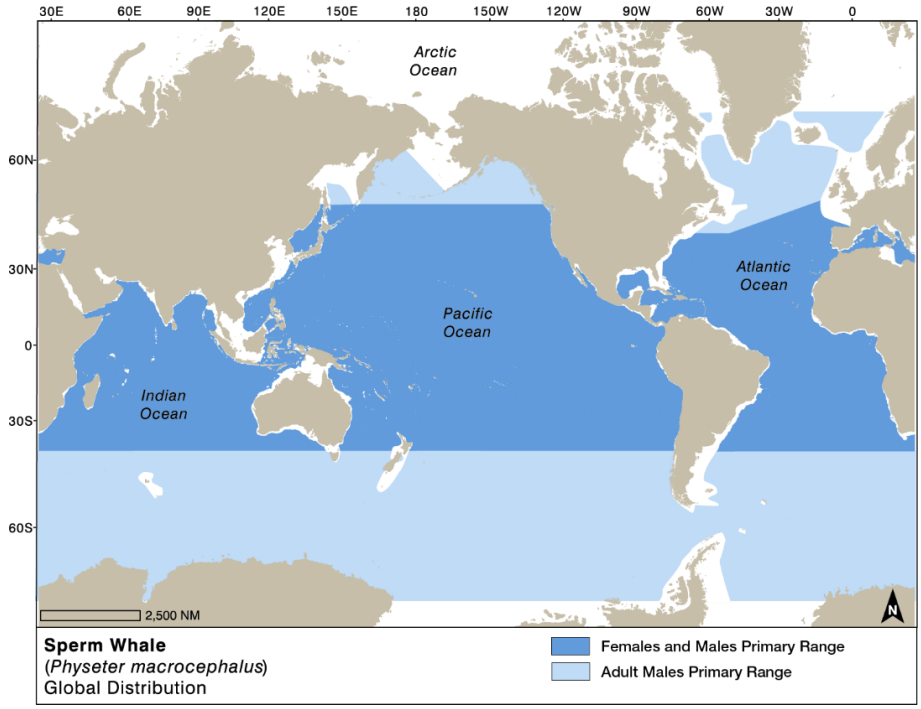

Figure 1.1 *- Sperm whale distribution* (source: International Whaling Commission, 2023a).

Social groups of females, calves and juveniles (Figure 1.2) usually show site fidelity (tendency of an animal to return to a previously occupied site) over the years in several locations with occasional visits of mature males (e.g., Galapagos, Whitehead, 1993; Caribbean, Gero et al., 2013; Mediterranean Sea, Frantzis et al., 2014; Macaronesia, Ferreira et al., 2022). In the Azores, sperm whales seem to be part of a large population, showing fidelity to this region which appears to constitute both a feeding and breeding ground (Clarke, 1956; Pinela et al., 2009; M. A. Silva et al., 2014; van der Linde & Eriksson,

2019). According to the North Atlantic Marine Mammal Commission (2016), there are an estimated 30,000 sperm whales in the North Atlantic, and approximately 300,000 worldwide. Sperm whales are globally designated as Vulnerable by the IUCN Red List of Threatened Species (International Whaling Commission, 2023b). For this reason, it becomes very important to understand the importance of the Azores archipelago for the species, especially given its relevance as a breeding area, so that conservation measures can be developed.

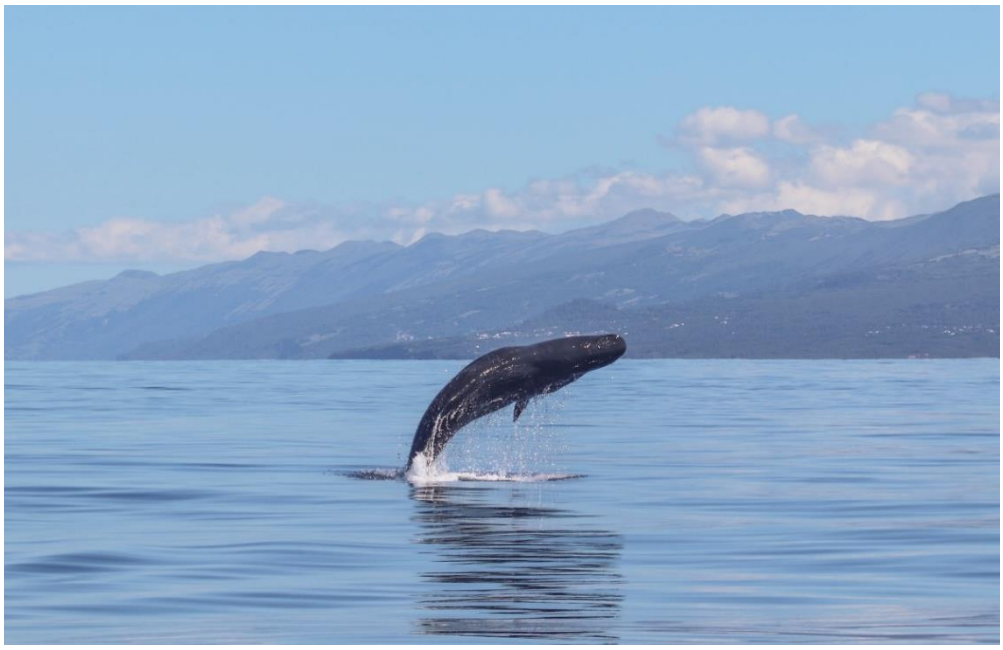

Figure 1.2 *- Young sperm whale breaching. Photo by: Naturalist, 19th of August 2022, in the vicinity of Faial Island.*

This species is still recovering from commercial whaling carried out between 1800 and the 1980s (ending definitively in 1987 in the Azores Archipelago) which had a major impact on the decline of its population (Vieira & Brito, 2009). After the end of the whaling period, sperm whales began to be highly sought after for whale-watching activities around 1989. Whale-watching is one of the fastest-growing tourism industries worldwide, often viewed as a sustainable, non-consumptive strategy for cetacean conservation and benefitting coastal communities (L. Silva, 2015).

Because of the predominantly offshore distribution of sperm whales, there are only a few places in the world where they can be regularly observed (International Whaling Commission, 2023a). In some regions, the development of whale-watching has provided the opportunity for continued data collection from whale-watching vessels operating out of different places including the Azores. However, although this activity has been ongoing for several years, there is no systematised data on the occurrence of this species in the region and on the archipelago's importance for the species, especially as a breeding area.

The main species observed are sperm whales, bottlenose dolphins, spotted dolphins, common dolphins, Risso's dolphins, striped dolphins, and short-finned pilot whales (Espaço Talassa, 2023; Pereira, 2008), where occasionally, some baleen whales can be observed passing by on their migratory routes. In the Azores whale watching vessels must follow the code of conduct that became legislation in 1999 (Decreto Legislativo Regional nº 9/99/A, de 22 de Março) and need to be licensed for this activity (DLR 10/2003/A) by the regional government, which helps limit the number of boats that can be around these species. On the other hand, there is still a great lack of information on the effects of boat operations on sperm whales in the Azores, with a study mentioning some disturbance signs in the whales' behaviour such as the change in their speed and the presence of aerial displays, from boat-

based observations (Magalhães et al., 2002) and a more recent study providing the first clues on the energetic constraints of the presence of boats (Oliveira et al., 2022).

The impact of anthropogenic activities on marine life is growing worldwide with the intensifying utilisation of the marine environment, including the increasing volume and speed of maritime traffic (Fais et al., 2016). The main threats to sperm whales can be related to fishing, including the entanglement in fishing gear and its ingestion and also other marine debris, and collisions with ships. There has also been an increase in depredation on longline fisheries by marine mammals, including sperm whales, resulting in competition between animals and humans over the same resources (Janc et al., 2018) which can become disadvantageous for both parts.
In Europe, some areas have been identified where high cetacean diversity and heavy marine traffic overlap, compromising some cetacean species populations such as those of the Mediterranean Sea, the Strait of Gibraltar and the Canary Islands (Arregui et al., 2019). In Macaronesia, specifically in the Canary Islands, ship collisions pose a significant threat to the sperm whale population, with one of the highest rates worldwide (Fais et al., 2016). This vulnerability is exacerbated by the species' tendency to spend extended periods "rafting" (Figure 1.3) at the surface between deep dives (Afonso et al., 2020) being frequently observed socializing or staying quiet at the surface possibly resting (Whitehead & Weilgart, 1991; Watkins et al., 1999). Given female philopatry and the complex social structure of this species, ship strikes appear to mostly affect females and young animals (Fais et al., 2016). The fact that the latter are not fully adapted to dive and need to spend more time at the surface, together with their relatively slow swimming speed compared to adults, may explain their higher vulnerability to ship strikes. By the same token, mothers with young calves may be at higher risk as they will spend more time at the surface with their offspring (Arregui et al., 2019). Even if there are no records of ship collisions with sperm whales in the Azores, due to the oceanic habits of sperm whales, they are likely to happen in offshore waters and remain unreported. This raises significant conservation concerns, especially since they continue to be susceptible to human-induced disturbances in these isolated oceanic archipelagos (Ferreira et al., 2022).

Figure 1.3 *- Mother and calf resting at the surface. Photo by Author, 5th of April 2023, in the vicinity of Faial Island.*

Since there is no study reporting the occurrence of sperm whale births in the Azores together with the use of the region as a breeding area, this thesis aims to fill this gap by taking advantage of the data collected by local whale-watching companies supervised by marine biologists over the last decade.

This dissertation's main goal is to assess the importance of the Azores as a maternity area for sperm whales. It evaluates whether the bathymetry of the region influences the use of its habitat, including the presence of calves in the groups. It analyses the seasonal and yearly distribution of the species around the Central Group of Azores and São Miguel Island. Based on a ship route analysis for the Azores, it also intends to assess the higher ship collision risk areas for sperm whales to propose conservation measures.

2. Materials and Methods

2.1 Study Area

The Azores is a Portuguese oceanic volcanic archipelago with nine islands, located in the North Atlantic Ocean, between latitudes 36◦55' and 39◦43' N and longitudes 24◦46' and 31◦16' W (Ávila et al., 2020), located approximately 1,800 km west of Portugal's capital, Lisbon (mainland Portugal). This archipelago is geographically divided into three groups (Figure 2.1): the western group - islands of Corvo and Flores; the central group - islands of Graciosa, Terceira, São Jorge, Faial and Pico; and the eastern group - islands of São Miguel and Santa Maria and the islets of Formigas (J. M. R. Pacheco et al., 2013). The study area is focused on the Central Group, mainly the marine area around Faial and Pico, and on the Eastern Group the area around São Miguel Island.

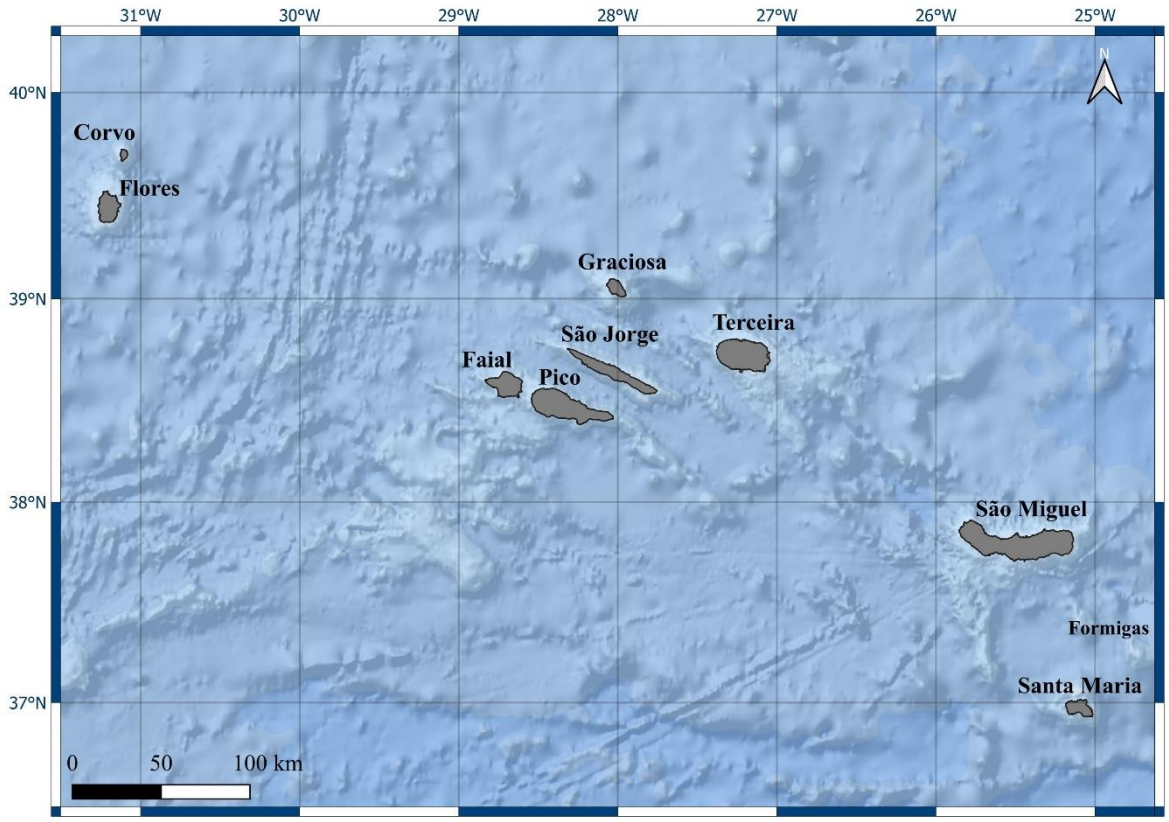

Figure 2.1 *- Autonomous Region of the Azores*

These islands are part of the Macaronesia biogeographic region (which also includes the archipelagos of Madeira, Canary Islands and Cape Verde), located on the northern boundary of the North Atlantic Subtropical Gyre and strongly influenced by the Gulf Stream that carries warm superficial water masses, of equatorial and tropical origin from the west to the cold waters of the North Atlantic. In this area, the Gulf Stream is divided into two branches: the North Atlantic Current in the north of the archipelago that continues to continental Europe; and the Azores Current that crosses towards southeast of the islands (Käse & Siedler, 1982).

This region has a rich and diverse marine ecosystem, characterized by a complex interaction of oceanographic features such as the Mid-Atlantic Ridge and the Azores Front. Some topographic features as the seamounts are thought to be common in the economic exclusive zone (EEZ) of the Azores archipelago, given the rugged volcanic and tectonically active seafloor that characterizes the region (Morato et al., 2008). This complex seabed topography is known to increase habitat diversity and enhance biological productivity by upwelling nutrient-rich waters into the photic zone likely increasing foraging opportunities for cetaceans, thus explaining the diversity of species encountered (M. A. Silva et al., 2014). This area includes a wide variety of marine habitats, with steep slopes and a wide range of depths, from shallow water areas on the very narrow continental shelf to deep waters that can reach more than 2000 meters relatively close to the coast (González, 2018).

2.2 Field data collection

For this study, boat-based encounter data collected opportunistically from 2016 to 2022 during whale-watching tours with the Naturalist company, by its biologists on board, was used. These tours usually took place around Faial Island and near Pico Island on a Zodiac boat. Tours took approximately 3 hours, being performed two to three times a day from about March to October and in the remaining months generally once a day. The number of trips depends on adequate weather conditions and a minimum number of customers. The cetaceans are usually sighted first by the lookouts or "vigias" on land, to ensure the sighting of at least one species during the tour and help guide the boats towards the locations where the species were found. Hydrophones were sometimes used to locate sperm whale individuals while they were diving and could not be spotted by the lookouts.

Participating in the data collection for the year 2023 (not considered in this study as it did not encompass a full year) with Naturalist, was a valuable opportunity to observe sperm whales, and many other species, and their behaviour, and to have a practical, hands-on understanding of the data collection methods used, including the sperm whale underwater detection methods using hydrophones.

Sperm whales' sighting data from MONICET (https://monicet.net/site2/about.html), was also used. MONICET is a platform that brings together observations made by different whale-watching companies, registered by their skippers and biologists/guides. Most companies' data collection did not fully fit this study's purposes, as many companies do not register calves' sightings. For that reason, only Terra Azul records were used, from all other islands besides Pico and Faial, with a considerable number of records of calves, in the São Miguel Island area. This process prevented overcounting by different sources on the same island. For the latter region, data was collected from 2009 to 2022 mostly all year-round but also more consistently from March to October.

On both datasets, the collected data included encounter date, start time, end time, position (GPS coordinates), group size, species encountered, minimum and maximum number of individuals spotted, number of calves (if present), behaviour, sea condition according to the wind (Beaufort scale) and boat presence, among others. Calves and juveniles were grouped since sometimes this identification is difficult to be accurately made.

Only one tour/sighting per day was considered for the number of sea days and the number of sperm whale observations to avoid the risk of overestimating observations of individuals and/or groups. Some data was also excluded from both datasets due to errors like missing coordinates or misplaced points (sperm whale sightings with coordinate points on land) or missing field values such as the life stage identification. The effort is then higher in areas closer to shore as well as in the months of spring and especially summer when weather and sea conditions are better. To minimise this issue, in this study the presence of other species was used as pseudo-absence, to count all the days when there were sea

tours, when no sperm whales were seen. Both datasets were then compiled and organised in a spreadsheet (Microsoft Excel).

2.3 Habitat

Bibliographic information was collected through the B-on platform, Google Scholar and Research Gate, regarding the target species, including distribution, known birth sites, population estimates, protection status, presence in the Azores region, occurrence patterns, type of groups and some environmental variables influence such as depth and slope. A search was conducted for studies from the earliest available records up to December 2023, considering some keywords such as: "sperm whales" and "births"; "sperm whales" and "Azores".

For the spatial distribution analysis, the spreadsheet with the sperm whales' observations data was loaded on the open-source geographic information system QGIS 3.30.0. Subsequently, some of the static variables that could influence the distribution of sperm whales were analysed, such as bathymetry, the slope of the ocean floor and distance from the coast. The distance from the coast was analysed since these islands have the characteristic of high depths at a short distance from the coast, which is an important factor for the species in terms of foraging.

Bathymetric data was obtained from the General Bathymetric Chart of the Oceans (www.gebco.net) and then imported to QGIS as a raster layer. A "contour" tool was also used to represent the bathymetric contour lines on the map. The bathymetry raster layer was also used to calculate the slopes for each observation point using the "slope" tool from Raster Terrain Analysis. Regarding the distance to the coast, a layer with the shapes of the Azores islands was added, from which the vertices were extracted with a vectorial geometry tool to allow the "distance matrix" tool (vectorial analysis) to calculate the distance between the sighting points and the vertices from the coast.

For the static variables, a statistical analysis on RStudio (RStudio Team, 2020) was performed for basic statistics such as mean depth, slope and distance to the coast. A null hypothesis was tested to assess whether there were significant differences in the preferred depth, slope, and distance from the coast of sperm whales between the Azores Central Group and the island of São Miguel. The null hypothesis tested the similarity of average values for each environmental variable across both locations.

First, the dataset normality (with Bartlett's test) was tested to understand if it was possible to apply an ANOVA. Since the data was non-normally distributed a Kruskal–Wallis test was instead applied. The Kruskal-Wallis is a non-parametric statistical test that assesses the differences among three or more independently sampled groups on a single, non-normally distributed continuous variable (Kruskal & Wallis, 1952). When the variable of interest does not meet normality assumptions, group means cannot be compared. This test is one option to analyse cetacean habitat distribution and has already been used in several studies (Azevedo et al., 2005; Di Sciara et al., 1993; López et al., 2004). These tests were also performed to check if there were differences in sperm whales' habitat use, according to the static variables, when there were calves present in the pods. The variables variance analysis would be considered statistically significant when the p-value on the Kruskal-Wallis analysis had a value lower than 0.05, in which case the null hypothesis was not rejected.

2.4 Births and calves' presence

In the data collected by Naturalist, observations recorded the minimum and maximum number of individuals (in this study, only the minimum number was considered) and the number of calves present

for each record (0 if there were no calves in the group). The MONICET data, included the numbers of individuals and there was a distinction between adults, juveniles and calves.

In both cases, being opportunistic datasets collected by several different observers, the sightings were not recorded uniformly so, in this study, instead of the number of calves present on each sighting, only calves' presence/absence was accounted for (0 and 1).

Some simple statistical analyses were performed to verify the presence of calves in the groups throughout the different years and seasons. It was not possible to make a distinction in groups (groups of females and calves or solitary males), so the only distinction made to analyse the presence of calves in the region was by considering two life stages: adults and calves (juveniles and calves considered together, as size may not have been accurately assessed by less experienced observers).

Each calf usually associates with several adults or subadults at the surface while its mother is on foraging dives (Gero et al., 2009). In general, individuals are considered calves when they present a body length of approximately up to 4 metres (Best et al., 1984; Whitehead, 2003) being easily distinguished from adult individuals, who usually have body lengths between 12 and 18 metres depending on their gender.

For each date, only one sighting of the species was considered (to avoid biased results). To analyse the percentage of calves present in the groups for both regions of the Azores according to seasonality, the number of sightings for each month was totalled, according to the type of group (adult individuals or groups made up of adults only and another for groups with calves' present), over the various years of the dataset. The number of tours/sea days for each month over the several years of the datasets was also totalled to serve as effort. This way it was possible to determine the encounter rate for both groups of sperm whales, by applying the following formulas:

$$\frac{Sum\ (nº\ of\ adults)}{Sum\ (nº\ of\ tours)} \times 100$$

$$\frac{Sum\ (nº\ of\ calves)}{Sum\ (nº\ of\ tours)} \times 100$$

Records of newborn sightings and births were collected from some partner companies and from bibliographic sources, including information on birthdate and time, birth description, the adult's behaviour before and after the birth and the behaviour of the newborn.

2.5 Ship Collisions

Of the different threats to the species, only ship collisions were considered, as they appear to particularly affect younger individuals, and represent one of the main potential threats to sperm whales in several regions. The dense maritime traffic, particularly in areas where sperm whales congregate, elevates the probability of such collisions. These encounters pose significant dangers to both whales and vessels, potentially resulting in injury or death for the whales and damage or disruption to maritime operations.

Moreover, the presence of calves and juveniles within sperm whale groups heightens their vulnerability to collisions, as younger individuals may be less adept at avoiding approaching vessels.

To understand if some high-density routes overlap with some of the species aggregation areas, route density maps were downloaded as GeoTIFF files from the EMODnet (EMODnet EU, 2022) catalogue. Route density maps were created by counting the number of routes (obtained by tracking each distinct

ship from the recorded positions during a given period) that cross each grid with a colour code corresponding to the number of crossings.

The occurrence and severity of ship collisions with cetaceans seem to increase with both the size and the speed of vessels (Fais et al., 2016). The types of ships most involved in collisions include cargo ships, tankers, cruise ships, high-speed ferries, and some sailing vessels (Carrillo, 2014; Laist et al., 2001; Ritter, 2012; Winkler et al., 2020). For this analysis, only 3 different types of ships we considered: tanker ships (liquids or gas transport ships, such as oil tankers, chemical tankers, and gas carriers), cargo ships (goods, and materials) and passenger ships (passenger transport at sea, which can include cruise ships and ferries). For each type of vessel, the files corresponding to 4 years of records (a raster layer corresponding to each year) from 2019 to 2022 were uploaded to QGIS, where the 4 raster files corresponding to each year were merged to form just one map for each type of vessel.

We utilized sighting data of calves from Naturalist and Terra Azul records during the specified timeframe to examine their presence in areas with high maritime traffic density. Additionally, we reviewed relevant literature on conservation measures for this species, considering the specific characteristics of the region.

3. Results

The original Naturalist dataset had 2,720 registers, of which 1,299 corresponded to sperm whale sightings. For the statistical analysis, an effort of 549 days (days with sea expeditions, avoiding the observations registers on repeated dates) was considered, of which 373 days where sperm whales were spotted (Figure 3.1).

The original MONICET dataset had records of 35,559 sightings, from different companies located in Faial, Pico, Terceira and São Miguel islands, of which 9,716 relating to sperm whales. This

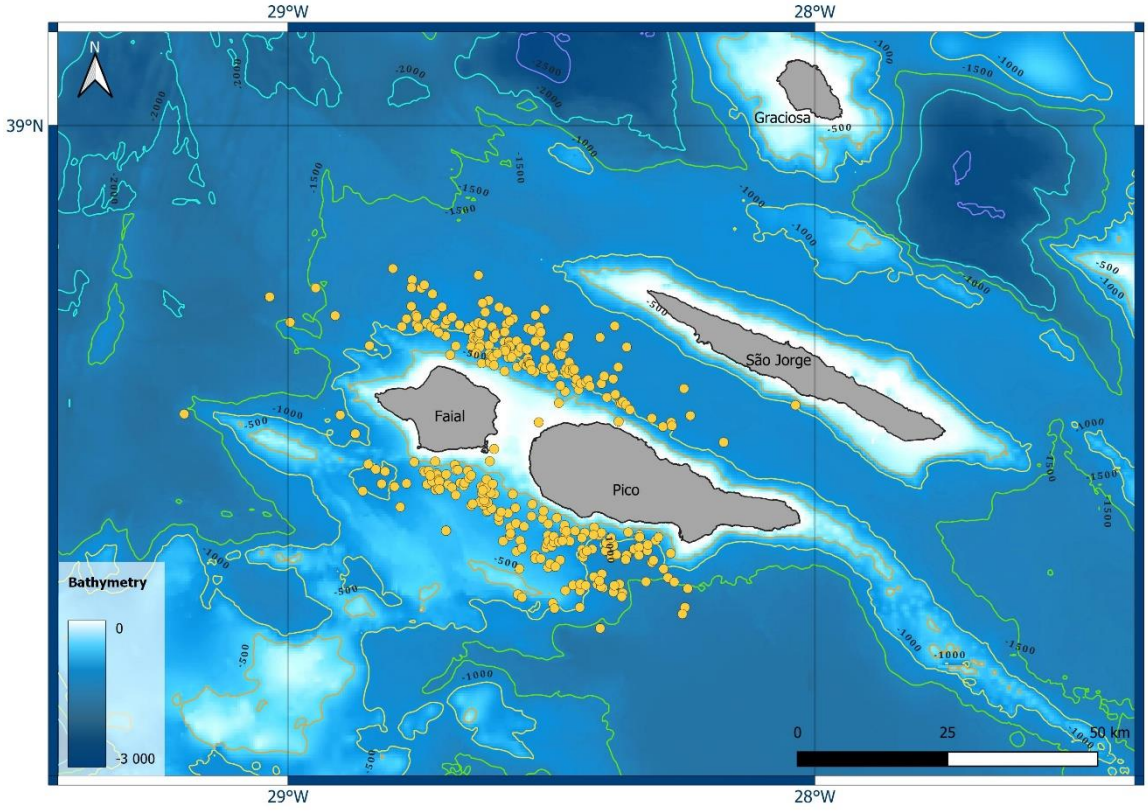

Figure 3.1 *- Sperm whale observations around Pico and Faial Islands.*

corresponded to 2,454 days of sperm whale sightings (1,228 in the Central Group and 1,126 São Miguel). Terra Azul was one of the companies with more sperm whale sightings records from the MONICET dataset that had more calves' sightings records, making it the only company with enough data to be considered in the statistical analysis, totalling 1,160 days were spotted sperm whales (Figure 2.2) from a total effort of 2,797 days (days with sea expeditions).

As shown in Figures 3.1 and 3.2, recorded sightings are limited to a certain distance from the coast, depending on the effort of the whale-watching companies. For the Central Group, the sightings are more dispersed, around Faial and Pico islands, since most lookouts of both islands work together for the various whale-watching companies. For São Miguel, the sightings are concentrated on the south part of the island since it is where most companies are located (Ponta Delgada and Vila Franca do Campo). Not only is S. Miguel a larger island, but the weather is typically better on the south coast, regarding mainly prevailing wind conditions.

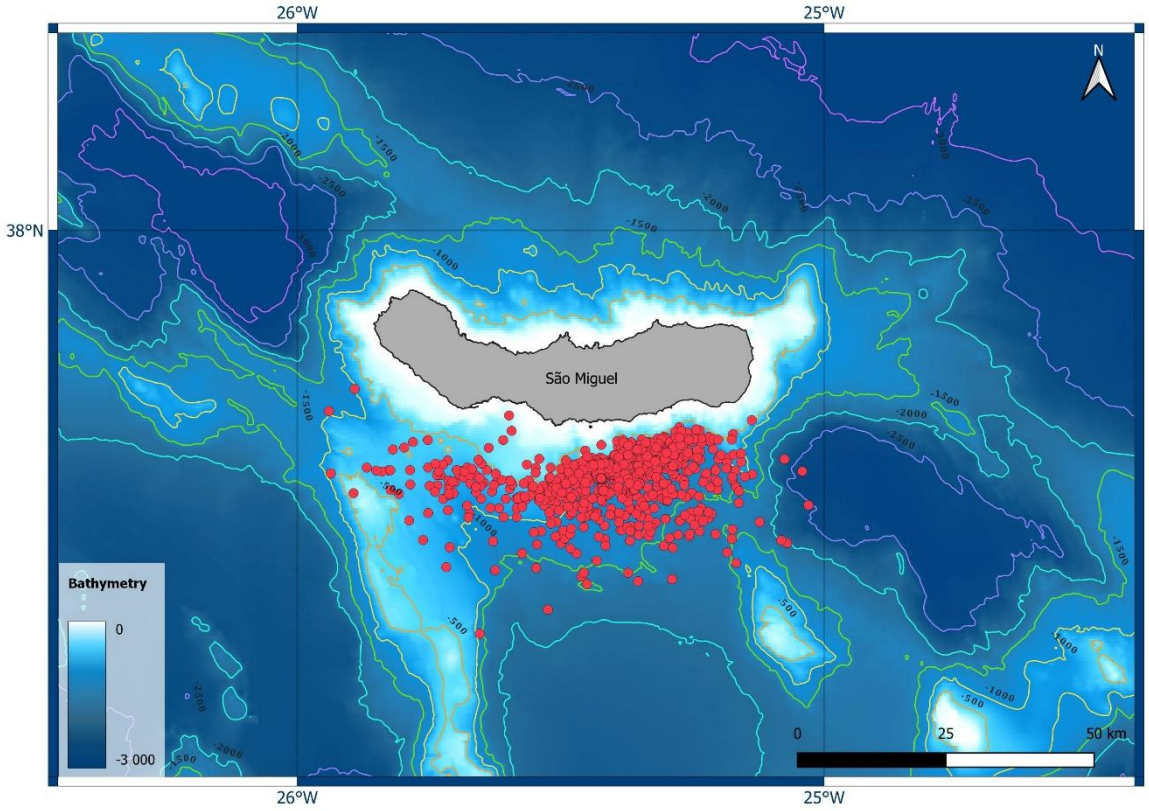

Figure 3.2 *- Sperm whale observations around São Miguel Island.*

3.1 Habitat

Figure 3.3 shows average, minimum and maximum values of depth, slope and distance to the coast obtained for each observation, where sperm whales were spotted for both regions of the Azores.

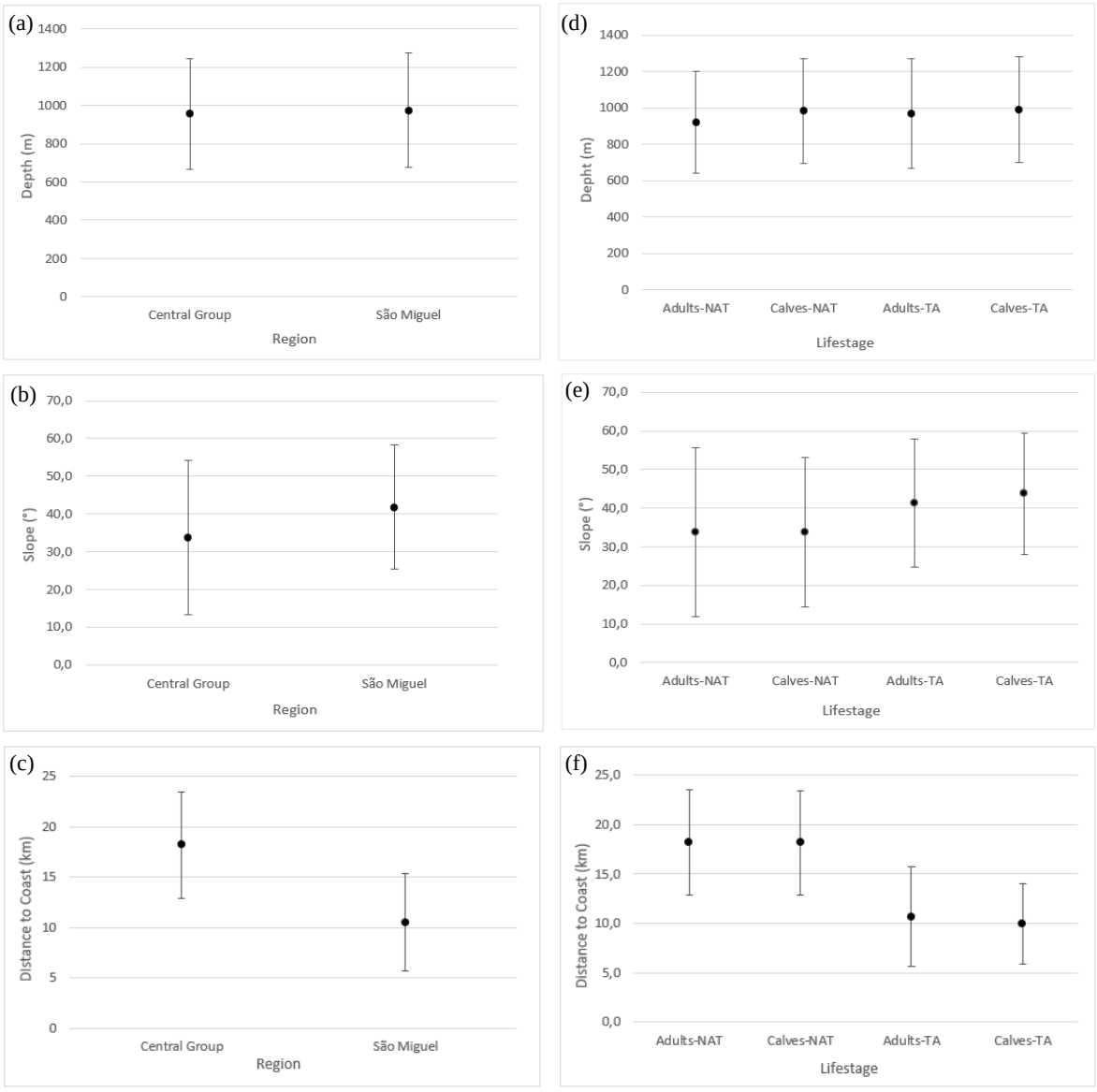

Figure 3.3 *- Mean values for (a) depth, (b) slope, (c) distance to the coast for each region and mean values for (d) depth, (e) slope and (f) distance to the coast for the different regions according to calves present or absence in the groups.*

The depths of the sightings recorded in the Central Group and São Miguel Island did not vary much, with an average value of 955 metres and 975 metres, respectively. For the slope values, a significant difference between both regions was observed, with a mean value of 41.8º for São Miguel and 33.7º for the central group. Some observations corresponded to a maximum value of approximately 77º. Regarding the distance to the coast for the observations, the mean value for the central group was 18 km and 10.5 km for São Miguel. When comparing the average values of the three geophysical parameters analysed associated with each sighting, there was no habitat preference based on the presence or absence of calves in the groups.

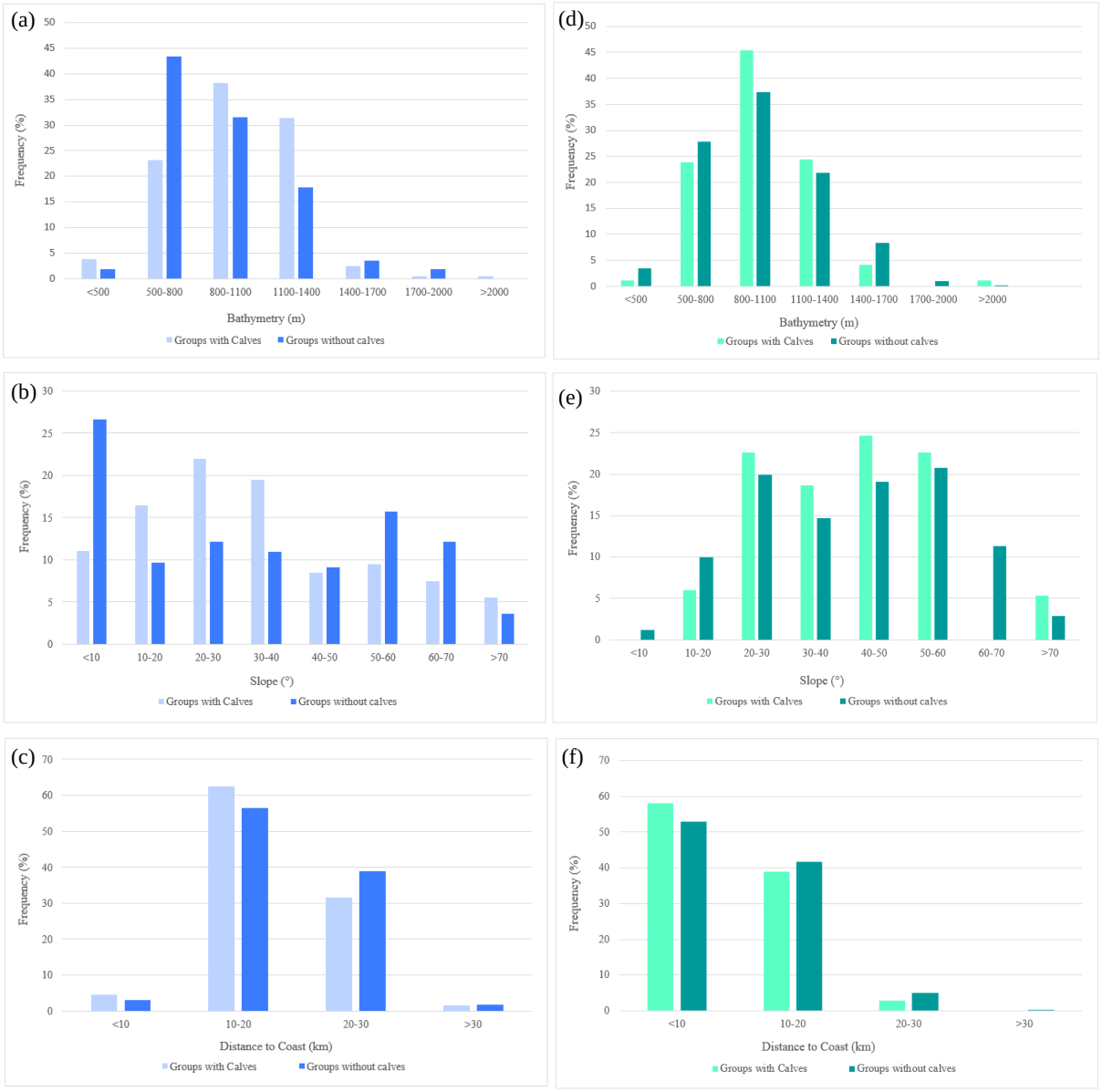

Figure 3.4 *- Sperm whales' distribution according to the considered static variables and region: (a) bathymetry, (b) bathymetric slope and (c) distance from the coast around the Central Group (mainly Faial Island); and (d) bathymetry, (e) bathymetric slope and distance from the coast around São Miguel Island.*

Some differences in the distribution of the groups with calves and those without calves were observed (Figure 3.4). Most sperm whales were spotted in areas with bathymetries ranging between 500 m and 1400 m, in both Central Group and São Miguel Island. In areas where bathymetries ranged between 500 m and 800 m, most sightings corresponded to groups without calves present, whereas for areas between 800-1100 m and 1100-1400 m, most groups sighted had calves present.

Regarding the slope, for the Central Group, sperm whale groups seemed to be relatively evenly distributed across different values, with the groups with calves standing out most between 10º and 40º in the Central Group and between 20º and 60º for the São Miguel region.

For the central group, the most common sighting distances were between 10 and 30 kilometres from the coast, with a greater occurrence of groups with calves between 10 and 20 kilometres. For São Miguel, a higher frequency of sightings was recorded closer to the coast, up to 20 km. This could be due to the type of routes/effort made by the various companies, and the influence of preferential depths location.

The statistical analysis relating to habitat use and depth (Table 3.1) showed no significant statistical differences between the sperm whales' preferred depths between the Central Group and S. Miguel (Kruskal-Wallis test, $\chi^2 = 2.9$; p-value = 0.0891). For slope (Kruskal-Wallis test, $\chi^2 = 121.2$; p-value < $2.2e^{-16}$) and distance to the coast (Kruskal-Wallis test, $\chi^2 = 1009.5$; p-value < $2.2e^{-16}$), both vary between the regions considered which means there were significant statistical differences.

Table 3.1 *- Kruskal Wallis analysis results for environmental variables.*

Environmental Variable	**Kruskal-Wallis (χ2)**	***p-value***
Depth	2.9	0.0891
Seafloor Slope	121.2	2.2e-16
Distance to the Coast	1009.5	2.2e-16

Regarding depth, the p-value shows that there are statistically significant differences between the depth values of the groups with and without calves for the sightings recorded by Naturalist (Kruskal-Wallis test, $\chi^2 = 10.6$; p-value = 0.0012), while for the Terra Azul records, there are no statistically significant differences between depths for the groups with and without calves (Kruskal-Wallis test, $\chi^2 = 0.2$; p-value = 0.6519). The Kruskal-Wallis analysis of the seafloor slope for the Central Group (Kruskal-Wallis test, $\chi^2 = 0.3$; p-value = 0.5698) and the island of São Miguel (Kruskal-Wallis test, $\chi^2 = 2.7$; p-value = 0.1006) showed that there were no statistically significant differences between the groups with and without calves according to the slopes where sperm whale sightings were recorded.

When analysing whether the presence of calves in groups would change according to the distance from the coast for the Central Group (Kruskal-Wallis test, $\chi^2 = 0.7$; p-value = 0.3974) and São Miguel island (Kruskal-Wallis test, $\chi^2 = 2.7$; p-value = 0.103), it showed that for both regions the distance did not have an influence (Table 3.2).

Table 3.2 *- Kruskal Wallis analysis results for calves' presence influence on habitat use according to the different environmental variables, for both Central Group and São Miguel Island.*

Area	**Environmental Variable**	**Kruskal-Wallis (χ2)**	***p-value***
Central Group	Depth	10.6	0.0012
	Seafloor Slope	0.3	0.5698
	Distance to the Coast	0.7	0.3974
São Miguel	Depth	0.2	0.6519
	Seafloor Slope	2.7	0.1006
	Distance to the Coast	2.7	0.103

3.2 Calves Presence and Births

Figure 3.5 shows all the sperm whale records made by Naturalist and the various maritime-tourism companies that provided their data to MONICET. Figure 3.6 represents the locations of groups with calves' sightings recorded by the various companies.

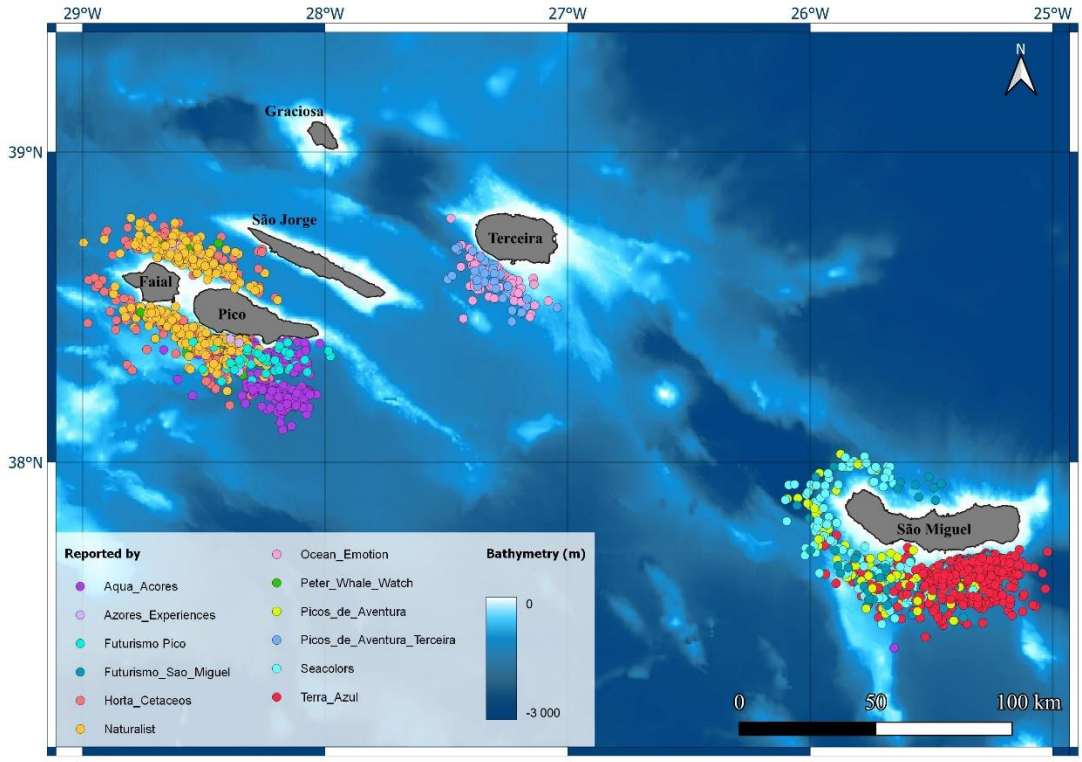

Figure 3.5 *- All sperm whale sightings from MONICET and Naturalist datasets.*

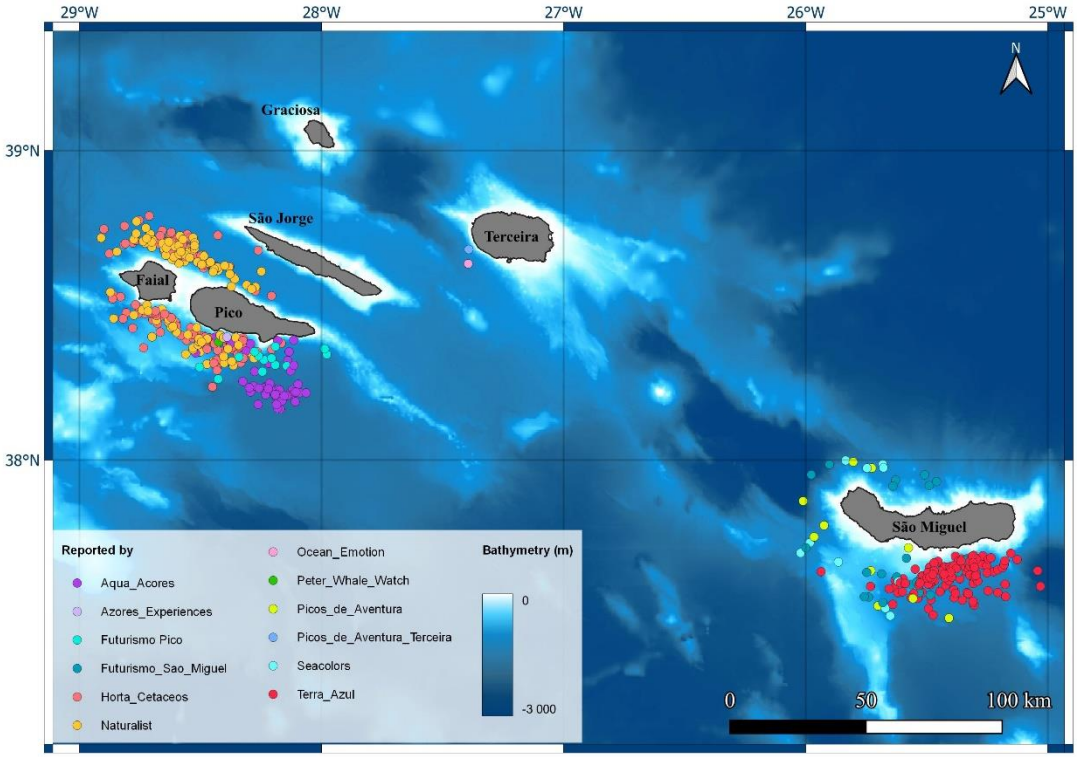

Figure 3.6 *- All sperm whale calves sightings from MONICET and Naturalist datasets.*

Many companies did not record the life stage of the individual of the respective sighting, as can be seen in Figure 3.7, which also shows the records of groups with and without calves and the corresponding total number of individuals recorded by each company. This allows an analysis of the proportion of groups with and without calves, considering the total number of individuals.

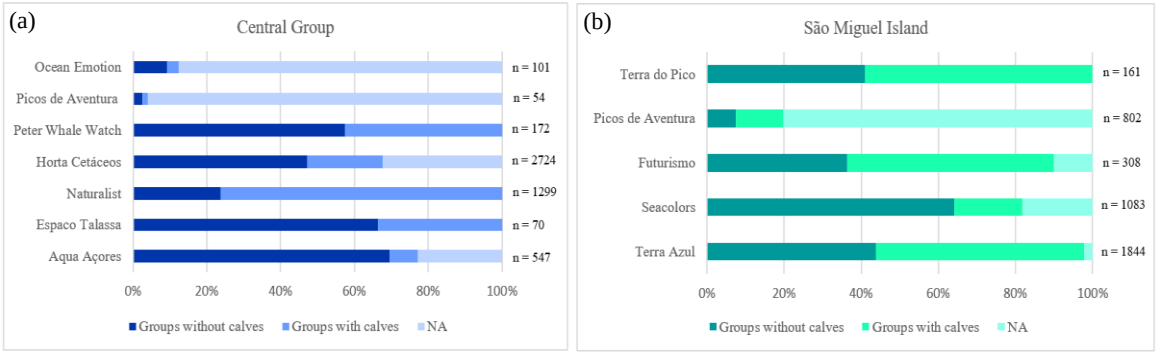

Figure 3.7 *– Sightings recorded by the different companies (a) in the Central Group and (b) in São Miguel, according to the presence/absence of calves in the groups (NA – not available) with n = number of registered sightings per company (without repeated days).*

Figure 3.8 shows all the sperm whale sightings from Naturalist and Terra Azul (the companies were selected based on the greater number of sighting records of sperm whales and their calves) and Figure 3.9 illustrates the distribution of calves' sightings in the different regions.

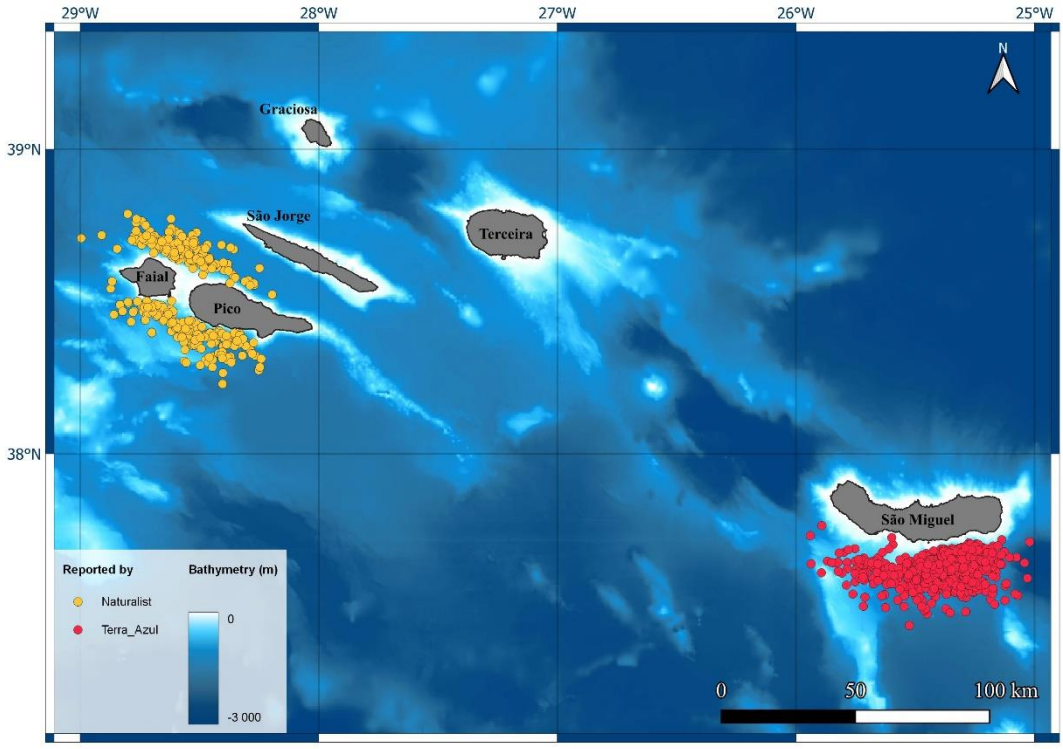

Figure 3.8 *- Sperm whale sightings collected by Naturalist and Terra Azul.*

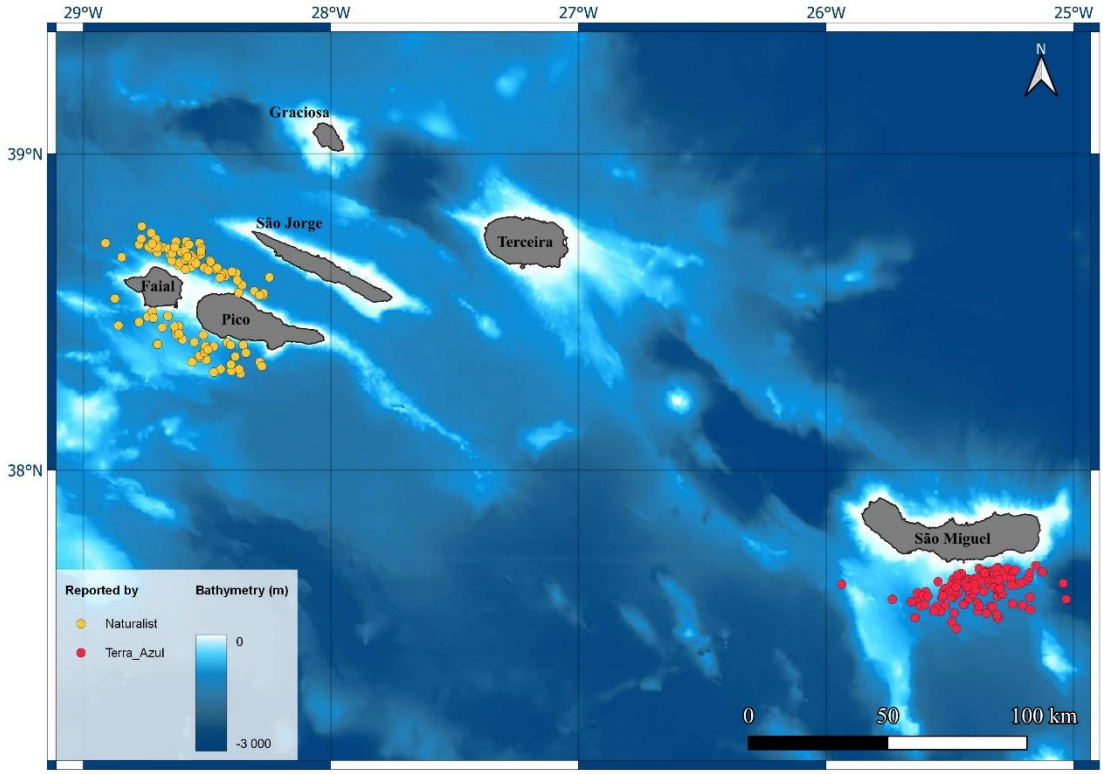

Figure 3.9 *- Sperm whale calf sightings collected by Naturalist and Terra Azul.*

Figure 3.10 shows the sperm whales' group structure obtained from the analysis of the sighting records of both companies. In the Central Group, 55.2 per cent of sightings corresponded to groups with calves, while on the island of São Miguel, only 22.5 per cent were of groups with calves. It should be noted that, on many occasions, not enough time is spent with the sperm whale groups to allow an accurate assessment of the presence or absence of calves in the group.

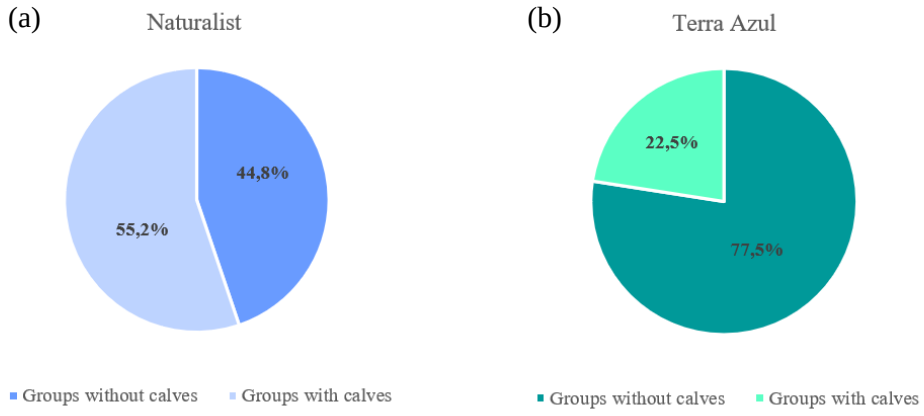

Figure 3.10 *- Percentage of sightings representing each group type by (a) Naturalist and (b) Terra Azul.*

The seasonal distribution of the species, and more specifically of the calves and juveniles, can be analysed in Figure 3.11, showing the presence of the species in the Central Group from the Naturalist dataset, and in Figure 3.12 showing the presence of the species in the surrounding region of São Miguel Island from Terra Azul dataset. The calves are present practically all year round on the Central Group, with a peak in July. These results do not appear to be directly associated with the observation effort. Although there were no tours between November and February, and therefore no data for this time of the year, it is expected/believed that the animals remain in the region.

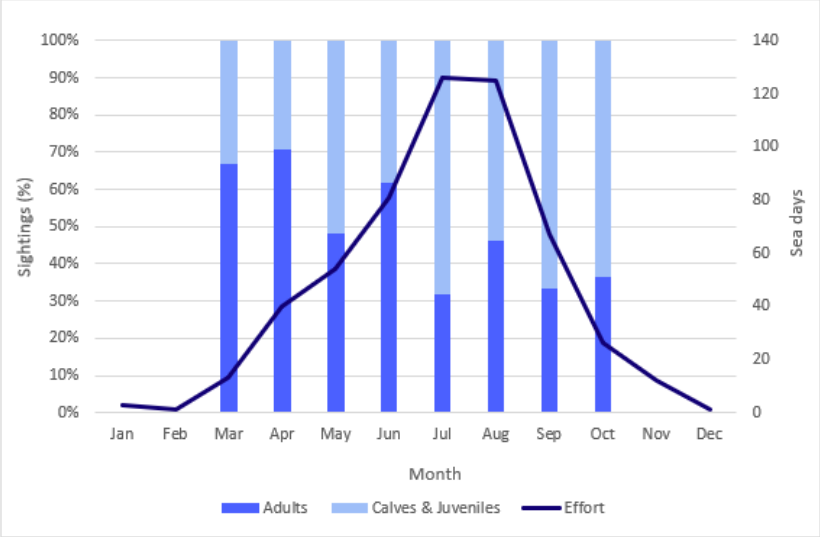

Figure 3.11 *- Total number of days per month on which adult sperm whales (n = 166) and groups with calves (n = 207) were sighted from March to October [2016 – 2022], where the effort (n = 549) corresponds to the total number of days where Naturalist performed tours.*

Analysis of the sightings registered around São Miguel Island over the years, show that the calves are present in most months other than February and December. These results do not appear to be directly associated with the observation effort. The results for S. Miguel seem to show a smaller proportion of sperm whale calves and juveniles present in the groups compared to the results obtained for the Central Group. For this region there was a wider period of years (2009 to 2022) on the dataset compared to Central Group (2016 to 2022), having more survey/tour days in account as well as more sightings recorded.

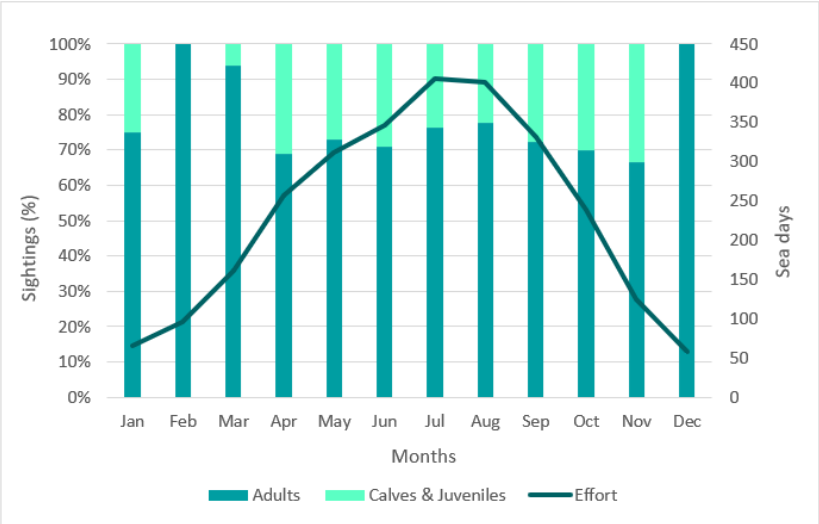

Figure 3.12 *- Total number of days per month on which adult sperm whales (n = 861) and groups with calves (n = 299) were sighted, from January to December [2009 – 2022], where the effort (n = 2797) corresponds to the total number of days where Terra Azul performed tours.*

The records of sperm whale births in the Azores gathered from the bibliography and different companies' records are listed in Tables 3.3 and 3.4, organized by event with the corresponding description.

Table 3.3 *- Summary of the birth record events*

Event	Status	Date	Location	Reagion/Area	Name
A	Birth	2016.06.20	São Miguel Island	North of São Miguel	Futurismo Azores
B	Birth	2016.06.20	São Miguel Island	North of São Miguel	Futurismo Azores
C	Birth	2016.06.20	São Miguel Island	North of São Miguel	Futurismo Azores
D	Birth	2021.08.18	Faial Island	North of Faial	Naturalist
E	Birth	2021.08.18	São Miguel Island	NA	Futurismo Azores
F	Birth/ Newborn	2021.09.(1st week)	Faial Island	Northwest of Faial	Brachmann
G	Very young	2022.08.20	Pico-São Jorge Channel	NA	Naturalist
H	Birth	2022.08.23	Santa Maria Island	North Coast of Santa Maria	Diogo Martins
I	Birth	2023.07.23	São Miguel Island	NA	Terra Azul

Table 3.4 *- Events Description*

Event	Status	Adult behavior prior & during the event	Adult behavior posterior	Calf behavior	Calf Size	Placenta observed	Umbilical remains
A	Birth	Estimated 50 sperm whales in the area, more or less 30 near the boat; they began to gather; agitation, tails out of the water; "clicks" sound; blood stain in the water;	"The mother seemed excited to show the calf to the boat, pushing her towards it"	Head out of the water; approaching the boat	NA	Blood stain at the water surface	NA
B	Birth	More or less 30 individuals near the boat; they began to gather; agitation, tails out of the water; "clicks" sound; blood stain in the water;	Lots of aggitation and heads out of the water	NA	NA	Blood stain at the water surface	NA
C	Birth	More or less 30 individuals near the boat; they began to gather; agitation, tails out of the water; "clicks" sound; blood stain in the water;	NA	NA	NA	Blood stain at the water surface	NA
D	Birth	Diving, socialization and some agitation; Tails in the air; Blood stain at the surface;	NA	Head out of the water	Small	Blood stain at the water surface	NA
E	Birth	Group agitation	Agitation, heads out of the water; and after the group moved in the direction of the boat to "show" the calf	Head out of the water	3/4m	Blood stain at the water surface	NA
F	Birth/ Newborn	Breaching observed several times	The adult approached following the calf towards the divers	Stayed in the location and approached the divers to inspect	NA	Brown/darker water	Yes
G	Very Young	Socializing with other juveniles	As the calf approached the zodiac boat, the engine was switched off. The young whale stayed close to the boat around 12 minutes	Attraction to boat	Less than 4,5m	No	NA
H	Birth	NA	Mother and calves at the surface initially, then moved near a socializing group (around 10 individuals).	NA	NA	Blood stain; tissues in the water; Tissue sampled;	NA
I	Birth	9-10 sperm whales calmly resting, socialising and sleeping vertically. Suddenly the whales started grouping together, splashing the water; codas and squeals were heard on the hydrophones.	The surrounding family members - adults and juveniles - were all so focused on taking care of the mother and her newborn. They repeatedly pushed the minutes old baby out of the water to help it take its first breaths.	Head out of the water	NA	NA	NA

Most births were described in very similar ways, starting with the aggregation of several individuals present in the area socialising and showing some agitation, with their tails out of the water and splashing, also with audible clicks on the surface. A bloodstain is then seen on the surface in dark red/brown colours and, after a few moments, the newborn is spotted, easily identified by its more wrinkled body with "fetal folds", in addition to a smaller size of approximately 4m long. Some observations report that newborns seem to be rather curious about the boats, sticking their heads out of the water, a behaviour known as "spy-hopping". They sometimes appear to head in the direction of the boat (it is uncertain if this behaviour is deliberate or not). The births reported here occurred in the summer between June and September, with August being the month with more births recorded (Figure 3.13).

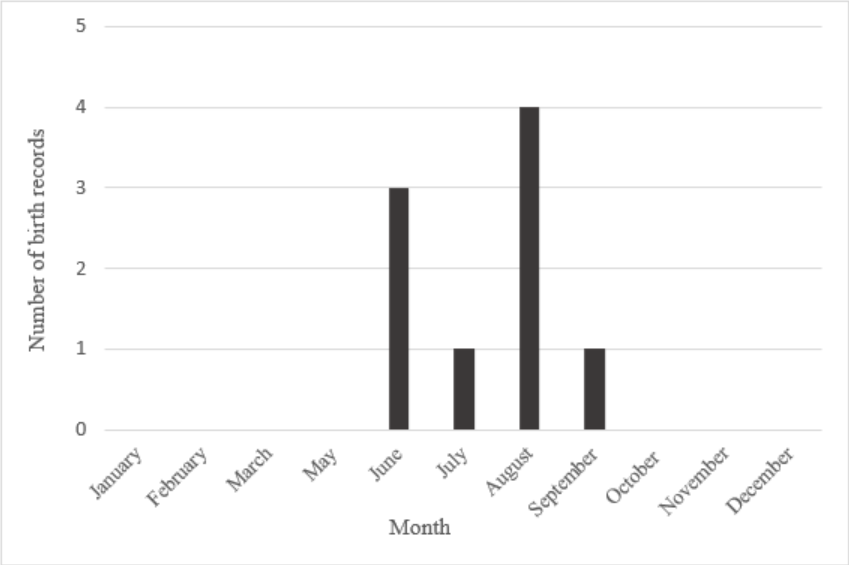

Figure 3.13 *- Available sperm whales' birth records that occurred in Azores (2016 to 2023) recorded by whale watching companies.*

3.3 Ship Collisions

The analysis of the routes of the 3 different main types of ship (cargo ships, tanker ships and passenger ships), highlighted the areas with the highest marine traffic intensity. For cargo ships, the maximum number was 466 of crossings per km^2 per year near Terceira Island's main port, in comparison with 177 routes per km^2 per year between Pico and São Jorge Islands, and 438 for São Miguel (Figure 3.14). For tanker ships, it was 137 crossings per km^2 per year for São Miguel Island and 88 for Faial Island (Figure 3.15). Passenger ships between Faial and Pico islands represented the highest marine traffic density, with 4726 crossings per km^2 per year and 180 for São Miguel (Figure 3.16).

During these four years, 167 sperm whale calves' sightings were recorded by Naturalist and Terra Azul. Some of them overlap with areas with a medium level of maritime traffic intensity, for cargo and tanker ships, and a higher level of maritime traffic intensity for passenger ships in the Faial-São Jorge and Pico-São Jorge areas. As for the Faial-Pico route, the one with the highest passenger ship traffic intensity, it does not seem to overlap with any of the sperm whale calves' sightings.

In general, the most concerning areas of overlap between sightings and maritime traffic are, for the Central Group, the area between the islands of Faial, Pico and São Jorge, and in the case of the Eastern Group, the area south of São Miguel.

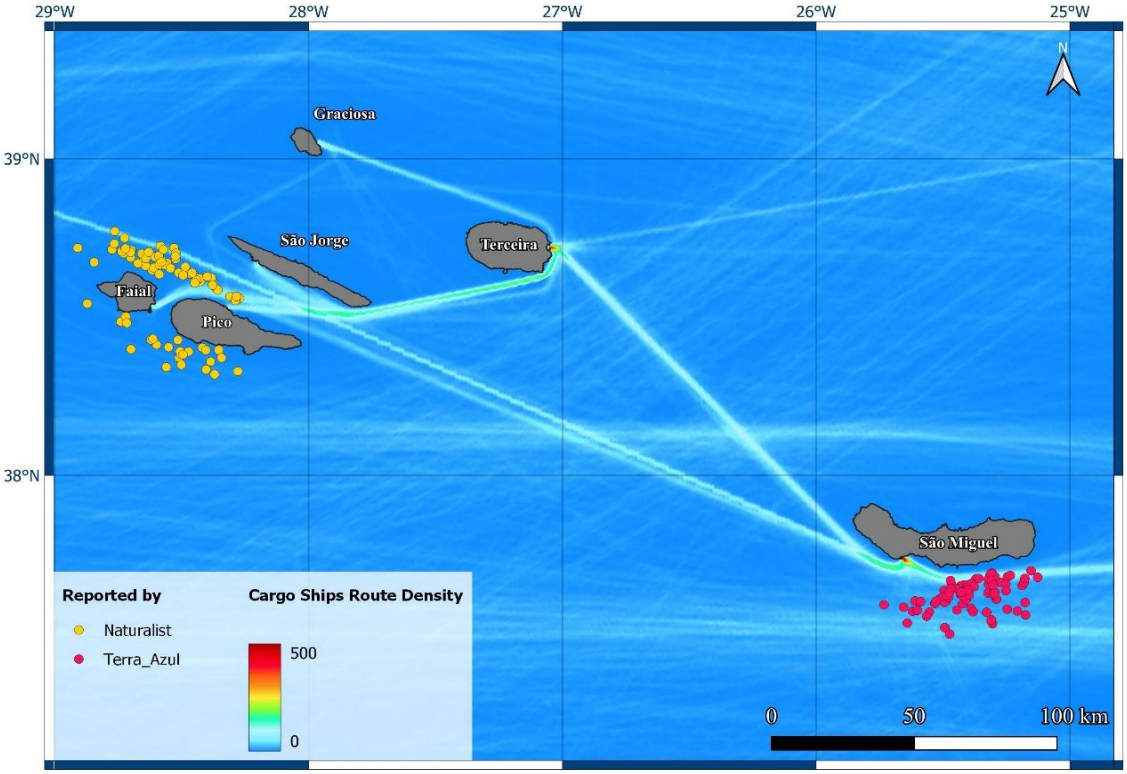

Figure 3.14 *- Cargo ships' route density overlaps with sperm whale calves' sightings from Naturalis and Terra Azul, from 2019 to 2022.*

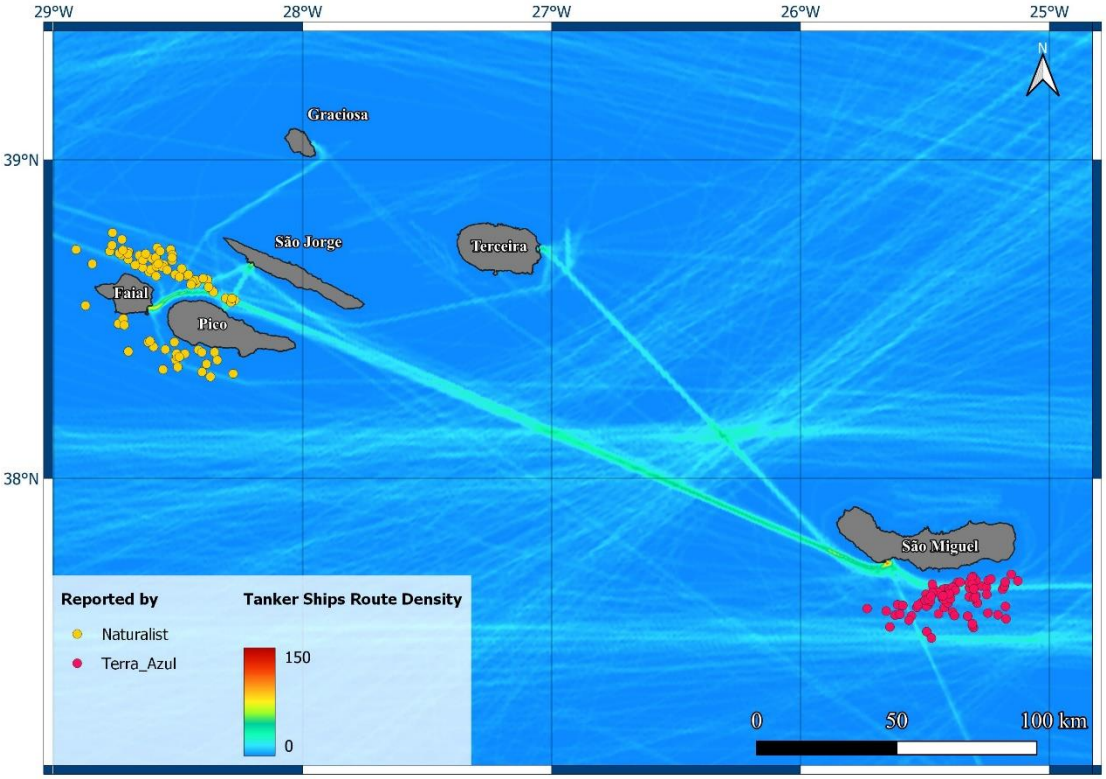

Figure 3.15 *- Tanker ships' route density overlaps with sperm whale calves' sightings from Naturalis and Terra Azul, from 2019 to 2022.*

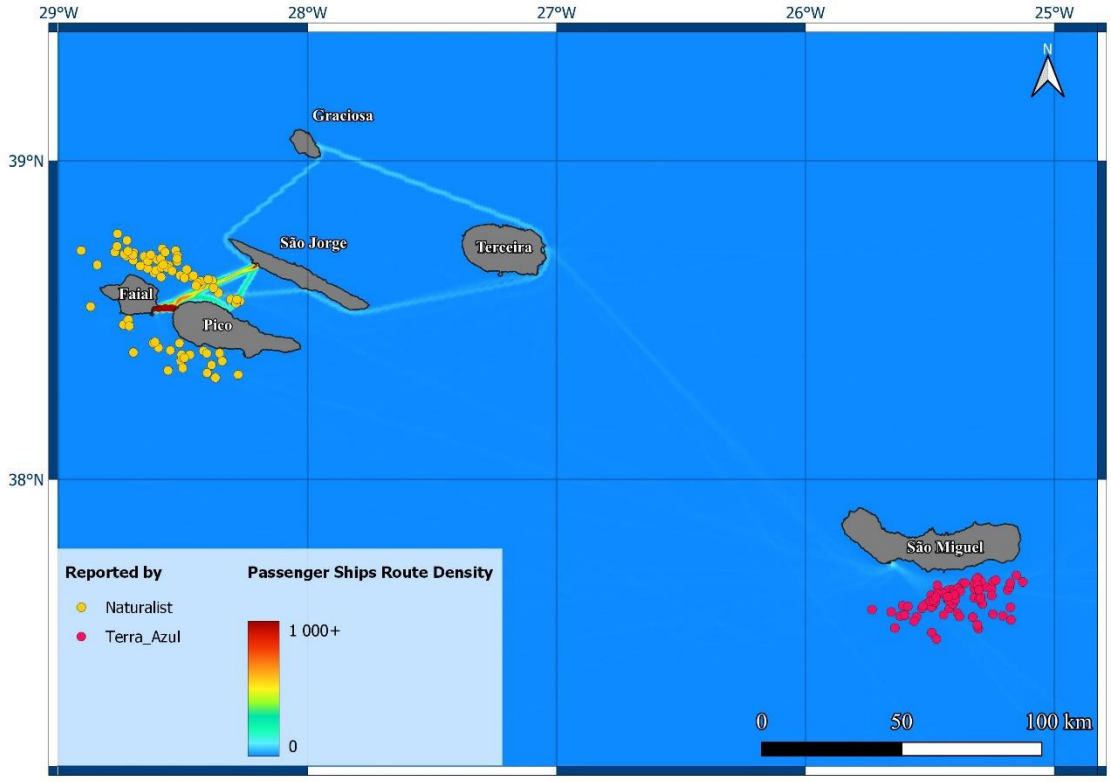

Figure 3.16 *- Passenger ships' route density overlaps with sperm whale calves' sightings from Naturalis and Terra Azul, from 2019 to 2022.*

4. Discussion

Although some studies mentioned sperm whale calves in the Azores (Coelho, 2021; van der Linde & Eriksson, 2019), this was the first study focused on sperm whales' births and calves' presence in the Azores islands, comprising both central and eastern groups of islands (Faial, Pico, São Jorge and São Miguel islands).

4.1 Environmental Variables

Depth appears to be the main variable influencing the distribution of sperm whales, highlighting the species' preference for waters deeper than 500 m, corroborating the findings of several previous studies (Coelho, 2021; Johnson et al., 2016; Oliveira & Wahlberg, 2016; Pirotta et al., 2011; Sahri et al., 2020; Seabra et al., 2005). Between the Central Group and S. Miguel Island there were no statistically significant differences, meaning that the average depth values for both regions associated with the sightings distribution may reinforce the species' preference for certain bathymetry intervals that are assumed to be related to the bathymetric zonation of cephalopod assemblages (Quetglas et al., 2000). When analysing the variables concerning the groups with and without calves present, only depth showed statistically significant differences for the Central Group, where slightly greater depths were found for the groups with calves. One possible explanation could be that the mothers are in search of food at greater depths, while the calves remain on the surface with the rest of the group (Gero et al., 2013).

The fact that there were statistically significant differences in the values for slope and distance from the coast between the sightings in the Central Group and São Miguel is related to the source data,

referring to the specific geomorphology of each site. It may indicate that these variables can be associated with depth and possibly vary with the seafloor characteristics. The steepness of the slope does not seem to influence the species' distribution directly as already verified in a previous study (Pirotta et al., 2011), nor does the distance from the coast. However, the complex ocean floor bathymetry of steep slopes, seamounts and canyons together with downwelling/upwelling water movements is often considered crucial for the aggregation of sperm whales' prey (Gannier et al., 2002; Pace et al., 2018; Pirotta et al., 2020; Praca et al., 2009; Virgili et al., 2022). Distance from the coast can vary from one island to another according to the different ocean floor bathymetry, related to sperm whales' preferential depths located at different distances from the coast, depending most likely on the different whale watching companies' efforts. Around São Miguel Island "ideal" depths (c. 800 m) can be found further away from the shore, in comparison with Pico and Faial islands, meaning that Terra Azul might have go further away from the coast to reach those average depths.

4.2 Sperm whales' calves and births

The presence of calves in the groups does not seem to influence habitat use according to this dataset. A possible preference for occurrence in the vicinity of the islands would only be possible to access with a region wide dataset. Sperm whales are present all year round in the archipelago. For the São Miguel Island region, sperm whales were sighted throughout the year and only in february and december, were there no sperm whale calf sightings. For the Central group area, sperm whales were sighted during all months covered by the dataset, from March to October and throughout these months there were always calves present. It should be noted that the months in which there were no sightings of sperm whales are winter months when there are fewer tours due to bad weather/sea conditions. From a study that considered POPA (Observation Programme for Fisheries in the Azores) and DOP (Department of Oceanography and Fisheries, of University of the Azores) surveys that include offshore sightings data, it is possible to confirm that there are groups of females accompanied by juveniles and calves around the archipelago every month (M. A. Silva et al., 2014).

Sperm whales perform movements within and beyond the archipelago (Matthews et al., 2001; M. A. Silva et al., 2014; Steiner et al., 2012, 2015) and based on photo-identification records, it is estimated that 300 individuals visit the area around Faial and Pico (Boys et al., 2019) and 393 individuals around São Miguel Island (van der Linde & Eriksson, 2019). These movements could be one reason why calves were not sighted during all months by the whale-watching companies.

The Azores region can be considered a nursery area for sperm whales in the North Atlantic. Births of sperm whales recorded in the Azores take place mainly from June to September, with a peak in August as suggested in previous studies in the archipelago (M. A. Silva et al., 2014; van der Linde & Eriksson, 2019) and confirmed in this study. Together with the presence of calves all year round, the Azores can be considered a nursery and breeding site of great importance for sperm whales, where many give birth, and raise their calves (Clarke, 1956; Pinela et al., 2009; M. A. Silva et al., 2014).

4.3 Ship Collisions

Sperm whales may occupy preferred areas within an archipelago likely indicating important foraging habitats (Fais et al., 2016), which can also apply to the Azores. These habitats could occur in areas where there are more sightings, which sometimes coincide with areas of high maritime traffic density, increasing the ship-strike risk, like for Pico-São Jorge canal and the southeast area of São Miguel. These areas should be considered important to protect, especially considering the frequent presence of calves and juveniles, who tend to spend more time at the surface and are therefore more vulnerable to

collisions with vessels (Carrillo & Ritter, 2010; Laist et al., 2001). Although there are few records of ship collisions with whales in the Azores, this does not mean that they do not occur, as many may go unreported. Furthermore, these islands are characterised mostly by rocky coastlines rather than shallow slopes with beaches where whales are more likely to be found when washed ashore (van Der Linde, 2019).

Given that ferries navigate between islands and rerouting their paths is not feasible, a practical approach could involve deploying onboard observers, a measure already adopted by POPA in certain cases. Additionally, implementing lower speed limits at certain bathymetries would allow for increased manoeuvring time following whale sightings. Specifically, a suggestion could be made to decrease the speed of ferries when navigating through bathymetries between 800 and 1100 meters, where sperm whales are frequently observed. Establishing communication channels between these vessels and onshore lookouts would also be valuable, enabling land-based observers to alert ferry operators about the presence of whales along their routes, increasing awareness and reducing the risk of collisions.

For the remaining types of ships analysed, rerouting cargo and tanker ships not destined for the Azores around the archipelago's maritime internal waters, would be a management measure that could be implemented through specific provisions. Internal maritime waters, resulting from UNCLOS (United Nations Convention on the Law of the Sea), include waterways such as rivers and canals, and sometimes the water within small bays, where foreign ships have no right of passage without the coastal state's authorization to do so. In the case of archipelagic states, the coastal waters between islands are treated as inland waters, but foreign ships must be allowed innocent passage. In the Azores archipelago, inland waters are distributed among the three island groups: internal waters of the islands of S. Miguel and Sta Maria, and the Formigas islets; the maritime space that includes Faial, Pico and S. Jorge channels; and the area between the islands of Corvo and Flores. The total area of the maritime internal waters of the Azores Archipelago is around 6,082 km^2 (Pacheco, 2013). Taking these areas into account, some of the shipping lanes could be redefined to avoid the passage of these types of ships in the most "sensitive" areas for sperm whale populations, i.e. where the highest concentration of sperm whale calf sightings take place. The routes could avoid the internal waters of the island groups (Pico-Faial-São Jorge and São Miguel-Santa Maria channels). This alteration to routes is only justified if it is possible to collect records of ship collisions with sperm whales and/or disturbances to the species in the Azores, possibly through observers on board these vessels.

Furthermore, establishing educational programs and increasing awareness among sailors about the presence of sperm whales and the importance of their conservation can lead to voluntary compliance with regulations and best practices. The programme could include information on the bathymetries where sperm whales predominantly occur so that greater precaution is taken in these areas. Although greater awareness can lead to greater caution by mariners, it is essential to balance the benefits of raising awareness with the potential risks of increasing the number of boats in these areas, which can affect the animals' welfare.

Given the importance of the Azores as a maternity area for sperm whales and their conservation, the creation of marine protected areas could be very important. In the Caribbean Sea, Dominica Island has recently created the world's first marine protected area for sperm whales which serves as key nursing and feeding grounds aiming for this species' conservation and considering their help combating climate change - circulation of nutrients derived from the vertical movement of whales (The Guardian, 2023). Both in this region and in the Azores, most groups are composed of females and calves, making the protection of the species fundamental in these areas as it could stimulate the development of the population. The reproductive biology of sperm whales adds another layer of complexity to conservation efforts. Female sperm whales typically give birth to a single calf approximately once

every five to seven years, with a gestation period lasting around 15 to 16 months (Whitehead, 2003). This means that each birth is a significant event for the population, and the loss of even a few individuals, particularly reproductive females or calves, can have a substantial impact on the overall population dynamics. Protecting areas where sperm whales aggregate during critical life stages, such as breeding and calving, becomes crucial.

Marine protected areas can serve as vital habitats for the species' survival and recovery. By designating MPAs in regions where sperm whales congregate for breeding and calving, conservation efforts can focus on protecting these vulnerable populations during critical periods of their life cycle. By safeguarding these key habitats, we can help ensure the long-term viability of sperm whale populations despite their wide distribution and slow reproductive rate. The results of this study may contribute to the future development of the (Azores Marine Protected Areas Network), a fundamental instrument in the recovery and conservation of marine biodiversity, and to inform the future designation of MPAs.

Although an MPA can protect sperm whales from direct human impacts, other environmental threats pose significant challenges to their conservation, such as climate change, pollution, and habitat degradation, requiring global cooperation.

In general, to mitigate the potential impact of marine traffic on sperm whales, several key conservation measures were envisaged: i) establishing marine protected areas where marine traffic is restricted or regulated; ii) designating specific shipping lanes and enforcing speed limits in areas where sperm whales are most spotted; iii) creating educational programs and increasing awareness among mariners about the presence of sperm whales and the importance of their conservation; iv) engaging with government agencies, shipping companies, conservation organizations, and local communities, to develop effective management strategies, share data and expertise, and advocate for policy changes.

Implementing these conservation measures in a coordinated manner can help ensure the long-term survival of sperm whales and their habitats in the face of increasing human activities in marine environments. Ongoing scientific research and monitoring would be essential to assess the effectiveness of conservation measures and adapt management strategies as needed.

4.4 Opportunistic Data

One of the major challenges of this study is associated with the opportunistic data collected by the whale-watching companies, since there is no "control" over the sampling methods and the study area is dependent on the company's activity, as the sighting data is collected from places where the company is informed by the lookouts that there are animals present, and it is sometimes the company's choice which species to target when more than one species is present, which impairs a real quantification of the effort. As such, this type of data is quite biased as many observations are registered on locations closer to the coast, producing a high concentration of data in certain regions and little or no data in other areas, which does not necessarily mean that there are no sperm whales in those areas. Additional cautions included: using only one dataset for each region and considering only one group of sperm whales per day (to avoid resighting and sample correlation). Despite the fixed location of the whale spotters and the resulting surveying area from where data was collected, the robustness is derived from the quantity and temporal scale of these types of datasets (Pereira, 2008).

There is also an observer error associated, where the characterisation of an individual can vary from person to person, as is the case when classifying an individual as a calf, juvenile or adult. Since the individuals are usually classified as calves according to their smaller size compared to adults (around 4m) and also by some distinct marks on their body and the shape of their dorsal fin (Gero et al., 2009,

2013; van der Linde & Eriksson, 2019), there can be some difficulties when making the distinction between calves and juveniles. Therefore, records of juveniles and calves were pooled together.

Often, different companies have different ways of recording data regarding the parameters used, and in the MONICET dataset, it was possible to observe gaps in several sighting records of some companies concerning the animals' life stage. On the other hand, this type of data is also very valuable since it is collected with reduced costs and almost all year round, allowing to observe the species' behaviour, and take samples and photos for subsequent photo identification. The experience with Naturalist provided a hands-on opportunity to observe the different types of information that can be collected from sightings to study this species, especially with the help of the whale-watching companies, although there is still a long way to go in standardising data collection and communication among companies so that they are all guided by the same parameters when registering the sightings and characterizing the individuals. It would be very valuable to combine all the available data from the different areas of the Azores to better understand the populations of this species and their most utilised areas for feeding and maternity.

5. Conclusions

Based on the extensive research conducted in this thesis, it is evident that the Azores archipelago serves as a crucial maternity area for sperm whales, as indicated by the collection of birth records and the analysis of calves' presence within sighted groups. The study also sought to determine whether the bathymetry of the region influences habitat use in association with the presence of calves, alongside examining trends over different years and months. Additionally, through an analysis of ship routes around the Azores Central and Eastern Group, this study proposes conservation measures aimed at conserving the early life stages of sperm whales.
Between both regions, differences in slope and distance from the coast were observed, likely due to specific geomorphological features. Notably, statistically significant differences were observed in the distribution of groups with and without calves based on depth for the Central Group region. The analysis suggests that most sperm whales are spotted in bathymetries between 800m and 1100m. The presence of calves did not significantly influence habitat use, and their occurrence was consistent throughout the year, with births predominantly occurring between June and September.

Moreover, the study highlights areas of concern regarding the overlap between sperm whale sightings and maritime traffic. Recommendations are made to avoid potential collisions and disturbances to sperm whales, with a focus on sensitive areas where calves are frequently sighted that could be considered crucial habitats for breeding and calving.

Whale-watching companies demonstrated to be a valuable way of collecting data throughout the year, especially for long-term studies. However, there is still a considerable gap to be covered in standardising data collection and communication between companies so that all are guided by the same parameters when recording sightings and characterising individuals.

In conclusion, this study provides valuable insights into the conservation of sperm whales in the Azores, shedding light on their distribution patterns considering some habitat preferences and the potential impacts of maritime traffic on this species. The proposed conservation measures aim to strike a balance between sustainable maritime activities and the protection of this iconic marine species, paving the way for informed conservation strategies in the region.

6. References

Afonso, P., Fontes, J., Giacomello, E., Magalhães, M. C., Martins, H. R., Morato, T., Neves, V., Prieto, R., Santos, R. S., Silva, M. A., & Vandeperre, F. (2020). The Azores: A Mid-Atlantic Hotspot for Marine Megafauna Research and Conservation. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/fmars.2019.00826

Arregui, M., de Quirós, Y. B., Saavedra, P., Sierra, E., Suárez-Santana, C. M., Arbelo, M., Díaz-Delgado, J., Puig-Lozano, R., Andrada, M., & Fernández, A. (2019). Fat embolism and sperm whale ship strikes. *Frontiers in Marine Science*, *6*(JUL). https://doi.org/10.3389/fmars.2019.00379

Ávila, S. P., Johnson, M. E., Rebelo, A. C., Baptista, L., & Melo, C. S. (2020). Comparison of modern and Pleistocene (MIS 5e) coastal boulder deposits from Santa Maria Island (Azores Archipelago, NE Atlantic Ocean). *Journal of Marine Science and Engineering*, *8*(6). https://doi.org/10.3390/JMSE8060386

Azevedo, A. F., Viana, S. C., Oliveira, A. M., & Van Sluys, M. (2005). Group characteristics of marine tucuxis (Sotalia fluviatilis) (Cetacea: Delphinidae) in Guanabara Bay, south-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, *85*, 209–212.

Best, P. B., Canham, P. A. S., & Macleod, N. (1984). Patterns of reproduction in sperm whales, Physeter macrocephalus. *Report of the International Whaling Commission*, *6*, 51–79.

Boys, R. M., Oliveira, C., Pérez-Jorge, S., Prieto, R., Steiner, L., & Silva, M. A. (2019). Multi-state open robust design applied to opportunistic data reveals dynamics of wide-ranging taxa: the sperm whale case. *Ecosphere*, *10*(3). https://doi.org/10.1002/ecs2.2610

Carrillo, M. (2014). *Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions*. https://www.researchgate.net/publication/264121084

Carrillo, M., & Ritter, F. (2010). Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions. In *J. CETACEAN RES. MANAGE* (Vol. 11, Issue 2).

Clarke, R. (1956). *Sperm whales of the Azores: Vol. XXVIII*.

Coelho, I. A. (2021). *HABITAT PREFERENCES OF SPERM WHALES (PHYSETER MACROCEPHALUS) OFF SÃO MIGUEL ISLAND, AZORES*.

Di Sciara, G. N., Venturino, M. C., Zanardelli, M., Bearzi, G., Borsani, F. J., & Cavalloni, B. (1993). Cetaceans in the central mediterranean sea: Distribution and sighting frequencies. *Bolletino Di Zoologia*, *60*(1), 131–138. https://doi.org/10.1080/11250009309355800

Espaço Talassa. (2023). *Sightings & Statistics*. https://www.espacotalassa.com/en/sightings-statistics/

European Union. (2022). *European Marine Observation and Data Network (EMODnet)*. EMODnet. https://emodnet.ec.europa.eu/en

Fais, A., Lewis, T. P., Zitterbart, D. P., Álvarez, O., Tejedor, A., & Soto, N. A. (2016). Abundance and distribution of sperm whales in the canary islands: Can sperm whales in the archipelago sustain the current level of ship-strike mortalities? *PLoS ONE*, *11*(3). https://doi.org/10.1371/journal.pone.0150660

Ferreira, R., Steiner, L., Martín, V., Fusar Poli, F., Dinis, A., Kaufmann, M., Fernandez, M., & Alves, F. (2022). Unraveling site fidelity and residency patterns of sperm whales in the insular oceanic waters of Macaronesia. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.1021635

Frantzis, A., Alexiadou, P., & Gkikopoulou, K. C. (2014). Sperm whale occurrence, site fidelity and population structure along the Hellenic Trench (Greece, Mediterranean Sea). *Aquatic*

Conservation: Marine and Freshwater Ecosystems, *24*(SUPPL.1), 83–102. https://doi.org/10.1002/aqc.2435

Gannier, A., Drouot, V., & Goold, J. C. (2002). Distribution and relative abundance of sperm whales in the Mediterranean Sea. *Marine Ecology Progress Series*, *243*, 281–293. https://doi.org/10.3354/meps243281

GEBCO. (2023). *Gridded Bathymetry Data*. https://www.gebco.net/

Gero, S., Engelhaupt, D., Rendell, L., & Whitehead, H. (2009). Who cares? Between-group variation in alloparental caregiving in sperm whales. *Behavioral Ecology*, *20*(4), 838–843. https://doi.org/10.1093/beheco/arp068

Gero, S., Gordon, J., & Whitehead, H. (2013). Calves as social hubs: Dynamics of the social network within sperm whale units. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1763). https://doi.org/10.1098/rspb.2013.1113

Gomes-Pereira, J. N., Carmo, V., Catarino, D., Jakobsen, J., Alvarez, H., Aguilar, R., Hart, J., Giacomello, E., Menezes, G., Stefanni, S., Colaço, A., Morato, T., Santos, R. S., Tempera, F., & Porteiro, F. (2017). Cold-water corals and large hydrozoans provide essential fish habitat for Lappanella fasciata and Benthocometes robustus. *Deep Sea Research Part II: Topical Studies in Oceanography*, *145*, 33–48. https://doi.org/10.1016/J.DSR2.2017.09.015

González, L. (2018). *Cetacean distribution in São Miguel (Azores): influence of environmental variables at different spatial and temporal scales*.

Gosho, M. E., Rice, D. W., & Breiwick, J. M. (1984). The sperm whale, Physeter macrocephalus. In *Marine Fisheries Review* (4th ed., Vol. 46, pp. 54–56).

International Whaling Commission. (2023a). *Portugal | Whale Watching Handbook*. https://wwhandbook.iwc.int/en/country-profiles/portugal

International Whaling Commission. (2023b). *Sperm whale*. https://iwc.int/about-whales/whale-species/sperm-whale

Janc, A., Richard, G., Guinet, C., Arnould, J. P. Y., Villanueva, M. C., Duhamel, G., Gasco, N., & Tixier, P. (2018). How do fishing practices influence sperm whale (Physeter macrocephalus) depredation on demersal longline fisheries? *Fisheries Research*, *206*, 14–26. https://doi.org/10.1016/J.FISHRES.2018.04.019

Johnson, C. M., Beckley, L. E., Kobryn, H., Johnson, G. E., Kerr, I., & Payne, R. (2016). Crowdsourcing modern and historical data identifies sperm whale (Physeter Macrocephalus) habitat offshore of South-Western Australia. *Frontiers in Marine Science*, *3*(SEP). https://doi.org/10.3389/fmars.2016.00167

Käse, R. H., & Siedler, G. (1982). Meandering of the subtropical front south-east of the Azores. *Nature*, *300*, 245–246.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis: Kruskal Wallis test. *Journal of the American Statistical Association*, *47*, 583–621.

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., & Podesta, M. (2001). Collisions between ships and whales. *Marine Mammal Science*, *17*(1), 35–75. https://doi.org/10.1111/j.1748-7692.2001.tb00980.x

López, A., Pierce, G. J., Valeiras, X., Santos, M. B., & Guerra, A. (2004). Distribution patterns of small cetaceans in Galician waters. *Journal of the Marine Biological Association of the United Kingdom*, *84*, 283–294.

Magalhães, S., Prieto, R., Silva, M. A., Gonçalves, J., Afonso-Dias, M., & Santos, R. S. (2002). Short-term reactions of sperm whales (Physeter macrocephalus) to whale-watching vessels in the Azores. *Aquatic Mammals*, *28*(3), 267–274.

Marine Conservation Institute. (n.d.). *30 x 30 — Protecting at least 30% of the ocean by 2030*. Retrieved December 28, 2023, from https://marine-conservation.org/30x30/

Matthews, J. N., Steiner, L., & Gordon, J. (2001). Mark-recapture analysis of sperm whale (Physeter macrocephalus) photo-id data from the Azores (1987-1995). *Journal of Cetacean Research and Management*, *3*(3), 219–226.

Morato, T., Machete, M., Kitchingman, A., Tempera, F., Lai, S., Menezes, G., Pitcher, T. J., & Santos, R. S. (2008). Abundance and distribution of seamounts in the Azores. *Marine Ecology Progress Series*, *357*, 17–21. https://doi.org/10.3354/meps07268

North Atlantic Marine Mammal Commission. (2016). *Sperm whale*. https://nammco.no/sperm-whale/

Oliveira, C., Pérez-Jorge, S., Prieto, R., Cascão, I., Wensveen, P. J., & Silva, M. A. (2022). Exposure to whale watching vessels affects dive ascents and resting behavior in sperm whales. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.914397

Oliveira, C., & Wahlberg, M. (2016). *Foraging behaviour of the sperm whale in the Azores*. https://www.researchgate.net/publication/301198483

Pace, D. S., Arcangeli, A., Mussi, B., Vivaldi, C., Ledon, C., Lagorio, S., Giacomini, G., Pavan, G., & Ardizzone, G. (2018). Habitat suitability modeling in different sperm whale social groups. *Journal of Wildlife Management*, *82*(5), 1062–1073. https://doi.org/10.1002/jwmg.21453

Pacheco, J. M. R., Queiroz, G., Ferreira, T. M., & Wallenstein, N. (2013). Notas sobre a geologia do arquipélago dos Açores. In *Geologia de Portugal* (Vol. 2, pp. 595–690). https://www.researchgate.net/publication/256986277

Pacheco, M. B. (2013). *Medidas da Terra e do Mar*.

Pereira, J. N. D. S. G. (2008). Daily species checklist from whale-watching—studying the research potential with an Azorean case study. *Journal of the Marine Biological Association of the United Kingdom*, *88*(6), 1283–1288. https://doi.org/10.1017/S0025315408001070

Pinela, A. M., Quérouil, S., Magalhães, S., Silva, M. A., Prieto, R., Matos, J. A., & Santos, R. S. (2009). Population genetics and social organization of the sperm whale (Physeter macrocephalus) in the Azores inferred by microsatellite analyses. *Canadian Journal of Zoology*, *87*(9), 802–813.

Pirotta, E., Brotons, J. M., Cerdà, M., Bakkers, S., & Rendell, L. E. (2020). Multi-scale analysis reveals changing distribution patterns and the influence of social structure on the habitat use of an endangered marine predator, the sperm whale Physeter macrocephalus in the Western Mediterranean Sea. *Deep-Sea Research Part I: Oceanographic Research Papers*, *155*. https://doi.org/10.1016/j.dsr.2019.103169

Pirotta, E., Matthiopoulos, J., MacKenzie, M., Scott-Hayward, L., & Rendell, L. (2011). Modelling sperm whale habitat preference: A novel approach combining transect and follow data. In *Marine Ecology Progress Series* (Vol. 436, pp. 257–272). https://doi.org/10.3354/meps09236

Praca, E., Gannier, A., Das, K., & Laran, S. (2009). Modelling the habitat suitability of cetaceans: Example of the sperm whale in the northwestern Mediterranean Sea. *Deep-Sea Research Part I: Oceanographic Research Papers*, *56*(4), 648–657. https://doi.org/10.1016/j.dsr.2008.11.001

Quetglas, A., Carbonell, A., & Sánchez, P. (2000). Demersal continental shelf and upper slope cephalopod assemblages from the Balearic Sea (north-western Mediterranean). Biological aspects of some deep-sea species. *Estuarine, Coastal and Shelf Science*, *50*(6), 739–749. https://doi.org/10.1006/ecss.1999.0603

Rice, D. W. (1989). *Sperm whale Physeter macrocephalus Linnaeus, 1758* (Vol. 4). Handbook of marine mammals.

Ritter, F. (2012). Collisions of sailing vessels with cetaceans worldwide: First insights into a seemingly growing problem. *Journal of Cetacean Research and Management*, *12*(2), 119–127. https://doi.org/10.47536/jcrm.v12i1.598

RStudio Team. (2020). *RStudio* (3.3.0).

Sahri, A., Putra, M. I. H., Mustika, P. L. K., & Murk, A. J. (2020). A treasure from the past: Former sperm whale distribution in Indonesian waters unveiled using distribution models and historical whaling data. *Journal of Biogeography*, *47*(10), 2102–2116. https://doi.org/10.1111/jbi.13931

Seabra, M. I., Silva, M. A., Magalhães, S., & Prieto, R. (2005). Distribution and habitat preferences of Bottlenose Dolphins (Tursiops truncatus) and Sperm Whales (Physeter macrocephalus) with respect to physiographic and oceanographic factors in the waters around the Azores (Portugal). In *Marine Ecology Progress Series* (Vol. 29, Issue 1). https://www.researchgate.net/publication/259705026

Shirihai, H., Jarrett, B., Kirwan, G. M., Cresswell, G., Macleod, K., Walker, D., & Dando, J. (2006). Sperm whale. In *Whales, dolphins and seals: a field guide to the marine mammals of the world* (pp. 21–24).

Silva, L. (2015). How ecotourism works at the community-level: the case of whale-watching in the Azores. *Current Issues in Tourism*, *18*(3), 196–211. https://doi.org/10.1080/13683500.2013.786027

Silva, M. A., Prieto, R., Cascão, I., Seabra, M. I., Machete, M., Baumgartner, M. F., & Santos, R. S. (2014). Spatial and temporal distribution of cetaceans in the mid-Atlantic waters around the Azores. *Marine Biology Research*, *10*(2), 123–137.

Steiner, L., Lamoni, L., Plata, M. A., Jensen, S. K., Lettevall, E., & Gordon, J. (2012). A link between male sperm whales, Physeter macrocephalus, of the Azores and Norway. *Journal of the Marine Biological Association of the United Kingdom*, *92*(8), 1751–1756. https://doi.org/10.1017/S0025315412000793

Steiner, L., van der Linde, M., Pérez-Gil, M., & Freitas, L. (2015). *Long distance movements of female/immature sperm whales in the North Atlantic Population Structure of Bottlenose dolphin in Iberian Peninsula View project*. https://www.researchgate.net/publication/344124949

The Guardian. (2023). *Dominica creates world's first marine protected area for sperm whales*. https://www.theguardian.com/environment/2023/nov/13/caribbean-dominica-whale-reserve

van Der Linde, M. (2019). *The loss of whales to ship strikes - Azores Whales*. Futurismo. https://whalewatchingazores.com/blog/the-loss-of-whales-to-ship-strikes/?lang=pt-pt

van der Linde, M., & Eriksson, I. K. (2019). An assessment of sperm whale occurrence and social structure off São Miguel Island, Azores using fluke and dorsal identification photographs. *Marine Mammal Science*, *36*(1), 47–65.

Vieira, N., & Brito, C. (2009). Past and recent sperm whales sightings in the Azores based on catches and whale watching information. *Journal of the Marine Biological Association of the United Kingdom*, *89*(5), 1067–1070. https://doi.org/10.1017/S0025315409000873

Virgili, A., Teillard, V., Dorémus, G., Dunn, T. E., Laran, S., Lewis, M., Louzao, M., Martínez-Cedeira, J., Pettex, E., Ruiz, L., Saavedra, C., Santos, M. B., Van Canneyt, O., Vázquez Bonales, J. A., & Ridoux, V. (2022). Deep ocean drivers better explain habitat preferences of sperm whales Physeter macrocephalus than beaked whales in the Bay of Biscay. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-13546-x

Watkins, A. W., Daher, M. A., Dimarzio, N. A., Samuels, A., Wartzok, D., Fristrup, K. M., Gannon, D. P., Howey, P., & Maiefskj, R. R. (1999). SPERM WHALE SURFACE ACTIVITY FROM TRACKING BY RADIO A N D SATELLITE TAGS1. In *MARINE MAMMAL SCIENCE* (Vol. 15, Issue 4).

Whitehead, H. (1993). *The behaviour of mature male sperm whales on the Galapagos Islands breeding grounds*. www.nrcresearchpress.com

Whitehead, H. (2003). *Sperm whales social evolution in the ocean*. The university of chicago press.

Whitehead, H. (2018). Sperm Whale. In *Encyclopedia of Marine Mammals* (pp. 919–925). Elsevier. https://doi.org/10.1016/b978-0-12-804327-1.00242-9

Whitehead, H., & Weilgart, L. (1991). Patterns of Visually Observable Behaviour and Vocalizations in Groups of Female Sperm. In *Source: Behaviour* (Vol. 118, Issue 3).

Winkler, C., Panigada, S., Murphy, S., & Ritter, F. (2020). *Global Numbers of Ship Strikes: An Assessment of Collisions Between Vessels and Cetaceans Using Available Data in the IWC Ship Strike Database.* www.m-e-e-r.org