VAN HALL LARENSTEIN
UNIVERSITY OF APPLIED SCIENCE

Bachelor of Science in Animal Management

Influence of environmental cycles on cetacean habitat use in the Azores
The influence of tidal and lunar cycles on the abundance, behaviour and
short-term distribution of cetacean species in the Azores

Saskia Cathrin Martin
Bachelor Thesis

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NOVA ATLANTIS
FOUNDATION

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short-term distribution of cetacean species in the Azores

A thesis submitted in fulfilment of the requirements
of the BSc degree Wildlife Management

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Cover photo – Szafranska, 2018

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Acknowledgements

The world of marine wildlife has always fascinated me, a passion which has accompanied and guided me throughout my life. With a strong desire in the protection of the greatest natural resources in the world, marine research is a valuable method to increase the stock of knowledge and to ensure that marine protected areas achieve their essential conservation value. I am very grateful that I have been given the opportunity by Nova Atlantis Foundation to work on this research project and contribute my tiny part to the big unknown blue.

The present thesis is the result and completion of my bachelor's degree Animal Management with focus on the Major Wildlife Management. The process of this paper turned out to be challenging but enlightening for both, my personal and professional development.

This work could not have been possible without the help of the stats teacher Henry Kuipers, who carried many students, including myself, through the rough phase of analysis. I would also like to express my thanks to my thesis supervisor Okka Bangma for the professional support in the completion of this thesis.

Many thanks are also extended to Janina and Oliver, who generously gave their time to help with data preparation and giving helpful comments that improved this thesis. Also, some unusual thanks to Alfred for the multiple coffee breaks during the analysis and writing process, forcing my dogged brain to take breaks.

Special thanks are given to Karin from Nova Atlantis Foundation and all voluntary observers that helped during fieldwork and collected the data over the many years.

Last but not least and once again, I extend my heartfelt thanks to Oliver, for the everlasting support and faith in me.

Saskia Martin, Leeuwarden, 17th June 2019

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Abstract

Azorean waters have long been known to be inhabited by a vast number of cetacean species, representing a hotspot for marine wildlife within the North Atlantic. Various ecological factors are related to the complex habitat requirements of marine species such as water temperature, physiography and presence of prey. Rhythmic patterns created by environmental cycles such as lunar and tidal phases generate and influence ocean currents. These, in turn, indirectly influence the movement patterns of prey species leading to an indirect influence on the presence, abundance and distribution of cetaceans. The present study investigated how the effects of environmental cycles impact the habitat use of cetaceans in the Azores. The emerging research questions are: 'What is the relation between the lunar cycle and the abundance and behaviour of cetaceans in the Azores?' and 'What is the relation between the semi-diurnal tidal cycle and the abundance, distribution and behaviour of cetaceans in the Azores?'. A long-term study has been focussing on monitoring cetacean species presence in the Bay of Ribeiras. Data used for analyses were collected through land-based surveys from a fixed lookout post south of Pico island. Data analysed in this study were collected from 2011 to 2018, resulting in a total of 964 days, covering 926 hours spent in search for cetaceans during 2613 dedicated surveys. A total of 17 species in 6015 single point-sampling sightings were observed and clustered into eight subcategories for further analyses. Grampus and Small Oceanic Delphinids were the predominant species-groups, present in more than 40% of all surveys, followed by Physeter (17%) and Tursiops (8%). The effect of lunar and tidal phases on cetacean abundance was investigated through running regression models with a correction on the effect of survey duration per environmental phase. To examine the relation of behavioural activity and the tidal and lunar cycle, Wald Chi-square tests were applied. Density distribution maps were generated using ArcGIS to detect spatial differences between tidal phases. A strong association between the lunar cycle and the abundance of cetaceans off Pico island was recorded. A significant difference was detected for Hyperoodon, Ziphiidae, Physeter, Grampus and Delphinids which were predominantly present during periods with less lunar illumination around new moon. During brighter periods such as full moon, these species were less sighted. The behaviour of Grampus and Delphinids also showed a correlation with the lunar phases. Grampus appeared to prefer periods of increasing lunar illumination for resting, waning lunar phases for travelling and the darkest periods of the lunar cycle to forage and socialise. Travelling behaviour of Delphinids also showed the highest recordings during waning moon, foraging activity however was mainly displayed during full moon. This relationship between lunar cycles and daytime cetacean abundance and behaviour may be linked to higher food and prey availability during different moon phases due to moonlight known to be reducing organisms' vertical migration during full moon, with effects that ripple throughout the food web. This pattern concerns especially known night-foraging species such as Grampus, while most generalised (Tursiops) or deep-sea predators (Hyperoodon, Balaenopteridae, Globicephala) showed different patterns or non-significant variations, suggesting the action of other environmental variables. Tidal phases were found to be an important factor influencing the abundance of Grampus and Delphinids, both sighted in greater numbers during low tide. Both species showed preference of coastal areas, however spatial distribution only showed minor movements towards offshore areas during descending and low tide. Grampus' behaviour appeared to be significantly affected by the tidal cycle, with most travelling activity occurring during low tide and resting and foraging mostly during high tide. Physeter, Globicephala and Tursiops seemed to use areas closer to the coast during rising and high tide. Movement patterns of Balaenopteridae and Ziphiidae did not seem to be related to the tidal current. Balaenopteridae showed foraging activity predominantly during low tide, whilst the majority of observed animals was travelling during rising tide and resting during high tide. No socialising behaviour was recorded for this species-group. Hyperoodon was mainly sighted in deeper waters with only one sighting closer to shore during high tide. The association between tides and cetaceans' abundance, behaviour and distribution may be linked to prey availability. During low tide, habitat within coastal areas decreases and density of prey increases. Also, incoming and high tide is associated with greater prey abundance. Moreover, swimming against the current has been suggested as a feeding activity. Differences in habitat use could also potentially be related to anthropogenic pressure in the research area and the tourism-linked seasonal increase of whale watching vessels in July and August. For future studies the complete dataset (2004–2018) will be analysed to detect more detailed patterns over a long-term, focussing on the impact of tidal and lunar cycle and also on the abundance of whale watching vessels and cetaceans over time.

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Contents

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1   Introduction

It has long been known that our oceans are the most important natural resource of our planet. Covering more than 70% of earth's surface, they determine a significant part of the climate and ecology (Costanza, 1999). However, the marine ecosystem with its inhabitants is facing a wide range of threats in this rapidly changing world. It is impacted by various anthropogenic activities such as habitat degradation (J. Harwood, 2001), pollution (O'Shea, Reeves, & Long, 1999; Reijnders, Aguilar, & Donovan, 1999), overfishing (Bearzi, Politi, & Notarbartolo di Sciara, 1999), and climate change (Würsig, Reeves, & Ortega-Ortiz, 2001), amongst many other factors, which are causing a decline in its conditions and consequently posing threats to all living organisms (Worm et al., 2006; Worm, Sandow, Oschlies, Lotze, & Myers, 2005). The greatest biodiversity on the planet is held and supported by our oceans, but threats are causing a raise in species extinction rates, resulting in the most severe global environmental problem, the loss of biodiversity (Ceballos, 2002; Myers, Mittermeier, Mittermeier, De Fonseca, & Kent, 2000). As a large-scale consumer, cetacean species play a prominent role in the marine ecosystem (Hocking, Marx, Park, Fitzgerald, & Evans, 2017), but due to their life span and low reproduction rate, these top predators are particularly at risk and suffering a slow-motion extinction (Parsons & Bauer, 2012).

Areas of a significant high density and species richness are often termed hotspots (L. A. Harwood, Iacozza, Auld, Norton, & Loseto, 2014; Hastie, Wilson, Wilson, Parsons, & Thompson, 2004). These hotspots are of great importance for particular behaviours (Garaffo, Dans, Pedraza, Crespo, & Degrati, 2007; Notarbartolo di Sciara, Hanafy, Fouda, Afifi, & Costa, 2009; Rayment, Dawson, & Webster, 2015) and represent essential foraging areas (Pirotta et al., 2014; Scott et al., 2010). Coastal waters are usually productive and sheltered, providing refuge from predators (Croll et al., 2005; Heithaus & Dill, 2006; Rayment et al., 2015), and are therefore a preferred habitat by many marine mammals (Ballance, 1992; Barco, Swingle, McLellan, Harris, & Pabst, 1999; Rayment, Dawson, & Slooten, 2010). The waters of the Azores Archipelago represent one of many hotspots of marine life around the globe, acting as feeding grounds for diverse top predators, including cetaceans (Cascão et al., 2009).

The infraorder Cetacea currently comprises about 89 cetacean species (Perrin, 2019) divided into the suborders Odontocetes (toothed whales) and Mysticetes (baleen whale) (Gill, 1870). Azorean waters have long been known to be inhabited by various numbers of these cetaceans with 26 Mysticetes and Odontocetes documented so far (Reiner, Gonçalves, & Santos, 1993; Santos-Reis & Mathias, 1996; Steiner, 1995; Steiner, Silva, Zereba, & Leal, 2008; Szlama et al., 2017). Several of the present species are currently categorised as threatened (vulnerable, endangered) by the International Union for Conservation of Nature (IUCN, 2018) and are also included in various other lists and appendices, such as CITES (CMS, 2004) and the Portuguese Red List (SNPRCN, 1990). Although many baleen whales have the highest protection status within the Azores due to their migrating behaviour (Santos-Reis & Mathias, 1996), several of the cetacean species present in the Azores are classified as 'data deficient' due to inadequate information on a global scale (IUCN, 2018). Since the Azores represent an important hotspot for marine wildlife and hold a vast number of cetaceans, the conservation of this area is of high value. Especially the ongoing process of cetacean conservation is of utmost importance (Reeves, Smith, Crespo, & Notarbartolo di Sciara, 2002) and the knowledge about a species' biology and ecology is crucial for creating strategies that may minimise or mitigate anthropogenic impacts upon their natural habitat (Hastie et al., 2004). To allow a greater understanding of the ecological role of a species, the identification of patterns of habitat use is key to our understanding of various ecological aspects (Krebs, 2008).

Several studies have shown that environmental cycles have a significant influence on the habitat use of cetacean species (Bordino, 2002; Fernandez-Betelu, Graham, Cornulier, & Thompson, 2019; Shane, 1990), although not all studies support this (Araújo, Araújo, Souto, Parente, & Geise, 2007; Azevedo, Oliveira, Viana, & Van Sluys, 2007).

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The rhythmic patterns created by environmental cycles such as lunar and tidal phases alter the abiotic conditions of an ecosystem (Aschoff, 2013). In coastal areas, these cyclical movements of ebb and flow cause periodic movements of many species to avoid unsuitable conditions (Gibson, 2003) and can serve as a beneficial mean to reduce energy expenditure when travelling or foraging (Lin, Akamatsu, & Chou, 2013). The cyclic patterns of cetaceans often match the movement and distribution of their prey, resulting in an indirect influence (Cañadas, Sagarminaga, & García-Tiscar, 2002; Davis et al., 1998) and a highly flexible behaviour in response to their dynamic habitat (Montevecchi, Benvenuti, Garthe, Davoren, & Fifield, 2009).

Species cetaceans prey upon include mesopelagic fish and cephalopods, which vertically migrate to the epipelagic zone during darker periods such as new moon (Benoit-Bird, Au, & Wisdom, 2009; Kampa, 1974; Ochoa, Maske, Sheinbaum, & Candela, 2013). Studies have shown that foraging behaviour of cetaceans is significantly influenced by the lunar phases, which may be related to the increased density of their prey as a response to moonlight (Simonis et al., 2017; H. Glotin, unpubl. data). To maximise foraging efficiency, marine predators adjust their response to the distribution of their prey and thus to nocturnal light conditions (Horning & Trillmich, 1999). However, not only external cues in form of moonlight have an effect on marine organisms, the lunar effect is also known to be linked to the reproduction activity of fish (Zimecki, 2006).

Whilst interactions between some of the prey species and various environmental cycles have been described, the information about the more complex responses in cetaceans is so far insufficient (Fernandez-Betelu et al., 2019). The understanding of the interactions between a species and its natural cycles is not only key to our knowledge of animal behaviour but it is also key to the management of their conservation.

The present study explores how the effects of environmental cycles impact the habitat use of cetaceans in the Azores and thus, contributes to the improvement of our understanding of the biology and ecology of these species. The resulting main research question and ensuing sub questions of this study are defined as followed:

'What is the relation of environmental cycles and the habitat use of cetaceans in the Azores?'

1. *What is the relation between the lunar cycle and the abundance and behaviour of cetaceans in the Azores?*
2. *What is the relation between the semi-diurnal tidal cycle and the abundance, distribution and behaviour of cetaceans in the Azores?*

This study will give an important contribution to our knowledge on how these cetacean species use their habitat, helps identifying potential areas for protection from threats, and provides a baseline for assessing habitat related impacts on cetaceans in the Azores.

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2 Methodology

2.1. Study area

The archipelago of the Azores, Portugal, is composed of a group of volcanic islands in the northeast Atlantic Ocean between 37°–41°N and 25°–31°W. The islands are situated on the Mid-Atlantic Ridge, about 1500 km west of Portugal's mainland and about 3200 km from the eastern coast of the United States, separated by deep waters with depths greater than 2000 m. The Azores comprise a wide range of habitat types with steep submarine walls, shallow scattered seamounts, ridges and submarine canyons.

The region is largely dominated by two ocean currents, the Azores Current which is flowing in south-eastward direction from the Gulf Stream (Johnson & Stevens, 2000) and the warm and dynamic Azores Front situated south of the islands (Angel, 1989; R. S. Santos, Hawkins, Monteiro, Alves, & Isidro, 1995). Both current systems are creating a complex pattern of ocean circulation, resulting in high salinity and high temperature (R. S. Santos et al., 1995), which consequently causes an increase in the abundance of food sources and cetacean species (Sá, 2006).

Data were collected off the coast of Pico island, the second largest island of the archipelago with a surface area of 436 km^2 (**Figure 1**). Along this coastline, the ocean floor descends steeply to >1000 m depth within 3 km from shore.
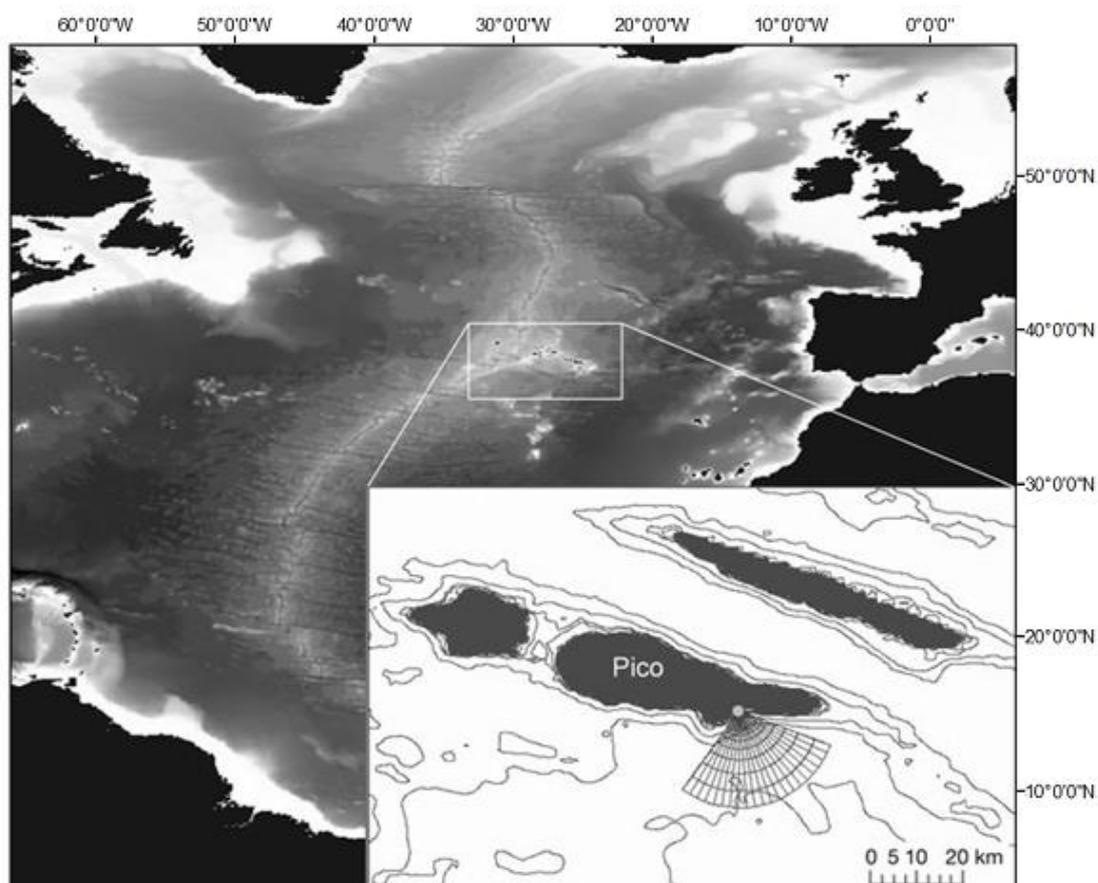
Figure 1. Bathymetry map of the North Atlantic Ocean (black areas = main land) and the location of the Archipelago of the Azores, Portugal, and the research area on Pico Island (inset). The grid outlines the observation range from the lookout point, covering about 367 km^2 with a sighting range of about 13 nautical miles to the South (Visser, Hartman, & Pierce, 2011).

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2.2. Study species

A total of 26 species of whales and dolphins have been documented near Pico and other islands of the Azorean archipelago including six taxonomic families so far (Reiner et al., 1993; Santos-Reis & Mathias, 1996; Steiner, 1995; Steiner et al., 2008; Szlama et al., 2017). Most species recorded belong to the family Delphinidae (dolphins), followed by Balaenopteridae (rorquals) and Ziphiidae (beaked whales) (**Table 1**).

Table 1. List of cetacean sightings recorded in the Azores. The harbour porpoise was excluded since data solely relies on stranding records (Barreiros, Teves, & Rodeia, 2006). Global IUCN categories: EN (endangered), VU (vulnerable), NT (near threatened), LC (least concern), DD (data deficient) (IUCN, 2018).

Scientific name	Code	Common name	Family	Suborder	IUCN status
Balaenoptera musculus (Linnaeus, 1758)	Bm	Blue whale	Balaenopteridae	Mysticeti	EN
Balaenoptera physalus (Linnaeus, 1758)	Bp	Fin whale	Balaenopteridae	Mysticeti	VU
Megaptera novaeangliae (Borowski, 1781)	Mnov	Humpback whale	Balaenopteridae	Mysticeti	EN
Balaenoptera borealis (Lesson, 1828)	Bb	Sei whale	Balaenopteridae	Mysticeti	EN
Balaenoptera edeni (Anderson, 1879)	Be	Bryde's whale	Balaenopteridae	Mysticeti	LC
Balaenoptera acutorostrata (Lacépède, 1804)	Ba	Minke whale	Balaenopteridae	Mysticeti	LC
Eubalaena glacialis (Muller, 1776)	Eg	Northern right whale	Balaenidae	Mysticeti	LC
Physeter macrocephalus (Linnaeus, 1758)	Pm	Sperm whale	Physeteridae	Odontoceti	VU
Kogia sima (Owen, 1866)	Ks	Dwarf sperm whale	Kogiidae	Odontoceti	DD
Kogia breviceps (Blainville, 1838)	Kb	Pygmy sperm whale	Kogiidae	Odontoceti	DD
Hyperoodon ampullatus (Forster, 1770)	Hamp	Northern bottlenose whale	Ziphiidae	Odontoceti	DD
Ziphius cavirostris (G. Cuvier, 1823)	Zcav	Cuvier's beaked whale	Ziphiidae	Odontoceti	VU
Mesoplodon bidens (Sowerby, 1804)	Mb	Sowerby's beaked whale	Ziphiidae	Odontoceti	DD
Mesoplodon europaeus (Gervais, 1855)	Me	Gervais' beaked whale	Ziphiidae	Odontoceti	DD
Mesoplodon densirostris (Blainville, 1817)	Md	Blainville's beaked whale	Ziphiidae	Odontoceti	DD
Mesoplodon mirus (True 1913)	Mm	True's beaked whale	Ziphiidae	Odontoceti	DD
Orcinus orca (Linnaeus, 1758)	Oo	Killer whale	Delphinidae	Odontoceti	DD
Pseudorca crassidens (Owen, 1846)	Pcras	False killer whale	Delphinidae	Odontoceti	NT
Globicephala melas (Traill, 1809)	Gmelas	Long-finned pilot whale	Delphinidae	Odontoceti	LC
Globicephala macrorhynchus (Gray, 1846)	Gmac	Short-finned pilot whale	Delphinidae	Odontoceti	LC
Grampus griseus (G. Cuvier, 1812)	Gg	Risso's dolphin	Delphinidae	Odontoceti	LC
Steno bredanensis (G. Cuvier, 1828)	Sb	Rough-toothed dolphin	Delphinidae	Odontoceti	LC
Tursiops truncatus (Montagu, 1821)	Tt	Bottlenose dolphin	Delphinidae	Odontoceti	LC
Delphinus delphis (Linnaeus, 1758)	Dd	Common dolphin	Delphinidae	Odontoceti	LC
Stenella frontalis (G. Cuvier, 1829)	Sf	Atlantic spotted dolphin	Delphinidae	Odontoceti	LC
Stenella coeruleoalba (Meyen, 1833)	Scour	Striped dolphin	Delphinidae	Odontoceti	LC

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2.3. Data sampling

This research is structured as an observational descriptive survey and studied potential relations between the variables, not causalities. Since 2000, activity data on all cetaceans off Pico island is continuously recorded by the Nova Atlantis Foundation and the data that were analysed in this study were collected from 2011 to 2018. The observational surveys were solely carried out during daytime and no nocturnal surveys were conducted. Although previous studies which investigated the influence of lunar phases mainly worked with data collected during the night, these results showed that the degree of influence was seen on a larger scale and is thus expected to be detectable by means of diurnal surveys. The database consisted of a collection of all sightings per survey with the respective information per column, and surveys without any observations (negative surveys). It was structured per rows, one row indicating one sighting or negative survey, including a column stating cetacean presence or absence per row. Data collected on whale watching vessels were not used in this study and therefore disregarded.

2.4. Data collection

Data were collected during daily land-based surveys from the southern coast of Pico island (38°24'N, 28°11'W). A lookout point is situated in Santa Cruz das Ribeiras at 30 m above sea level and encompasses a research area of approximately 367 km^2 with a sighting range of about 13 nautical miles to the South (110 degrees covering from East to West). Surveys were conducted between sunrise and dusk, for an average of 20 minutes per survey and spaced at least two hours apart to obtain independent samples and correct for double counting. Research effort was maintained daily, as long as daylight and weather conditions were considered adequate (and when sea state was below 4 Douglas scale). Depending on the number of observers in the field, a minimum of one and a maximum of eight sets of surveys were carried out per observation day.

To detect cetacean presence within the study area, two to three observers scanned the surface from the coast out to the horizon using 25x80 mm binoculars (Steiner Binoculars, Bayreuth, Germany). Data collected covered inter alia information about the observed species, environmental conditions and sighting effort. Only data relevant for this research were included in the analyses and other data collected by the Nova Atlantis Foundation were disregarded from this study (**Appendix I**).

Information on the location of the observed species (calculated with a Global Positioning System) was recorded at the time of the first observation moment and behavioural data were recorded using the point sampling method (Martin & Bateson, 1993) and continuous focal group follow (Altmann, 1974; Mann, 1999). Data collected included information about the observed species and other variables such as the lunar phases and environmental conditions (**Table 2**). Data on tidal currents were obtained from the Instituto Hidrográfico in Portugal and included afterwards to each survey accordingly.

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Data	Description
Date, start- and end time, duration	Date of each survey (dd/mm/yy); Start- and end time of each survey hh:mm; Duration of each survey (hh:mm)
Time of sighting	Time of first observation of the species (hh:mm)
Species, group number and group size	Species identity (abbreviation of scientific name used, e.g. GG=*Grampus griseus*, Appendix III); Number of groups sighted per species per survey; Number (n) of individuals sighted
Location, distance	Location in the bay in degrees (using a compass from observation point); estimated distance between animals and shoreline (%) where land is 0% and the horizon 100%
Behaviour	Most dominant behavioural states recorded at first sighting: Most dominant behavioural states recorded at first sighting: *Travelling – Moving steadily in one direction* *Socialising – Group members are in frequent physical contact, displaying surface behaviours (e.g. close social interactions)* *Foraging – Feeding activities performed close to the surface* *Resting – Lying motionless at the surface or move very slowly*
Lunar phases	- Waxing crescent (Moon is less than half illuminated by the sun and illumination is increasing) - First quarter (Moon is half illuminated by the sun and illumination is increasing) - Waxing gibbous (Moon is more than half illuminated by the sun but not completely illuminated) - Full moon (Moon is fully illuminated by the sun; except during lunar eclipse) - Waning gibbous (Moon is more than half illuminated but not completely and illumination is decreasing) - Third quarter (Moon is half illuminated by the sun and illumination is decreasing) - Waning crescent (Moon is less than half illuminated by the sun and illumination is decreasing) - New moon (Moon is not visible in the sky; except during solar eclipse)
Percentage moon	Percentage of illuminated part of the moon (full moon = 100%)
Tidal phase	High tide (Sea water level is highest) Descending tide (Sea water level is decreasing after high tide) Low tide (Sea water level is lowest) Rising tide (Sea water level is increasing after low tide)
Environmental data	Weather quality (1-7); Cloud cover (%); Wind direction (N, NE, E, SE, S, SW, W, NW); Wind force (Beaufort); Sea state (Douglas scale); Visibility (%, intervals of 10)

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2.5. Data preparation

The collected data have been stored and were organised in Microsoft Excel and then imported to the statistical software IBM SPSS for further analyses (**Appendix II**). Data entries without any survey effort (start-and end time), usually scheduled surveys that didn't take place due to bad weather conditions, were excluded from the dataset.

Species were clustered into eight subcategories for further analyses: Balaenopteridae (n=5), Hyperoodon (n=1), Ziphiidae (n=3), Physeter (n=1), Globicephala (n=2), Grampus (n=1), Tursiops (n=1), and Small Oceanic Delphinids (n=3) (**Appendix III**). With a frequency occurrence <5% and due to their unique ecological niche, the False killer whale and Pygmy sperm whale (n=17) were not grouped with other species and excluded from the analyses.

To avoid errors and identify potential problems, the data has been explored following the eight steps of the protocol of data exploration (Zuur, Ieno, & Elphick, 2010).

Tidal phases were divided into four classes: high tide (1), descending tide (2), low tide (3) and rising tide (4) (**Figure 2**). Since the rhythm of tidal cycles is not equal, the start and end times of the respective phases were calculated using the duration between each high and low tide (d) divided by four (d/4=t). This resulted in the interval (t) used to calculate the time before and after the respective tides (e.g. given time high tide – t = start; given time high tide + t = end → phase 1). The lunar phases were divided into eight categories ranging from New Moon (0-14%), Waxing Crescent (15-30%), First Quarter (31-60%), Waxing Gibbous (61-90%), Full Moon (91-100%), Waning Gibbous (90-61%), Third Quarter 60-31%) and Waning Crescent (30-15%) (**Table 2**).
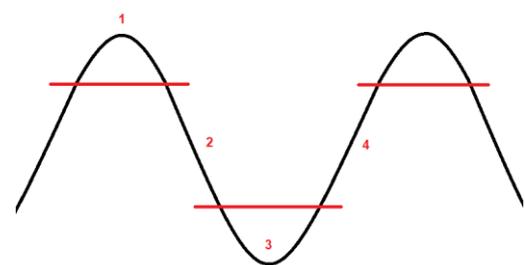
Figure 2. Tidal phases class A; 1=high tide, 2=descending tide, 3=low tide, 4=rising tide.

2.6. Data analysis

All statistical analyses were conducted with IBM SPSS version 24 with a set significance level of $p < 0.05$. Environmental factors (weather, wind force, sea state, cloud cover, visibility) were used as control variables, whereby wind force and weather were disregarded from analyses due to a high correlation to the variable sea state. For an illustrative overview about the methods applied, the conceptual model (**Figure 3**) gives a visualisation of the criteria (independent variables) and their indicators (dependent variables), including its hypotheses and the tools applied to obtain the criteria target.

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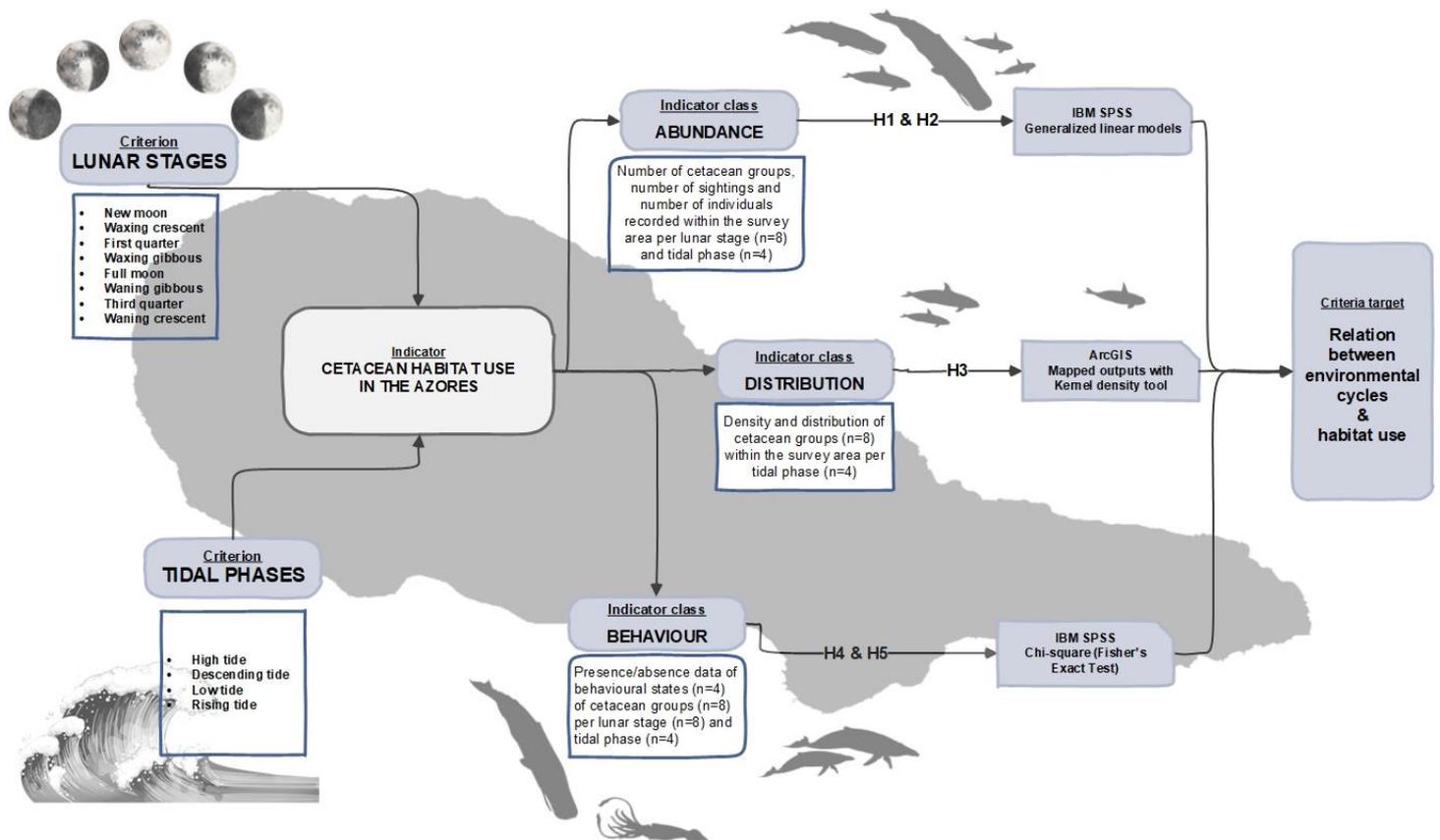
Figure 3. Conceptual model with criteria (lunar & tidal phases), indicator (cetacean habitat use), indicator classes (abundance, distribution, behaviour), followed by the hypotheses H1-6 and the used tool, concluding the criteria target (relation between environmental cycles and habitat use).

It is expected that the lunar phases affect cetaceans' abundance within the research area in different ways: cetaceans will be sighted more frequently and in greater group sizes during darker periods of new moon, waxing and waning crescent, a decrease over the first quarter moon, followed by the lowest abundance during the brighter periods of waxing and waning gibbous and full moon, followed by an increase of abundance over third quarter moon (**H1**).

The tidal state is also hypothesised to affect cetaceans' abundance in various manners: cetaceans will be encountered more frequently and in greater group sizes during high tide, followed by a decrease over descending tide and the lowest abundance during low tide, again followed by an increase over rising tide (**H2**) (De Boer, Eisfeld, & Simmonds, 2012; Fernandez-Betelu et al., 2019).

Tidal phases are also expected to affect the distribution with cetaceans closer to shore during rising and high tide and further out at sea during descending and low tide (**H3**) (Bordino, 2002; Gibson, 2003).

Cetaceans' behaviour might be affected by the lunar cycle and is hypothesised to be recorded most frequently as resting and travelling during full and waning moon, and mainly foraging and socialising during new and waxing moon (**H4**) (Simonis et al., 2017).

Furthermore, during rising and high tide a greater amount of travelling and foraging activity is expected, whereas resting and socialising is most frequent during descending and low tide (**H5**) (Shane, 1990).

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Abundance

In this study, species abundance was measured as presence-absence, the number of sightings and the group sizes of cetacean species recorded per survey within the research area (**Figure 1**). If an individual or group of species was followed continuously, only the first sighting was considered for the analyses.

To test for the effect of the lunar and tidal cycles on cetaceans' sightings, Generalised Linear Models (GLM) were applied. The number of sightings and number of individuals (group size) were defined as the response (dependent) variables and the logarithm of the survey duration (in hours) was set as an offset variable to correct for survey effort. All tests were run with a confidence interval of 95 % (Zar, 1999). For species with enough sightings, a negative binominal regression was applied to test whether the number of sightings per hour per species-group differed during lunar and tidal phases (independent variables). For species with a low number of sightings, a binary logistic regression was used to assess the relation between cetacean presence per hour per species-group and the predictors.

A Generalised Estimation Equation (GEE) model with a linear distribution was applied to test for the effect of the lunar and tidal phases on the group size of each species-group per sighting (Ghisletta & Spini, 2007). To correct for a right-skewed distribution and to make data conform to normality, a log-transformation of the group size was used as the response variable. The subject variable in the GEE was the survey number of each sighting.

To select the best model using the negative binominal or binary logistic regression, the Akaike's Information Criterion (AIC) was used. AIC is a measure of 'the goodness of fit', so of how well a model fits a dataset. The lower the AIC, the better the model (Claeskens & Hjort, 2008). To select the best model when a linear distribution was applied, the Corrected Quasi-likelihood under Independence Model Criterion (QICC) was used. The model with the smallest QICC is the best according to this criterion. All models included a pairwise multiple comparison test (Sidak) to determine which variables differ (Abdi, 2007).

Distribution

The research area was delineated in consideration with the maximum sighting range of the land station in Ribeiras. ArcGIS version 10.6.1 was used to create a GIS environment that projected the coordinates of recorded cetacean species collected both from the lookout point.

The coordinates of each species were calculated using the recorded location in degrees and the estimated distance (%) between animals and the shoreline. For the conversion of the percentages of the distance, a calculation table by Van Geel (2007) was used, where exact distances were measured by means of sailing certain fixed points and recording their coordinates.

To determine the distribution of cetacean species in relation to the different tidal phases, density distribution maps were generated using ArcGIS. To project the collected cetacean sightings, the coordinates (UTM) were imported as point data using the coordinate system for Azores Central 1995 UTM zone 26N. Transformed as a shapefile, the points were then overlaid onto a shore line base map and afterwards used as an input feature for the kernel density tool (Silverman, 1986). With a given output cell size of 30 m, and a radius of 2000 m, density maps with a high accuracy were generated. The processing extent was set to the research area to extrapolate the cetacean densities according to the area surveyed. Each point was weighted with its group size (input population field), which was defined as the average of the cumulative minimum and maximum individuals per group observed (also see the Model builder in **Appendix V**). For each species-group (n=8) and tidal phase (n=4), a separate map was created, showing the location, group size and density of all observed cetaceans.

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Behaviour

To examine the relation between various recorded behavioural states (**Table 2**) and the different lunar and tidal phases, Wald Chi-square tests were applied (Agresti, 2007). The data is discrete, binominal and unpaired with >2 groups, and tests were carried out using all positive sightings per species. Since for most species more than 20% of the expected values of the contingency table were <5, the assumption for the Chi-square was violated and therefore the Fisher's Exact Test was used alternatively (Mehta & Patel, 1983). This test has no lower bound on the amount of data (Fleiss, Levin, & Paik, 2003) and provides a means for obtaining accurate results. Also, trying to minimise the violation of the assumption for the behavioural analyses, the eight lunar phases were merged into four categories to get bigger portions of values per behavioural state per lunar phase. Consecutive observations of the same group could lead to non-independence of data. Trying to minimise this problem, the first recorded activity per species per survey was chosen to perform the statistical analysis (Azevedo et al., 2007).

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3   Results

3.1. Sightings and effort

Between 2011 and 2018, a total of 2613 surveys were carried out, covering 926 hours in 964 days (Table 3). During these scans, 6015 individual cetacean sightings were recorded, involving 17 species within eight clustered subcategories (Appendix III). The species-groups included in the analyses (1-8) were recorded every year (**Table 3**), of which 137 Balaenopteridae, 48 Hyeroodon, 175 Ziphiidae, 686 Physeter, 177 Globicephala, 2406 Grampus, 226 Tursiops and 2160 Small Oceanic Delphinids sightings were recorded. The highest number of sightings within one scan was 19 (Grampus, n=16; Delphinids, n=3), with an average of 2.3 (SD 2.48) cetacean sightings per survey.

Table 3. Annual survey effort of the land surveys carried out within the study area, showing effort in number of surveys, positive (+) surveys (surveys with cetacean sightings), effort in hours, number of survey sightings (SS) and the code of the recorded species (Appendix III).

Year	Month	Nr Surveys	+ Surveys	Hours	SS	Species
2011	January - September	381	292	130:50:00	947	1 - 8
2012	April - September	454	311	185:47:00	836	1 - 8
2013	May - September	199	175	63:10:00	597	1 - 8
2014	May - October	149	116	50:59:00	356	1 - 8
2015	May - September	216	176	74:13:00	528	1 - 8
2016	May - September	368	242	130:51:00	570	1 - 8
2017	May - September	437	373	140:50:00	1474	1 - 8
2018	June - September	409	284	150:06:00	707	1 - 8
Total		2613	1969	926:46:00	6015	

1=Balaenopteridae, 2= Hyperoodon, 3= Ziphiidae, 4=Physeter, 5= Globicephala, 6=Grampus, 7=Tursiops, 8= Small Oceanic Delphinids

Effort was not equally distributed throughout the years, with 2011, 2012, 2017 and 2018 receiving noticeably high effort (**Table 3**). Numbers of cetacean sightings range from 356 sightings in 2014 to 1479 in 2017. Effort was also strongly skewed towards summer months, with the highest proportion of effort occurring during May–September for each year.

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3.2. Lunar cycle

Abundance

The regression analyses applied to identify effects of the observed lunar patterns on the abundance of the present cetacean species showed that these variables are significantly related to Hyperoodon, Ziphiidae, Physeter, Grampus and Small Oceanic Delphinids.

For the genus Hyperoodon, analysis revealed a significant effect of the lunar phases on both its presence (p=0.034) and group size (p=0.000). Both models were best without any control variables (AIC=35.533, QICC=18.364). Although pairwise comparisons showed no significant factor differences between the lunar phases in regard to the mean presence per hour (**Table 4**), the Wald Chi-Square yielded a statistically significant low abundance during the lunar phase full moon, followed by an overall increase towards new moon (p=0.004; estimated coefficient B=-2.368; **Figure 4**). The mean number of individuals in a group recorded per sighting did not deduce any clear trends within the lunar cycle. However, during new moon sightings of Hyperoodon consisted of significantly more individuals compared to sightings during waxing crescent (p=0.000). This pattern was reversed around full moon, with a significantly increase in group size after waxing crescent and first quarter moon (p=0.000; **Figure 5**).
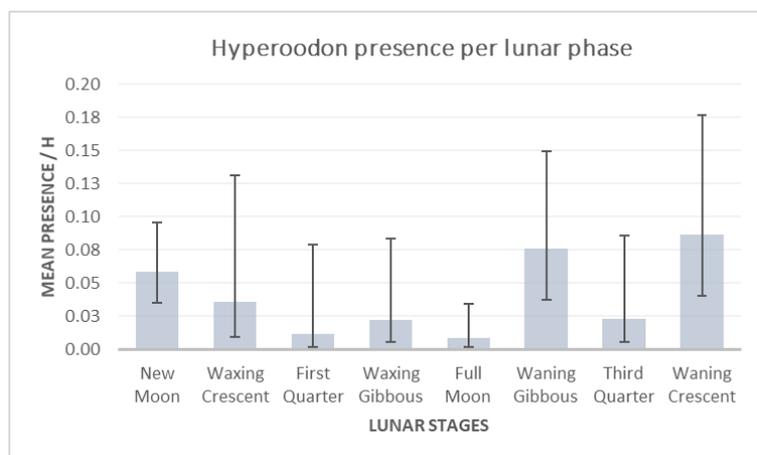
Figure 4. Mean presence of Hyperoodon per hour compared to lunar phases within the survey area.
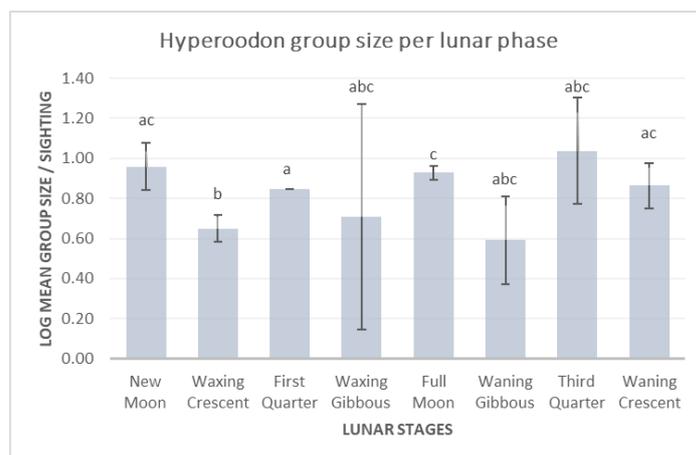
Figure 5. Mean number of Hyperoodon individuals (group size) per sighting compared to lunar phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

For Ziphiidae, the analysis yielded in no significant association between the presence per hour and the lunar pattern (p>0.05, **Table 4**). However, the regression model without any control variables (QICC: 31.808, **Appendix VI**) reveals that the variable group size per sighting was correlated with the lunar phases (p=0.001; **Table 5**). Ziphiidae were sighted in significantly greater numbers during waxing crescent with a decrease towards waning crescent (p=0.003) and followed by a significant increase during new moon (p=0.027; **Figure 6**).
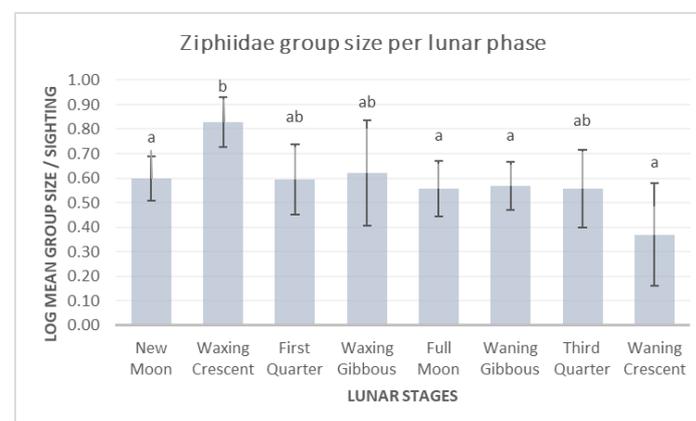
Figure 6. Mean number of Ziphiidae individuals (group size) per sighting compared to lunar phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

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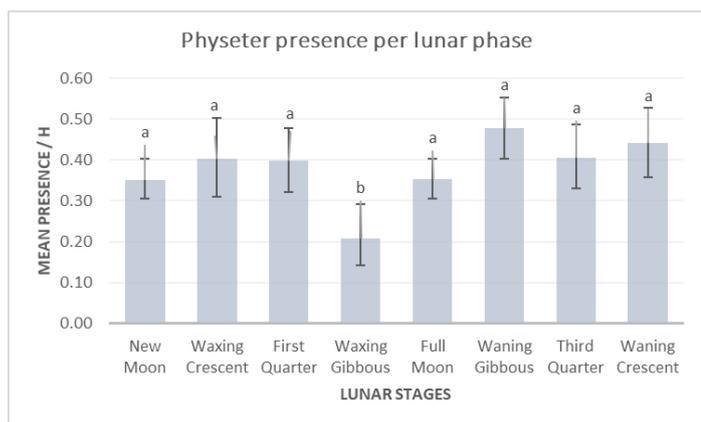
Figure 7. Mean presence of Pyseter per hour compared to lunar phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

Physeter abundance showed a clear difference between brighter periods around full moon and darker nights around new moon (p=0.001). With a mean presence of 0.207 (±0.038) per hour (**Table 4**), this species appeared to be significantly least abundant during waxing gibbous, right before the brightest phase of full moon (p=0.000; **Figure 7**). Analysis (best model without any control variables, AIC: 11.226) revealed a mean presence of 0.207 (±0.038) right before full moon and almost double (>0.352) during all other lunar phases. There was no effect of lunar phases on the group size of Physeter (p>0.05, **Table 5**).

The GLMs also showed a significant effect of the lunar cycle on the mean numbers of sightings per hour of both Grampus (p=0.010) and Small Oceanic Delphinids (p=0.001). The best model for Grampus included the control variables sea state, wind direction and cloud cover with an AIC of 5325.696. The variables sea state (p=0.000) and cloud cover (p=0.043) both had a significant negative correlation with the number of sightings per hour. For Delphinids, the model with the lowest AIC included all control variables, which all showed a significant correlation to the number of sightings (**Appendix VI**).

Although the number of Grampus sightings did not show any significances between the lunar phases concerning factor differences, the Wald Chi-Square resulted in a statistically significantly higher abundance during the lunar phase first quarter moon (p=0.049; estimated coefficient B=0.316), followed by an overall decrease towards full moon (**Figure 8**).

The species-group Small Oceanic Delphinids shows similar results with a significantly higher amount of 2.163 (±0.243) mean sightings per hour during the darker periods of new moon, followed by a significant decrease towards waxing and waning gibbous with about 1.4 (±0.21) mean sightings per hour (**Figure 9**).
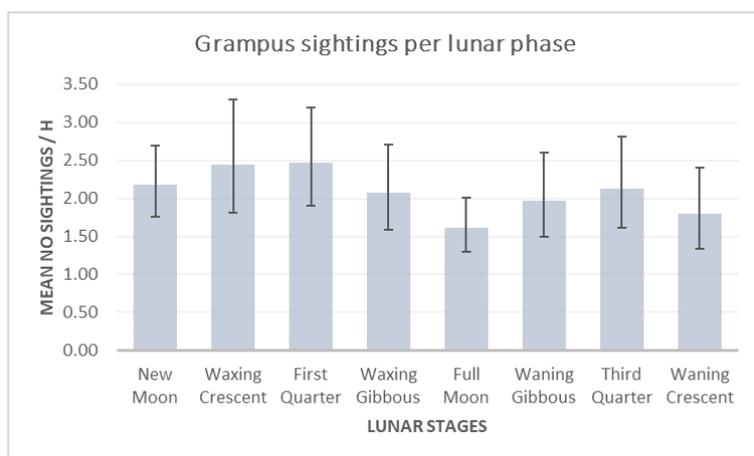
Figure 8. Mean number of Grampus sightings per hour compared to lunar phases within the survey area.
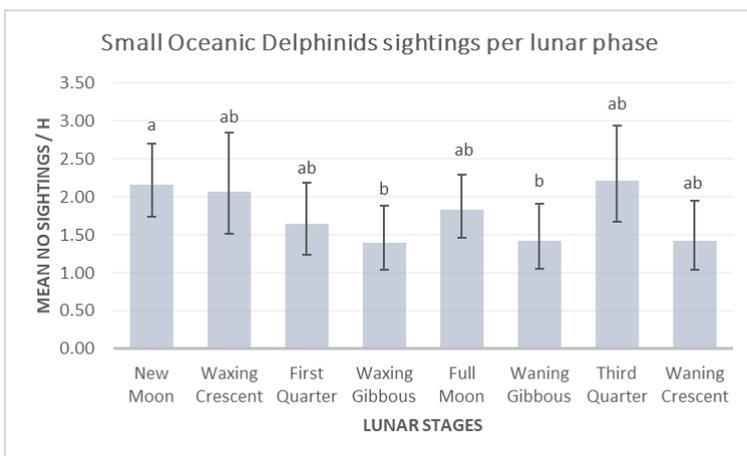
Figure 9. Mean number of Small Oceanic Delphinids sightings per hour compared to lunar phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

No significant relation was found with the predictor lunar cycle and the abundance of Balaenopteridae, Globicephala and Tursiops.

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Table 4 and Table 5 give a detailed overview of the Estimated Marginal Means (EMM) of all species tested with the different lunar phases. The full SPSS outcomes can be found in **Appendix VI**.

Table 4. Estimated Marginal Means of the presence of Balaenopteridae, Hyperoodon, Ziphiidae, Physeter, Globicephala and Tursiops and the number of sightings of Grampus and Small Oceanic Delphinids per hour compared to the lunar phases; including Standard Deviation (SD), Pairwise Comparison (PC), Wald Chi-Square, Degree of Freedom (df) and Significance (p).

								Species	
Phase	Balaenopteridae	Hyperoodon	Ziphiidae	Physeter		Globicephala	Grampus	Tursiops	Small Oceanic Delphinids	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	PC	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	PC
New Moon	0.086 ± 0.018	0.058 ± 0.015	0.136 ± 0.021	0.352 ± 0.025	a	0.151 ± 0.022	2.177 ± 0.237	0.172 ± 0.022	2.163 ± 0.243	a
Waxing Crescent	0.087 ± 0.036	0.036 ± 0.025	0.223 ± 0.049	0.403 ± 0.050	a	0.104 ± 0.039	2.442 ± 0.373	0.151 ± 0.044	2.073 ± 0.333	ab
First Quarter	0.112 ± 0.032	0.012 ± 0.012	0.191 ± 0.038	0.398 ± 0.040	a	0.132 ± 0.034	2.464 ± 0.326	0.200 ± 0.038	1.645 ± 0.241	ab
Waxing Gibbous	0.144 ± 0.034	0.022 ± 0.015	0.075 ± 0.027	0.207 ± 0.038	b	0.125 ± 0.033	2.071 ± 0.285	0.233 ± 0.039	1.400 ± 0.213	b
Full Moon	0.108 ± 0.019	0.009 ± 0.006	0.157 ± 0.022	0.353 ± 0.025	a	0.104 ± 0.019	1.613 ± 0.182	0.223 ± 0.024	1.832 ± 0.212	ab
Waning Gibbous	0.066 ± 0.025	0.076 ± 0.027	0.156 ± 0.035	0.478 ± 0.038	a	0.146 ± 0.035	1.974 ± 0.278	0.175 ± 0.037	1.421 ± 0.214	b
Third Quarter	0.129 ± 0.033	0.023 ± 0.016	0.177 ± 0.037	0.405 ± 0.040	a	0.167 ± 0.036	2.130 ± 0.303	0.148 ± 0.035	2.215 ± 0.318	ab
Waning Crescent	0.087 ± 0.033	0.087 ± 0.033	0.100 ± 0.035	0.440 ± 0.044	a	0.073 ± 0.031	1.796 ± 0.270	0.188 ± 0.043	1.428 ± 0.228	ab
Wald Chi-square	5.306	15.135	10.838	25.760		6.510	18.411	6.065	24.140	
df	7	7	7	7		7	7	7	7	
p	0.623	**0.034**	0.146	**0.001**		0.482	**0.010**	0.532	**0.001**	

Table 5. Estimated Marginal Means of the group size per species per sighting compared to the lunar phases; including Standard Deviation (SD), Pairwise Comparison (PC), Wald Chi-Square, Degree of Freedom (df) and Significance (p).

								Species		
Phase	Balaenopteridae	Hyperoodon	PC	Ziphiidae	PC	Physeter	Globicephala	Grampus	Tursiops	Small Oceanic Delphinids
	Mean ± SD	Mean ± SD		Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
New Moon	0.072 ± 0.026	0.959 ± 0.061	ac	0.598 ± 0.046	a	0.108 ± 0.021	0.855 ± 0.056	0.672 ± 0.023	1.115 ± 0.082	1.636 ± 0.029
Waxing Crescent	0.046 ± 0.014	0.651 ± 0.034	b	0.828 ± 0.052	b	0.164 ± 0.032	1.077 ± 0.183	0.605 ± 0.044	1.093 ± 0.213	1.589 ± 0.063
First Quarter	0.120 ± 0.035	0.845 ± 0.000	a	0.593 ± 0.073	ab	0.124 ± 0.021	0.993 ± 0.119	0.705 ± 0.033	0.885 ± 0.111	1.551 ± 0.070
Waxing Gibbous	0.059 ± 0.041	0.707 ± 0.287	abc	0.620 ± 0.109	ab	0.181 ± 0.074	0.828 ± 0.111	0.636 ± 0.035	0.982 ± 0.092	1.596 ± 0.057
Full Moon	0.118 ± 0.033	0.929 ± 0.018	c	0.557 ± 0.057	a	0.093 ± 0.016	0.943 ± 0.069	0.697 ± 0.022	1.098 ± 0.047	1.528 ± 0.031
Waning Gibbous	0.137 ± 0.068	0.592 ± 0.112	abc	0.568 ± 0.050	a	0.114 ± 0.022	1.045 ± 0.090	0.681 ± 0.036	1.114 ± 0.091	1.583 ± 0.063
Third Quarter	0.067 ± 0.028	1.038 ± 0.136	abc	0.558 ± 0.081	ab	0.084 ± 0.018	0.885 ± 0.121	0.654 ± 0.045	1.223 ± 0.111	1.551 ± 0.052
Waning Crescent	0.050 ± 0.031	0.864 ± 0.058	ac	0.369 ± 0.107	a	0.130 ± 0.036	0.598 ± 0.105	0.709 ± 0.042	1.119 ± 0.144	1.635 ± 0.080
Wald Chi-square	8.328	64.590		24.457		7.672	13.766	6.976	6.428	7.745
df	7	7		7		7	7	7	7	7
p	0.305	**0.000**		**0.001**		0.362	0.056	0.431	0.491	0.356

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Behaviour

For Grampus and Small Oceanic Delphinids there was a significant difference between behaviour and the predictor lunar phases. A pairwise comparison per behavioural state indicates significant factor differences between several phases (**Appendix VII**).

The Chi-Square test showed that Grampus' behaviour was significantly associated to the lunar phases (Pearson=21.186, df=9, p=0.012), visualised in **Figure 10**. With 53.7% of all sightings, travelling was the predominant behaviour recorded, followed by resting with 34.4%. Compared to waxing moon, Grampus displayed significantly more travelling behaviour during waning moon where 57.6% of all observed Grampus during that phase were recorded. Of all recorded foraging activity by Grampus, a significant difference was detected between new and waning moon (<15%) and waxing moon (31.9%), showing that Grampus is more likely to display foraging behaviour during darker and increasing lunar illumination phase. Socialising behaviour was mostly observed during the darker periods of new moon and waxing moon with a significant higher activity during new moon (30.1%) compared to waning moon (19.7%). Grampus displaying resting behaviour were more likely to do so during waxing moon (29.8%) and least likely during new moon (23.7%).
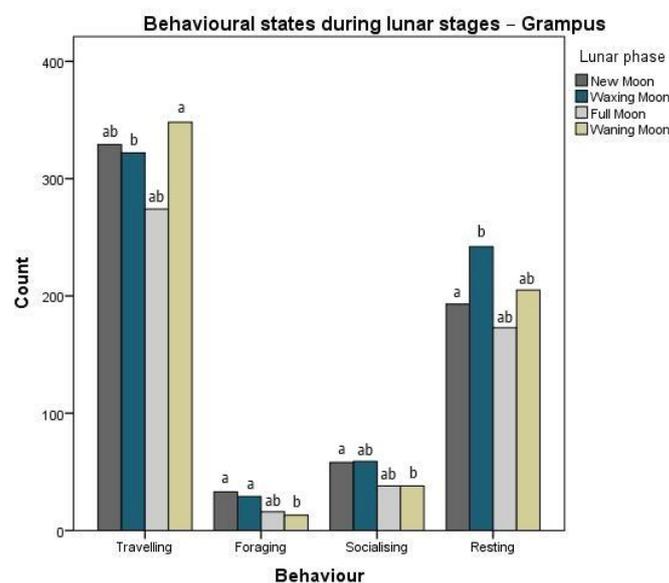
Figure 10. Frequency count of recorded behaviours (n=4) of all sightings during lunar phases (n=4) of Grampus within the survey area off Pico island in the years of 2011–2018. Different subscript letters (a-b) indicate significant differences at the level of 0.05.
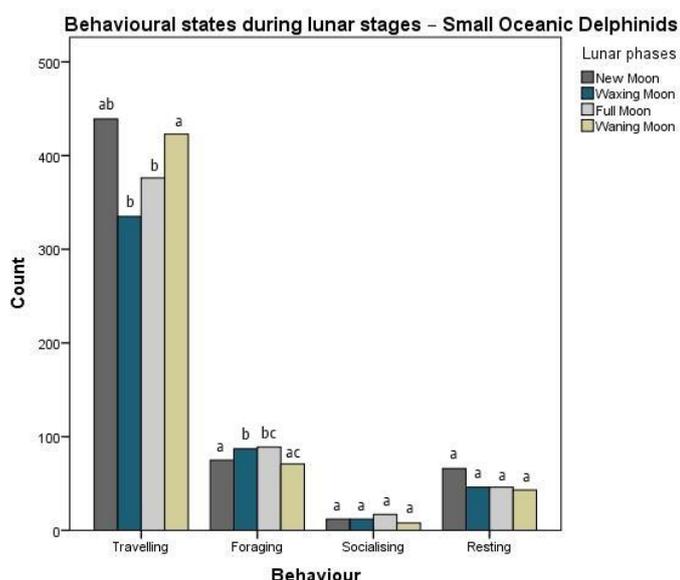
Figure 11. Frequency count of recorded behaviours (n=4) of all sightings during lunar phases (n=4) of Small Oceanic Delphinids within the survey area off Pico island in the years of 2011–2018. Different subscript letters (a-b) indicate significant differences at the level of 0.05

Lunar phases also appeared to have a significant effect on the behaviour of Small Oceanic Delphinids (Pearson=17.873, df=9, p=0.037). Travelling was the most recorded behavioural state for this species-group, covering 73.3% of all sightings.

Delphinids were significant more likely to be travelling during waning moon, with observations resulting in a significantly higher travelling activity (77.6%) than during waxing moon (69.8%) (**Figure 11**). Foraging activity was shown to a significantly greater extent during waxing and full moon compared to the decreasing phases waning and new moon. With only 2.3% recorded socialising activity of all Delphinids sightings, this behaviour showed no overall significant difference between the lunar phases. Neither did resting activity, covering 9.4% of all observations.

No significant relation was found with the predictor lunar phases and the displayed behaviour of Balaenopteridae, Hyperoodon, Ziphiidae, Physeter, Globicephala and Tursiops.

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3.3. Tidal cycle

Abundance

Tidal patterns showed a significant relation to the abundance in Grampus and Small Oceanic Delphinids of the eight analysed species-groups. Although no relation between tides and group sizes of these cetaceans was detected, analyses revealed a significant relation between the tidal currents and sightings per hour of Grampus (p=0.007) and Delphinids (p=0.002).

The best regression model for Grampus (AIC: 5324.013) included the control variables sea state, wind direction and cloud cover, of which the sea state (p=0.000) and the cloud cover (p=0.018) both had a significant negative correlation with the number of sightings per survey (**Appendix VIII**). Grampus was most frequently recorded during low tide, with a mean of 2.334 (±0.243) sightings per hour and with 1.723 (±0.190) sightings per hour least during high tide, resulting in a significant difference between these two tidal phases (p=0.007; **Figure 12**).
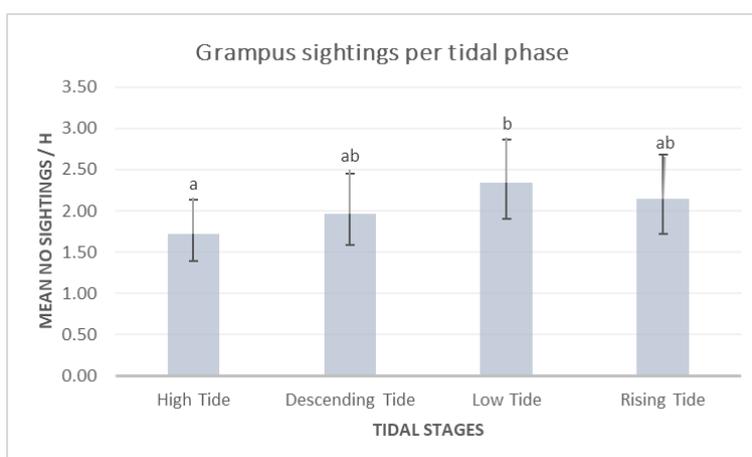
Figure 12. Mean number of Grampus sightings per hour compared to tidal phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

The best model for Delphinids (AIC: 5019.454) included all control variables of which all had a significant correlation with the number of Delphinids sightings per hour (**Appendix VIII**). With 2.182 (±0.236) sightings per hour, Delphinids were also recorded in greater numbers during low tide, but with a significant difference to descending tide (p=0.003; **Figure 13**).
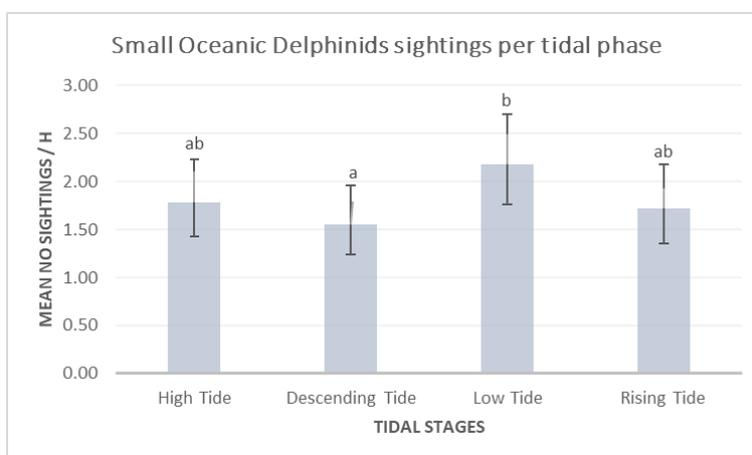
Figure 13. Mean number of Small Oceanic Delphinids sightings per hour compared to tidal phases within the survey area. Different subscript letters (a-b) indicate significant differences at the level of 0.05.

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No significant relation was found with the predictor tidal cycle and the abundance, both number of sightings and group size, of Balaenopteridae, Hyperoodon, Ziphiidae, Physeter, Globicephala and Tursiops. Table 6 gives an overview of the EMM of the presence or number of sightings of all observed species tested with the different tidal phases. The group sizes of all eight analysed species-group did not show any significant correlation with the tidal phases and the EMM table can be found in **Appendix VIII**.

Table 6. Estimated Marginal Means of the presence of Balaenopteridae, Hyperoodon, Ziphiidae, Physeter, Globicephala and Tursiops and the number of sightings of Grampus and Small Oceanic Delphinids per hour compared to the tidal phases; including Standard Deviation (SD), Pairwise Comparison (PC), Wald Chi-Square, Degree of Freedom (df) and Significance (p).

	Species									
Phase	Balaenopteridae	Hyperoodon	Ziphiidae	Physeter	Globicephala	Grampus		Tursiops	Small Oceanic Delphinids	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	PC	Mean ± SD	Mean ± SD	PC
High Tide	0.087 ± 0.017	0.041 ± 0.012	0.102 ± 0.018	0.334 ± 0.025	0.135 ± 0.020	1.723 ± 0.190	a	0.203 ± 0.023	1.780 ± 0.203	ab
Descending Tide	0.137 ± 0.021	0.035 ± 0.012	0.148 ± 0.022	0.348 ± 0.025	0.114 ± 0.020	1.967 ± 0.218	ab	0.219 ± 0.024	1.556 ± 0.182	a
Low Tide	0.083 ± 0.016	0.038 ± 0.011	0.165 ± 0.020	0.409 ± 0.022	0.114 ± 0.018	2.334 ± 0.243	b	0.182 ± 0.020	2.182 ± 0.236	b
Rising Tide	0.106 ± 0.022	0.039 ± 0.014	0.187 ± 0.026	0.387 ± 0.028	0.159 ± 0.025	2.146 ± 0.244	ab	0.155 ± 0.025	1.715 ± 0.209	ab
Wald Chi-square	5.251	0.092	7.623	6.389	2.978	12.147		3.840	14.790	
df	3	3	3	3	3	3		3	3	
p	0.154	0.993	0.540	0.094	0.395	**0.007**		0.279	**0.002**	

Behaviour

For Balaenopteridae, analysis showed that the behaviour of these baleen whales was significantly associated to tidal state (Fisher's exact=17.234, p=0.005). The predominant behaviour recorded of Balaenopteridae was travelling, covering 73.8% of all sightings (**Appendix IX**). The majority of observed animals during rising tide was displaying travelling activity (90.3%), showing a significant difference to high tide (56.7%). Compared to descending tide, the amount of foraging Balaenopteridae was significantly higher during low tide (22.6%). Resting behaviour was mostly recorded during high tide and was significantly higher during that tidal phase compared to low and rising tide (**Figure 14**). The behavioural state socialising was not recorded for this species.
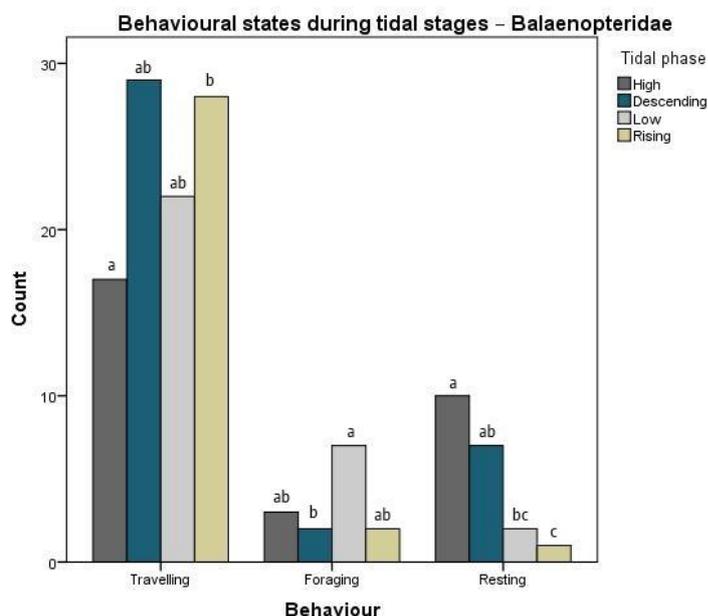
Figure 14. Frequency count of recorded behaviours (n=4; no recordings for socialising) of all sightings during tidal phases (n=4) of Balaenopteridae within the survey area off Pico island in the years of 2011–2018. Different subscript letters (a-c) indicate significant differences at the level of 0.05

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Grampus also showed a significant correlation between its behaviour and the tidal phases (Pearson=39.338, df=9, p=0.000). As the pairwise comparison in **Appendix XI** and **Figure 15** show, all behavioural states were mostly recorded during low tide. With 36.4%, travelling was predominant during low tide and significantly different compared to rising tide. Grampus was significantly least likely to be foraging during high tide, with a significant difference between the three other tidal phases. Socialising activity of Grampus did not show any significant differences between the tidal phases, resting however, was significantly higher during low tide (35.4%) than high and rising tide.
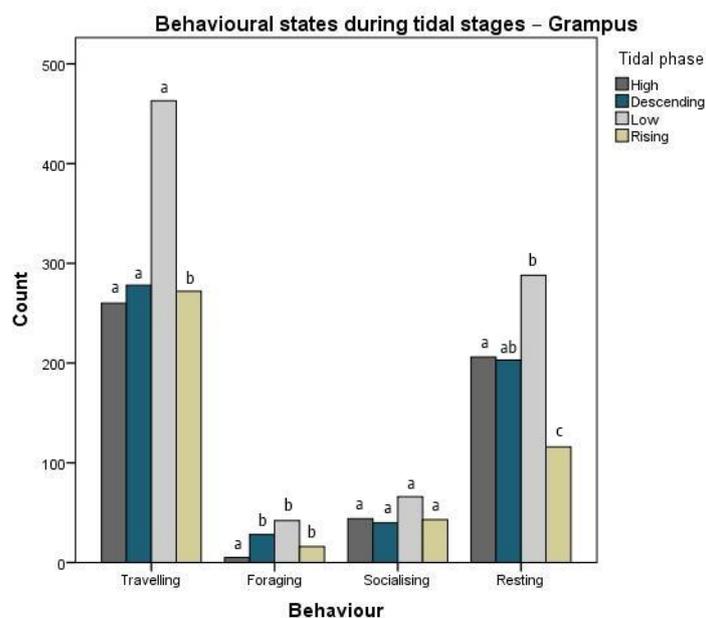
Figure 15. Frequency count of recorded behaviours (n=4) of all sightings during tidal phases (n=4) of Grampus within the survey area off Pico island in the years of 2011–2018. Different subscript letters (a-c) indicate significant differences at the level of 0.05.

No significant relation was found with the predictor tidal phases and the displayed behaviour of Hyperoodon, Ziphiidae, Physeter, Globicephala, Tursiops and Small Oceanic Delphinids. The full SPSS outcomes for Balaenopteridae and Grampus can be found in **Appendix IX**.

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Distribution & density

According to the results of this study, the Bay of Ribeiras revealed to hold important densities of Hyperoodon, Physeter, Grampus and Small Oceanic Delphinids during low tide. Balaenopteridae presence yielded highest during rising tide, whereas Ziphiidae was sighted in greater numbers during descending tide and Globicephala and Tursiops during high and descending tide. The spatial distribution during tidal phases however, only showed clear patterns for Physeter, Globicephala and Tursiops.

As visualised in **Figure 16**, the largest Odontoceti was widely distributed in the study area and appeared to predominantly occupy both coastal and offshore waters with mean group sizes ranging from 1–17 individuals per sighting. The most common group size was 1–2 Physeter individuals per sighting (91.3%) followed by 3-5 in 6.8%, and 10-13 and 14-17 occurring in less than 1% of all recordings. With 10.3-12.8 animals/km^2, the highest Physeter density was recorded during low tide. The spatial distribution of this species indicated the lowest abundance during rising tide (7.8–10.3 animals/km^2) and animals were generally closer to shore. Towards low tide, the number of sightings increased and rather spread throughout the survey area than being concentrated in coastal regions of the bay.
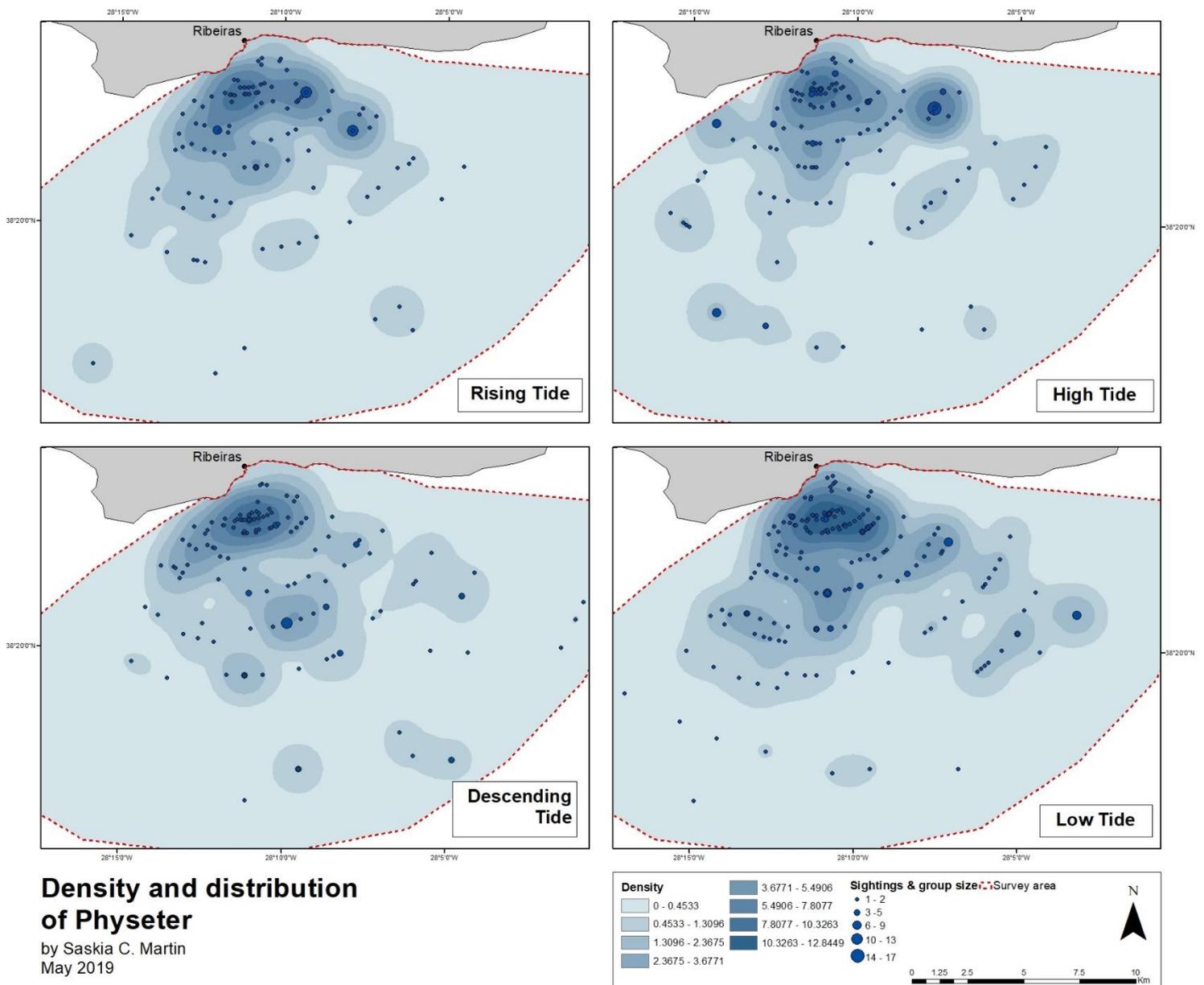
Figure 16. Density distribution of Physeter in the survey area.

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Although sightings during high and low tide were distributed more widely within the survey area, Physeter was detected to be densest in the same location of about 2 km from the coast during all tidal phases.

The species-group Globicephala generally occurred equally throughout all tidal phases and both, in and offshore waters, with mean group sizes ranging from 1–60 individuals per sighting. The majority of Globicephala was sighted in groups of 6–15 animals (42.3%), followed by group sizes of 1–5 in 31.6%, 16–30 in 19.2%, 31–50 in 5.6% and 51-60 in less than 1% of all sightings. Their highest density was recorded during high and descending tide with 25.5–31.1 animals/km^2. During rising tide, Globicephala was sighted in greater numbers closer to shore and during high tide, animals were spread more southwest towards offshore areas, with the densest area still close to shore. With descending tide, Globicephala appeared to move east and spread even further into that direction during low tide. During this tidal phase, when the sea water was at its lowest level, animals were distributed more evenly throughout the survey area and more towards deeper waters, without a particular area of high concentration (**Figure 17**).
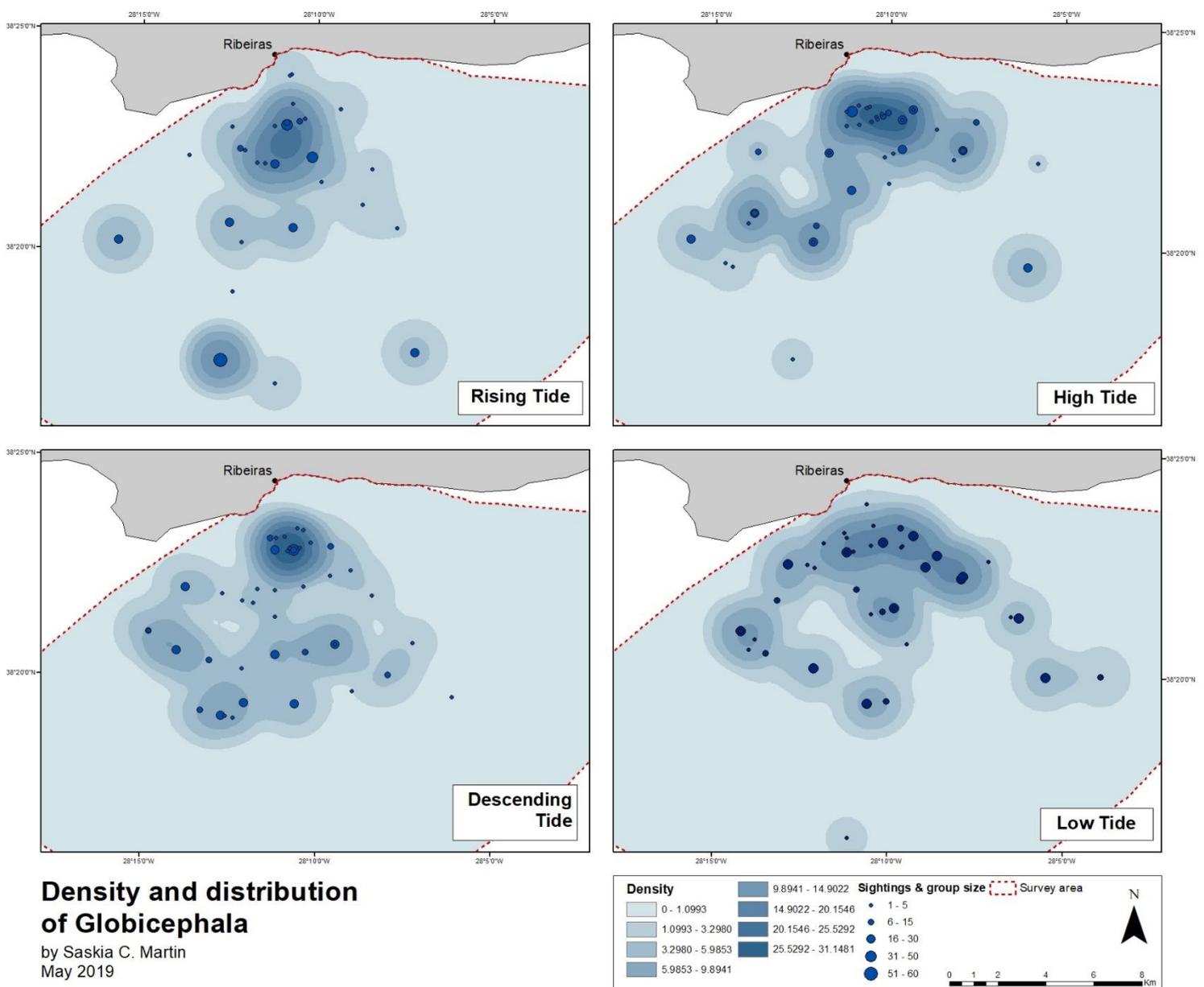
Figure 17. Density distribution of Globicephala in the survey area.

Tursiops appeared to generally prefer coastal regions, with the highest density recorded during descending tide with 76.9–94.7 animals/km². Mean group sizes varied between 1–250 individuals per sighting, whereas greatest numbers of more than 125 animals were only sighted during descending and low tide. In more than 80% of all sightings, Tursiops appeared in groups of up to 30 individuals (1–10 42.5%; 11–30 41.2%), 10.2% in groups of 31–50 and everything between 51–250 individuals in less than 3% of all recordings. Distributional patterns of this species showed a clear preference of coastal areas during rising and high tide and a spread southeast and southwest towards deeper offshore regions of the survey area during descending and low tide (**Figure 18**).
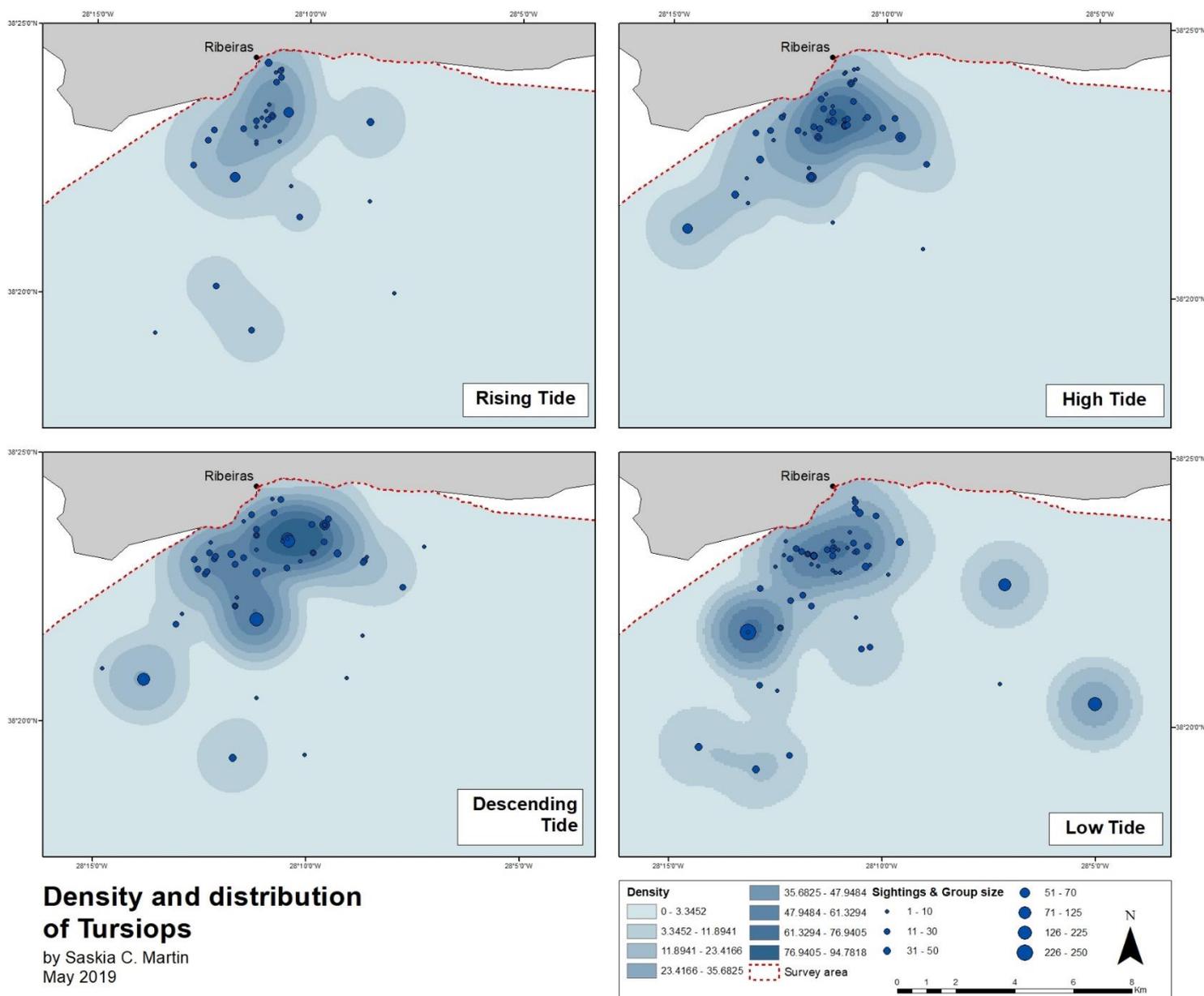
Figure 18. Density distribution of Tursiops in the survey area.

Movement patterns of Hyperoodon, Grampus and Small Oceanic Delphinids indicated slight changes between tidal phases, Balaenopteridae and Ziphiidae however, did not show any clear relation between spatial patterns and the tidal cycle. The respective density distribution maps of these species-groups can be found in **Appendix X**.

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Balaenopteridae was distributed throughout the entire research area, with group sizes ranging from 1-5 individuals per sighting. These mysticete species were most commonly recorded in groups of 1 with 70% of all sightings and revealed to be most abundant during high tide with a density of 1.8-2.3 animals/km^2. They showed no clear indication of any depth preference between tidal phases.

Compared to other species-groups, the genus Hyperoodon resulted in the lowest sighting rate with 48 sightings between 2011–2018. The group sizes of these beaked whale species were ranging from 3–17 individuals per sighting, whereby most pods formed aggregations of 6–11 animals (41.6%). Biggest group sizes of Hyperoodon were detected during low tide with a density of 11.6–14.3 animals/km^2. During rising and descending tide, animals were rarely encountered with only 6–8 sightings per phase. With 11 sightings and about 3.2–5.1 animals/km^2, Hyperoodon was sighted most frequently during high tide. The highest abundance regarding group size however was recorded during low tide, also with 11 sightings in total but greater group sizes of up to 17 individuals per sighting (2%). A clear preference of offshore areas is apparent in the maps throughout all tidal phases with one sighting closer to the coast during high tide (**Appendix X**).

Although Ziphiidae was also sighted in offshore areas, these species appeared to be most abundant in rather coastal areas. Groups consisted of 1–20 individuals with most frequent group sizes of 1–5 animals per sighting (64.6%). The highest density was recorded during descending and low tide with 14.2–17.5 animals/km^2, however no certain spatial pattern between the tidal phases was detected.

Groups of the species Grampus were sighted in pods ranging between 1–80 individuals, mainly forming aggregations of up to ten animals (80%). Low tide resulted in the highest density with 351.6–424.9 individuals/km^2 close to shore. Although a clear preference of coastal areas was detected throughout all tidal phases, densities slightly increased within offshore areas during descending and low tide.

Regarding Small Oceanic Delphinids, their groups were sighted in numbers of up to 2500 animals but were mainly recorded in pods of 1–50 individuals per sighting (63.6%). With a density of 2696.1–3321.3 animals/km^2, this species also showed to be most abundant during low tide. Distribution was mainly confined to coastal areas with some slight changes towards deeper waters during descending and low tide.

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4   Discussion

Azorean waters are considered an area of high productivity, containing a great food availability for cetaceans compared to the surroundings within the North Atlantic Ocean (R. S. Santos et al., 1995). The present study reports a high species richness within the Azores, yielding in 19 recorded cetacean species in the Bay of Ribeiras between 2011–2018. In total, the data of 17 species, clustered into eight subcategories, have been analysed in the present paper. Highest species richness was located relatively close to shore within the research area, which was also found by Van Geel (2007).

Fixed land stations are a useful way to collect data and avoid interference of research vessels with animal behaviour (David, 2002). However, boat surveys allow closer approaches which enables the determination of generally unrecordable elements such as animal condition and the identification of species and particular individuals (Giacoma, Papale, & Azzolin, 2013). Data used for analyses were solely collected from land, which hindered the determination of various cetaceans on a species-level. Thus, they were clustered into subcategories by their genus or family. This limitation needs to be considered when interpreting the results of the analyses, as environmental cycles and other factors can influence species from the same subcategory differently but might indicate an overall association. As suggested by Giacoma, Papale & Azzolin (2013), the use of a combination of vessel and land-based surveys might provide a better approach to collect data on distribution, habitat use and behaviour, specifically in relation to vessel disturbance and other anthropogenic factors.

Survey effort showed great variations between days and years. Some days included up to eight surveys, while other days only covered a single survey. Also, the duration of surveys was not standardised, resulting in effort ranging between a few minutes up to more than six hours. Although abundance and behavioural data was corrected for effort, distribution and density data did not include any corrections for the amount of time surveyed in each tidal phase. It should also be stressed that survey effort was strongly skewed towards the summer months with low effort during winter months due to poor weather conditions, resulting in rather seasonal results since cetaceans may occur more frequently during these periods. Therefore, the present study mainly represents summer abundance, distribution and behaviour and research covering all seasons are therefore suggested to determine year-around habitat use.

Another possible source of error might be the lack of consistency running surveys on a regular basis. A large number of sightings during the first survey of the day entailed less surveys throughout the rest of the day, resulting in an under dispersion for cetacean sightings. No sightings during the first observation period consequently meant another survey after 2 hours. These methodological limitations might explain the poor results in the abundance of most species-groups, which therefore lead to the use of presence-absence data instead of number of sightings per survey. With more sighting data, more precise models could have been used, which usually require a minimum sample size (Peduzzi, Concato, Kemper, Holford, & Feinstein, 1996). Although performance was not ideal it must be noted that the data collected on a long-term basis by the Nova Atlantis Foundation are nevertheless an important contribution and shed new light on cetacean habitat use in the Azores.

Various environmental factors can influence the sighting abilities and as reported by Giacoma, Papale, & Azzolin (2013), weather conditions have a significant effect on sighting frequencies from land-based platforms. Analyses showed that variables such as sea state, wind direction, cloud cover and visibility had a markedly correlation with the sightings of Grampus and Small Oceanic Delphinids. With decreasing visibility and increasing sea state and cloud cover the probability to detect these cetaceans decreased. This deduction in detectability due to environmental factors was also evidenced by several other studies such as Evans & Hammond (2004), who also noted that the glare may be another factor that particularly influences the detectability of whale species. Therefore, it is recommended to add this variable during data collection for following research by the Nova Atlantis Foundation.

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Proofreading entered data is of great importance. A lack of these follow-up inspections of the data entered from the sheets to Excel by largely unexperienced volunteers, lead to a high number of false or missing data which consequently had to be disregarded from the analysis. Even though the swell might have an influence on the habitat use of cetaceans, it was not possible to include this as a variable due to a lack of data.

Grampus appeared to be the most observed species within the research area (**Appendix IV**), although other studies performed within the archipelago of the Azores reported Small Oceanic Delphinids and Tursiops to be most frequently sighted (Gordon et al., 1987, 1989; M. A. Silva, 2007; M. A. Silva et al., 2003). These differences might be explained by the characteristics of methodology and the focal species during surveys. Whereas main emphases of the studies of Silva et al. (2003) and Silva (2007) was on Tursiops, data collection for this study was focussed on Grampus. However, Delphinids were the second most recorded species, followed by Physeter (**Appendix IV**). Habitat and prey preferences of many cetaceans are still unknown and vary strongly between species. Even so, Grampus seems to prefer coastal, shallower regions within the North Atlantic (Reid, Evans, & Northridge, 2003). Hence, the chance of spotting this species off shore is higher than detecting oceanic species that prefer deeper waters such as elusive beaked whales (Hyperoodon and Ziphiidae) which are distributed further out or even beyond the research area. This might affect the probability of detection from a land-based station greatly and could explain the differences in cetacean abundance.

Not only human activities alter spatial and temporal abundance as well as behavioural patterns of cetaceans, but also environmental cycles have a significant influence on their habitat use (Bordino, 2002; Fernandez-Betelu et al., 2019; Shane, 1990). The present study reports several of the cetacean species present within the waters of the Azores archipelago appeared to be affected by lunar and tidal phases.

The apparent lack of correlation between the lunar and tidal cycle and the abundance, distribution and behaviour of some species could also be explained by anthropogenic activities within the area and the method of collecting data during the day, as daylight surveys hinder the direct record of the lunar effect. Based on practical benefits, most studies on behavioural patterns focused the data collection period on day-time hours and thus nocturnal patterns remain largely unexplored. Further experimental nocturnal investigations in form of Passive Acoustic Monitoring would help reveal the direct effect of the lunar cycle on relative abundance, behavioural patterns, and habitat use.

4.1. Lunar cycle
Abundance of Hyperoodon, Ziphiidae, Physeter, Grampus and Small Oceanic Delphinids showed clear lunar patterns between 2011–2018 within the research area off Pico island. These species-groups indicated a clear preference of periods with less lunar illumination around new moon. Hyperoodon, Physeter, Grampus and Delphinids were least sighted around the brightest lunar phase of full moon, with an increase shortly after, whereas Ziphiidae showed a further decrease until new moon. Previous findings of a study conducted in the same area by Van Geel (2007) already proposed that the nocturnal illumination from the lunar state might be a cue for cetaceans' abundance and distribution within Azorean waters, which might substantiate the results of the present study. Furthermore, Grampus and Physeter are believed to mainly forage on cephalopods (Roberts, 2003), whereas Grampus appears to be nocturnal feeder (Kruse, Caldwell, & Caldwell, 1999). As stated by Tarling, Buchholz, & Matthews (1999) and Benoit-Bird et al. (2009), moonlight has a strong effect on the vertical migration of marine organisms. Several other studies have proffered that organisms will not migrate as far up during full moon or that they start migrating during periods with less lunar illumination such as an eclipse (Richards, Possingham, & Noye, 1996). These cyclic movements of many marine prey species lead to an indirect influence on the habitat use of cetaceans (Benson, Croll, Marinovic, Chavez, & Harvey, 2002; Croll et al., 1998; Gaskin, 1972, 1982; Littaye, Gannier, Laran, & Wilson, 2004), which would corroborate the findings of this study.

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However, it is not known whether Physeter also uses the vertical migration of cephalopods through the water column, as suggested for Grampus.

According to Norris & Dohl (1980) and Wells, Irvine, & Scott (1980) the abundance and distribution of food resources are also known to affect cetacean populations in their group size, stating that more food means more individuals in one group. However, analyses revealed a rather opposing result of a greater number of individuals of Hyperoodon sighted during full moon, when food is supposed to be less abundant, and smaller groups during periods with least or no lunar illumination.

Although these species feed principally on deep-water squid (Hooker, 1999; Papastavrou, Smith, & Whitehead, 1989) which again, undergo strong vertical migrations due to solar and lunar illumination (Barham, 1966; Bianchi & Mislan, 2016; Klevjer et al., 2016), it is not known whether group sizes changed between lunar phases as a result of the distribution and abundance of its prey. Also, behavioural analysis did not detect any association with the lunar cycle. Various cetacean species have been reported to be actively foraging during night, due to the increased prey availability (Norris, Würsig, Wells, & Würsig, 1994; Sazima, Sazima, & Da Silva Jr, 2003; F. J. D. L. Silva & Da Silva Jr, 2009), therefore it is suggested that Hyperoodon is likely to be a nocturnal feeder, which could give a possible explanation, since foraging activity was then most likely underestimated due to sampling during daylight hours. Furthermore, given the applied method and that the findings are based on a limited number of sightings (n=48; **Appendix IV**), the conclusions drawn from the present result have limitations and are compromised and should therefore be interpreted with caution. According to the global conservation status by IUCN (2018), species of the family Ziphiidae (beaked whales) are currently listed as either threatened or data deficient. Further research specifically aimed towards beaked whale species would help to get more insight on the behavioural and distributional ecology of these elusive cetaceans.

Grampus appeared to prefer periods of increasing lunar illumination for resting and the darkest periods of the lunar cycle to forage and socialise. These changes in foraging over the lunar cycle correlate with the suppression of the vertical migration of prey by lunar light and supports the findings by Henderson, Hildebrand, Smith, & Falcone (2012), Wiggins, Frasier, Henderson, & Hildebrand (2013) and Simonis et al. (2017). The correlation of resting behaviour and increasing lunar illumination seem to confirm Sekiguchi & Kohshima's (2003) observations, that resting tends to predominate during brighter periods of the night, when food resources are not as abundant.

Foraging behaviour of deep-diving cetaceans such as Grampus was reported to be influenced by the time of day. Dusk and dawn have shown to be the preferential time for feeding (Baird, Borsani, Hanson, & Tyack, 2002; Pusineri et al., 2007) as prey species are coming closer to the surface during darker periods. Visser, Hartman, Rood, et al. (2011) determined that Grampus' foraging activity within Azorean waters mostly occurred during darker periods, corroborating the findings of the present study.

Travelling behaviour of Small Oceanic Delphinids showed highest recordings after full moon, foraging activity however was mainly displayed before and during full moon. This outcome in fact refutes the findings by the previous studies and the reason for this rather contradictory result could again be explained by the sole use of daylight surveys. Henderson et al. (2012) and Wiggins et al. (2013) have identified Delphinids' foraging behaviour to mainly occur nocturnally, whereas travelling and socialising activity was mainly observed during the day.

Moreover, it cannot be ruled out that whale watching activities within the Bay of Ribeiras may have influenced behavioural patterns of Grampus and Delphinids, as these species were predominantly present and thus a main target for boat operators (Visser, Hartman, Rood, et al., 2011). Research that compares the data of cetacean habitat use within Azorean waters on an annual level would help reveal effects of human disturbance, should they exist. Further assessment of the impact of marine vessel disturbance on cetacean species, as well as the application of additional management measures for this area are strongly recommended.

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Contrary to expectations, the observed lunar phase had no effects on Balaenopteridae, Globicephala and Tursiops. The reason for the lack of correlation for Globicephala is not yet entirely understood, as this species-group has similar dietary preferences compared to Hyperoodon, Ziphiidae, Physeter, Grampus and Delphinids, all mainly foraging on cephalopods. Tursiops however is an opportunistic feeder, consuming a wide variety of fish, cephalopods and shrimps (Mörzer Bruyns, 1971; M. B. Santos et al., 2001) which might indicate that this species switches to other prey species during times with greater lunar illumination.

Other than odontocete species, Balaenopteridae have different feeding strategies and prey preferences, mainly foraging on krill (Cotté & Simard, 2005; Piatt et al., 1989; Whitehead & Carscadden, 1985; Yochem & Leatherwood, 1985) which also migrates vertically due to illumination (Marlowe & Miller, 1975). However, it is generally believed that foraging activity of Balaenopteridae mostly occurs during daylight hours, as proposed by Friedlaender et al. (2009) who reported humpback whales to produce bubble nets only during the day. This could explain that no correlation between the abundance and behaviour of Balaenopteridae and the lunar cycle was detected, since prey species are mainly affected during night times.

4.2. Tidal cycle
Most cetacean-groups were sighted in higher abundance in coastal areas, corroborating findings by Van Geel (2007) within the same research area. This might be explained by the bathymetric features, specifically the lack of continental slope, as already suggested by Van Geel (2007), as steep slopes and great depths close to shore allow the observation of else offshore species from land-based stations.

Abundance of Grampus and Small Oceanic Delphinids showed clear tidal patterns between 2011–2018 within the research area off Pico island. Contrary to expectations, the number of sightings of these species indicated a clear preference of periods when water levels were lowest. Both species-groups seemed to move slightly towards offshore areas during descending and low tide.

At low tide there is a decrease in habitat and increased density of fish, the main prey source of many dolphin species, and this increase in resource availability may result in a higher abundance of predators (Reis-Filho, Barros, Da Costa Nunes, Sampaio, & De Souza, 2011). Also, swimming against the current during flood or ebb has been suggested as a feeding activity (Shane et al., 1986) and could indicate that Grampus and Delphinids use this technique during descending and low tide.

Moreover, dolphin abundance and distribution has been reported to be extremely variable. According to Parsons (1998), the Indo-Pacific humpback dolphin in Hong Kong was mostly seen during low tide, while Mendes, Turrell, Lütkebohle, & Thompson (2002) reported Tursiops sightings in Scotland to be most common during rising and high tide. An increasing number of studies have shown that the habitat use in relation to the tidal cycle might even differ between cetacean populations of the same species (Lin et al., 2013; Parsons, 1998). This suggests that the influences of the tidal phases are determined by the characteristics of the habitat and consequently, how dolphins use it (Lin et al., 2013). Bathymetry has been indicated as being a markedly factor in the presence and distribution of cetaceans in the Azores, with depth and slope having the strongest influence (Van Geel, 2007). As initially expected, Grampus' behavioural activity showed that this species was primarily travelling during low tide and foraging during high tide, a period associated with a greater quantity of prey (Saayman & Tayler, 1979). Resting behaviour on the other hand was mostly displayed during low tide, contrary to expectations.

Balaenopteridae, the largest group of baleen whales, which mostly prefer offshore waters, supported by their density distribution within the survey area, have been reported to show higher feeding rates in cooler (Owen, Jenner, Jenner, McCauley, & Andrews, 2018) upwelling waters (Forcada, 2002; LeDuc, 2002). This could explain the unexpected outcome that foraging behaviour predominantly occurred during low tide, when prey species from shallower areas are being transported to deeper waters by the tidal stream. Most sighted species of the family Balaenopteridae are currently classified as threatened by IUCN (2018; **Table 1**), giving more reason to identify and minimise potential stressors and impacts on the habitat use of these species around the Azores.

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Despite the fact that densities appeared to be highest during specific tidal phases, no significant correlation between the abundance of Balaenopteridae, Hyperoodon, Ziphiidae, Physeter, Globicephala and Tursiops, and the tidal cycle was found. Yet, the distribution patterns of Physeter, Globicephala and Tursiops showed clear shifts between tidal phases, with more sightings within coastal areas during rising and high tide and animals moving towards offshore areas with descending and low tide as hypothesised. It is generally thought that increased sightings of cetaceans with incoming and high tide is associated with greater prey species abundance (Bordino, 2002) and specifically spatial patterns of coastal cetacean species are believed to be related to the movement of prey (Gaskin, 1982). In addition, swimming with the tidal current could be also used as an energy efficient feeding strategy as suggested by Bordino (2002). A study about the distribution of Globicephala has also shown that these species alter their depth preferences between seasons, being found in shallower water during winter and deeper areas during summer (Bernard & Reilly, 1999) which confirms the findings of this study.

Also, Delphinids' and Hyperoodons' distribution patterns indicated a slight change of distribution between tidal phases. Delphinids tended to move towards offshore areas during descending and low tide, whilst Hyperoodon was sighted closer to shore during high tide. However, given the small number of Hyperoodon sightings (n=48) and the extent of change in distribution of Delphinids (**Appendix X**), caution must be applied.

The two oceanic species belonging to the genus Hyperoodon are known to favour cold water, reflected by their distribution and abundance at higher latitudes (Reid, Evans, & Northridge, 2003). The area used throughout tidal phases indicated a small tendency towards coastal waters during high tide when cooler water was brought in during flood. Generally, salinity and water temperature have been reported to influence the distribution of cetacean prey species (Wells et al., 1990) and consequently affect cetaceans themselves (Findlay, Best, Ross, & Cockcroft, 1992; Jaquet, 1996; Ross & Cockcroft, 1990; Wells et al., 1990). Within the region of the Azores, water is rather warm with a high salinity due to the two ocean currents (R. S. Santos et al., 1995). Incoming waters during rising and high tide bring colder sea water closer to the coast and could explain why offshore species like Hyperoodon, Delphinids, Physeter and Globicephala are more abundant during these tidal phases.

A reanalysis of the data used for this study, focussing on the swimming direction of cetacean species, could help reveal further movement patterns in association with the tidal cycle. Generally, surveys should be as standardised as possible. This may be difficult when influencing factors on cetacean presence within the survey area are unknown. Even with surveys at the same time on a daily basis, species presence might be strongly determined by the tidal phase which changes roughly every six hours. A more precise way of measure would be the inclusion of the current in its strength and direction as suggested by Evans & Hammond (2004).

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5 Conclusions

The result of this study showed a strong association between both environmental variables and cetaceans' abundance, distribution and behaviour to different extents. Lunar phases were found to be an important predictor for the abundance of Hyperoodon, Ziphiidae, Physeter, Grampus and Small Oceanic Delphinids. Abundance of these species-groups seemed to increase around new moon and decrease around full moon. Grampus showed more travelling behaviour after full moon, more resting with increasing lunar illumination and most foraging and socialising activity around darker periods of new moon. Delphinids displayed travelling behaviour mainly after full moon and foraging activity occurred mostly before and during full moon. Hyperoodon was sighted in greater group sizes during full moon.

Tidal phases were found to be an important factor influencing the abundance of Grampus and Delphinids, both sighted in greater numbers during low tide. Grampus showed a strong preference of coastal areas, however spatial distribution only showed minor differences between tidal phases, moving slightly towards offshore areas during descending and low tide. This species was primarily travelling and resting with low tide and foraging occurred mostly during high tide. Delphinids appeared to be most abundant when sea water was lowest, however spatial patterns only revealed a slight change between tidal phases with movements towards offshore areas during descending and low tide. Physeter, Globicephala and Tursiops seemed to use areas closer to the coast during rising and high tide. Movement patterns of Balaenopteridae and Ziphiidae did not seem to be related to the tidal current. Balaenopteridae showed foraging activity predominantly during low tide, whilst the majority of observed animals was travelling during rising tide and resting during high tide. No socialising behaviour was recorded for this species-group. Hyperoodon was mainly sighted in deeper waters with only one sighting closer to shore during high tide.

The effect of environmental cycles on cetaceans' habitat use is obvious, but whether it is solely due to the tidal or lunar cycle is uncertain. Cetaceans are heavily dependent on sound to communicate, navigate and detect prey and predators. For that reason, anthropogenic impacts such as vessel disturbance, a conflict that is particularly likely to occur in coastal regions such as the bay of Ribeiras, may negatively impact cetaceans' habitat use (Visser, Hartman, Rood, et al., 2011). Several studies have evidenced the vast richness of cetacean species in Azorean waters (e.g. Van Geel, 2007), and the present study shows that they are most abundant around new moon and low tide within the research area off Pico island. This is valuable information for conservation and management and to reduce potential adverse impacts on cetaceans. The present study enhances our knowledge of critical habitat characteristics for cetacean species present in the Azores, and these factors should be considered when planning local human activities targeting species conservation. The pollution our oceans, specifically in form of noise, has dramatically shaped queries on the impact of the whale watching industry on cetaceans' behaviour and physiology in recent years.

Preferred areas are particularly important for survival and reproduction, and changes to these areas are most likely to affect the abundance and distribution of these species (J. Harwood, 2001). Identifying critical habitats for cetaceans, in particular foraging and breeding grounds, is the first step towards Marine Protected Area implementation and management (Hoyt, 2005).

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Glossary

Absence	Cetacean species are considered absent when no visual data were recorded
Beaufort Wind force	A wind force scale from 0 (calm) to 12 (hurricane) (Tibbs, 2005)
Cetacean	Marine mammals of the order Cetacea which include whales, dolphins and porpoises (Perrin et al, 2008).
Cetacean group	Any aggregation of cetaceans (>=1), observed in a clearly visible constellation within five body lengths (chain rule) showing similar behavioural activities.
Collinearity	Different variables influence each other which could make it difficult to assign independent variable effects (Dormann et al., 2013)
Douglas Sea State (DSS)	A scale describing the sea state, meaning the height of the waves and also assesses the swell; ranging from 0 (glassy) to 9 (phenomenal)
Lunar Phases	The shape of the illuminated portion of the Moon from the sun as viewed from Earth
Observation	Instance of observing animals during a survey
Presence	A cetacean species is considered present when at least one visual sighting was recorded
Sighting	Recorded observation of a group (n>=1) of a cetacean species, irrespective of its group size
Survey	Collection of observations / sightings (n>=0) during a set period of time, scanning the water surface for cetaceans.
Tides	Vertical movements of water. When the water is rising, the tide is coming in (flooding). When the water level decreases, the tide is going our (ebbing)

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Appendix I: Full record of data collected

Data collected during land-based surveys by the Nova Atlantis Foundation (2004-2018).

Data collected	Description
Date, start- and end time, duration	Date of each survey (dd/mm/yy); Start- and end time of each survey hh:mm; Duration of each survey (hh:mm)
Time of sighting	Time of first observation of the species (hh:mm)
Species, group number and group size	Species identity (abbreviation of scientific name used, e.g. GG=*Grampus griseus*); Number of groups sighted per species per survey; Number (n) of individuals sighted
Formation, movement	Formation states and events of the group (tight, loose, spread out, line etc.), also position of a particular individual (e.g. leader); Type of movement of the animals (speed, dives, blows etc.)
Location, distance, direction	Location in the bay in degrees (using a compass from observation point); estimated distance between animals and shoreline (%); Direction species is travelling (North, East, South, West)
Behaviour	Behavioural states (socialising, travelling, resting, foraging, mating etc.); Events (tail/flipper slap, breaching, spy-hopping, nursing etc.); Interaction with present boats/research vessel (bow-riding, approaching, diving, etc.); Reaction towards present vessels (diving, group spreads out, change of direction and/or formation etc.)
Calf presence	Calves present within observation group, indicates that animal it's swimming close to is the cow (female)
Lunar phase	New moon (*Moon is not visible in the sky; except during solar eclipse*) Waxing crescent (*Moon is less than half illuminated by the sun and illumination is increasing*) First quarter (*Moon is half illuminated by the sun and illumination is increasing*) Waxing gibbous (*Moon is more than half illuminated by the sun but not completely illuminated*) Full moon (*Moon is fully illuminated by the sun; except during lunar eclipse*) Waning gibbous (*Moon is more than half illuminated but not completely and illumination is decreasing*) Third quarter (*Moon is half illuminated by the sun and illumination is decreasing*) Waning crescent (*Moon is less than half illuminated by the sun and illumination is decreasing*)
Percent moon	Percentage of illuminated part of the moon (full moon = 100%)
Tidal phase	High tide (*Sea water level is highest*) Descending tide (*Sea water level is decreasing after high tide*) Low tide (*Sea water level is lowest*) Rising tide (*Sea water level is increasing after low tide*)
Environmental data	Weather (rain, storm, fog, haze); Cloud cover (% intervals of 10); Wind direction (N, E, S, W); Wind (Beaufort); Sea state (Douglas scale); Swell (low, medium, high); Visibility (%)
Quality	Quality of survey (focal-follow possible, land-based survey only, disrupted etc.)

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Vessels	Type (small/large fishing boat, whale watch boat [company], research boat, cruiser, tanker, military); Presence of vessels (arrive/leave bay, present/arriving/leaving cetaceans); Behaviour towards cetaceans (following, searching, approaching, waiting, …); Vessel action (enclose, cross-over group, herding animals, swimmers in water start/end time, etc.)

Appendix II: Data preparation code book

Variable/factor/file	Description	Format	Year	Scale/grid	Values	Source
Species sighting data	Collected data on cetacean sightings (Presence-absence, #sightings, group size/mean#individ.)	xls	2011 – 2018	Scale	Nr	Nova Atlantis Foundation
Coordinates	Longitude and latitude of each cetacean group observed	xlsx, shp	2011 – 2018	Azores Central 1995/UTM zone 26N	UTM	Nova Atlantis Foundation, Van Geel
Behavioural data	Recorded behavioural states (foraging, socialising, travelling, resting) per cetacean group observed	xls	2011 – 2018	Nominal	Presence [1], absence [0]	Nova Atlantis Foundation
Environmental data	Cloud cover	xls	2011 – 2018	Scale	Percentage (%)	Nova Atlantis Foundation
	Wind direction	xls	2011 – 2018	Nominal	N, NE, NW, E, S, SE, SW, W	
	Sea state	xls	2011 – 2018	Ordinal	1-9 (Douglas scale)	
	Visibility	xls	2011 – 2018	Ordinal	Percentage (%)	
Tides	Tidal phase (high tide, descending tide, low tide, rising tide)	xls	2011 – 2018	Nominal	1-4	Instituto Hidrográfico
Lunar phases	Lunar phases (New moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, third quarter, waning crescent)	xls	2011 – 2018	Nominal	1-8	Instituto Hidrográfico

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Appendix III: Clustered subcategories species codes

Species codes recorded 2011 – 2018	Species name / definition	Grouped
Bspec	Baleen whales (general)	Balaenopteridae
Be	Bryde's whale	
Bb	Sei whale	
Bm	Blue whale	
Bp	Fin whale	
Mnov	Humpback whale	
Hamp	Northern Bottlenose whale	Hyperoodon
Mspec	Beaked whales (general)	Ziphiidae
Mb	Sowerby's beaked whale	
Md	Blainville's beaked whale	
Zcav	Cuviers's beaked whale	
Pm	Sperm whale	Physeter
Kb	Pygmy sperm whale	excluded
Pcras	False killer whale	excluded
Gmac	Short-finned pilot whale	Globicephala
Gmelas	Long-finned pilot whale	
Gg	Risso's dolphin	Grampus
Tt	Bottlenose dolphin	Tursiops
Sspec	Small delphinid species (general)	Small Oceanic Delphinids
Dd	Common dolphin	
Scour	Striped dolphin	
Sf	Spotted dolphin	

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Appendix IV: Species sightings

Species * Year Crosstabulation

Count

		Year								Total
		2011	2012	2013	2014	2015	2016	2017	2018	
Species	Balaenopteridae	17	18	5	23	6	22	30	16	137
	Hyperoodon	5	3	1	4	6	26	3	0	48
	Ziphiidae	11	32	8	7	4	21	32	60	175
	Physeter	129	198	37	29	56	32	108	97	686
	Globicephala	47	16	57	6	5	16	9	21	177
	Grampus	292	219	157	146	255	293	842	202	2406
	Tursiops	14	41	30	17	18	35	35	36	226
	Small Delphinids	432	309	302	124	178	125	415	275	2160
Total		947	836	597	356	528	570	1474	707	6015

Species * Year Crosstabulation

Count

		Year								Total
		2011	2012	2013	2014	2015	2016	2017	2018	
Species	Bb	2	2	0	0	1	2	0	2	9
	Be	0	0	2	0	0	0	0	0	2
	Bm	6	0	2	7	0	3	4	0	22
	Bp	6	3	0	6	2	10	13	6	46
	Bspec	3	12	1	8	3	3	10	8	48
	Dd	142	120	127	94	78	28	113	55	757
	Gg	292	219	157	146	255	293	842	202	2406
	Gmac	47	16	57	5	5	16	9	21	176
	Gmelas	0	0	0	1	0	0	0	0	1
	Hamp	5	3	1	4	6	26	3	0	48
	Kb	0	0	0	0	0	0	1	1	2
	Mb	0	11	0	1	1	3	5	4	25
	Md	2	0	4	1	0	4	0	3	14
	Mnov	0	1	0	2	0	4	3	0	10
	Mspec	7	21	2	4	3	13	26	52	128
	Pcas	0	2	0	0	0	3	4	6	15
	Pm	129	198	37	29	56	32	108	97	686
	Scour	3	2	4	0	1	0	5	0	15
	Sf	3	1	2	4	9	9	12	28	68
	Sspec	284	186	169	26	90	88	285	192	1320
	Tt	14	41	30	17	18	35	35	36	226
	Zcav	2	0	2	1	0	1	1	1	8
Total		947	838	597	356	528	573	1479	714	6032

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Appendix V: Model builder
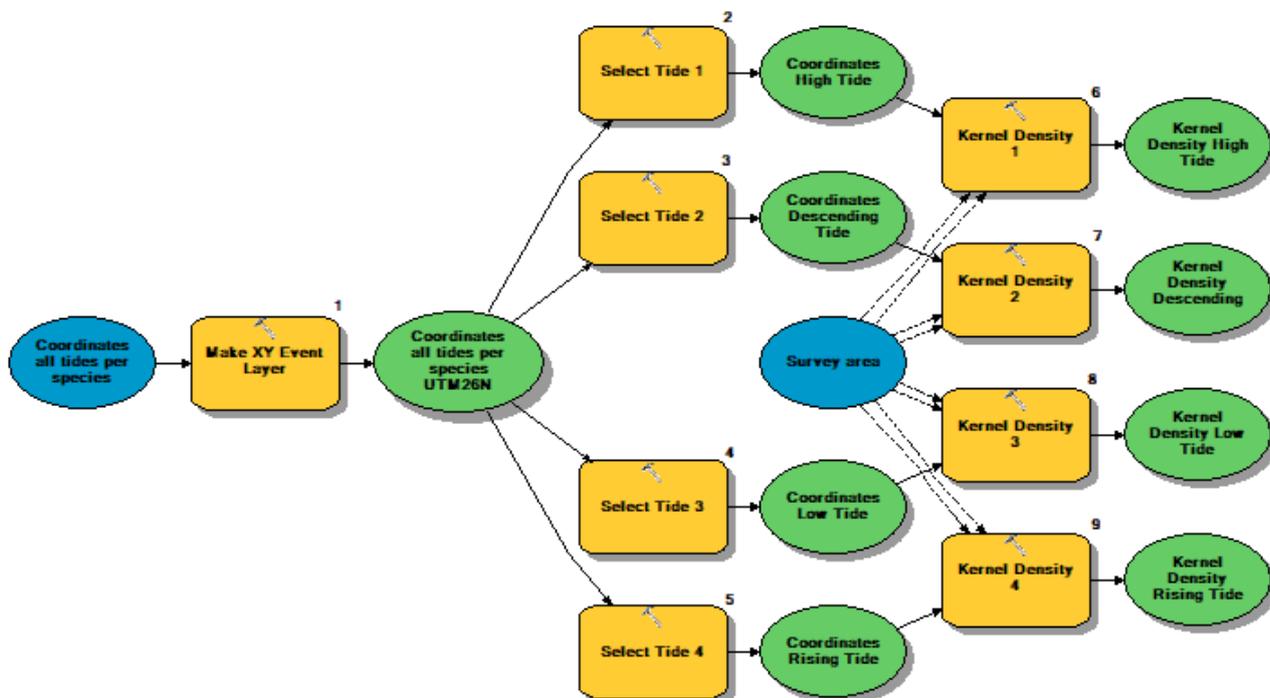
Step	Input	Tool	Settings	Output
1	Coordinates all tides per species	Make XY event layer	X field: Easting, Y field: Northing, Spatial Reference: Azores_Central_1995_UTM_Zone_26N	Coordinates all tides per species UTM26N
2	Coordinates all tides per species UTM26N	Select	Expression: `Tide`=1	Coordinates High Tide
3	Coordinates all tides per species UTM26N	Select	Expression: `Tide`=2	Coordinates Descending Tide
4	Coordinates all tides per species UTM26N	Select	Expression: `Tide`=3	Coordinates Low Tide
5	Coordinates all tides per species UTM26N	Select	Expression: `Tide`=4	Coordinates Rising Tide
6	Coordinates High Tide	Kernel Density	Population field: Group size, ourput cell size: 30, search radius: 2000, Area units: Square Kilometers; Survey area extent & mask	Kernel Density High Tide
7	Coordinates Descending Tide	Kernel Density	Population field: Group size, ourput cell size: 30, search radius: 2000, Area units: Square Kilometers; Survey area extent & mask	Kernel Density Descending Tide
8	Coordinates Low Tide	Kernel Density	Population field: Group size, ourput cell size: 30, search radius: 2000, Area units: Square Kilometers; Survey area extent & mask	Kernel Density Low Tide
9	Coordinates Rising Tide	Kernel Density	Population field: Group size, ourput cell size: 30, search radius: 2000, Area units: Square Kilometers; Survey area extent & mask	Kernel Density Rising Tide

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Appendix VI: GLM & GEE outcomes lunar cycle

Hyperoodon sightings – GLM binary logistic regression

Categorical Variable Information

			N	Percent
Dependent Variable	PresSAbs	Absent	2577	98.6%
		Present	36	1.4%
		Total	2613	100.0%
Factor	Lunar	NewMoon	655	25.1%
		WaxingCrescent	154	5.9%
		FirstQuarterMoon	243	9.3%
		WaxingGibbous	255	9.8%
		FullMoon	637	24.4%
		WaningGibbous	235	9.0%
		ThirdQuarterMoon	239	9.1%
		WaningCrescent	195	7.5%
		Total	2613	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Offset	offsetdur	2613	-3.00	1.85	-1.1100	.36603

Case Processing Summary

	N	Percent
Included	2613	100.0%
Excluded	0	0.0%
Total	2613	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2.034	0	.
Scaled Deviance	2.034	0	
Pearson Chi-Square	2.252	0	.
Scaled Pearson Chi-Square	2.252	0	
Log Likelihood[b]	-9.766		
Akaike's Information Criterion (AIC)	35.533		
Finite Sample Corrected AIC (AICC)	35.588		
Bayesian Information Criterion (BIC)	82.479		
Consistent AIC (CAIC)	90.479		

Dependent Variable: PresSAbs
Model: (Intercept), Lunar, offset = offsetdur[a]

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Estimates

Lunar	Mean	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper
NewMoon	.06	.015	.04	.10
WaxingCrescent	.04	.025	.01	.13
FirstQuarterMoon	.01	.012	.00	.08
WaxingGibbous	.02	.015	.01	.08
FullMoon	.01	.006	.00	.03
WaningGibbous	.08	.027	.04	.15
ThirdQuarterMoon	.02	.016	.01	.09
WaningCrescent	.09	.033	.04	.18

Tests of Model Effects

	Type III Wald Chi-Square	df	Sig.
Source			
(Intercept)	222.840	1	.000
Lunar	15.135	7	.034

Dependent Variable: PresSAbs
Model: (Intercept), Lunar, offset = offsetdur

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
(Intercept)	-2.356	.4155	-3.170	-1.542	32.148	1	.000	.095	.042	.214
[Lunar=1]	-.424	.4964	-1.397	.549	.729	1	.393	.655	.247	1.732
[Lunar=2]	-.931	.8249	-2.548	.686	1.274	1	.259	.394	.078	1.985
[Lunar=3]	-2.061	1.0850	-4.188	.065	3.609	1	.057	.127	.015	1.067
[Lunar=4]	-1.430	.8232	-3.043	.184	3.016	1	.082	.239	.048	1.202
[Lunar=5]	-2.368	.8213	-3.978	-.759	8.315	1	.004	.094	.019	.468
[Lunar=6]	-.140	.5667	-1.251	.970	.061	1	.804	.869	.286	2.639
[Lunar=7]	-1.401	.8233	-3.015	.212	2.897	1	.089	.246	.049	1.237
[Lunar=8]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									

Dependent Variable: PresSAbs
Model: (Intercept), Lunar, offset = offsetdur

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

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Pairwise comparison lunar phases & Hyperoodon sightings

Pairwise Comparisons

(I) Lunar	(J) Lunar	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
NewMoon	WaxingCrescent	.02	.029	1	1.000	-.07	.11
	FirstQuarterMoon	.05	.019	1	.337	-.01	.11
	WaxingGibbous	.04	.021	1	.932	-.03	.10
	FullMoon	.05	.016	1	.058	.00	.10
	WaningGibbous	-.02	.031	1	1.000	-.11	.08
	ThirdQuarterMoon	.04	.022	1	.951	-.03	.10
	WaningCrescent	-.03	.036	1	1.000	-.14	.08
WaxingCrescent	NewMoon	-.02	.029	1	1.000	-.11	.07
	FirstQuarterMoon	.02	.027	1	1.000	-.06	.11
	WaxingGibbous	.01	.029	1	1.000	-.08	.10
	FullMoon	.03	.025	1	1.000	-.05	.11
	WaningGibbous	-.04	.037	1	1.000	-.15	.07
	ThirdQuarterMoon	.01	.029	1	1.000	-.08	.10
	WaningCrescent	-.05	.041	1	.999	-.18	.08
FirstQuarterMoon	NewMoon	-.05	.019	1	.337	-.11	.01
	WaxingCrescent	-.02	.027	1	1.000	-.11	.06
	WaxingGibbous	-.01	.019	1	1.000	-.07	.05
	FullMoon	.00	.013	1	1.000	-.04	.04
	WaningGibbous	-.06	.030	1	.572	-.16	.03
	ThirdQuarterMoon	-.01	.020	1	1.000	-.07	.05
	WaningCrescent	-.07	.035	1	.604	-.18	.03
WaxingGibbous	NewMoon	-.04	.021	1	.932	-.10	.03
	WaxingCrescent	-.01	.029	1	1.000	-.10	.08
	FirstQuarterMoon	.01	.019	1	1.000	-.05	.07
	FullMoon	.01	.017	1	1.000	-.04	.07
	WaningGibbous	-.05	.031	1	.913	-.15	.04
	ThirdQuarterMoon	.00	.022	1	1.000	-.07	.07
	WaningCrescent	-.06	.036	1	.891	-.18	.05
FullMoon	NewMoon	-.05	.016	1	.058	-.10	.00
	WaxingCrescent	-.03	.025	1	1.000	-.11	.05
	FirstQuarterMoon	.00	.013	1	1.000	-.04	.04
	WaxingGibbous	-.01	.017	1	1.000	-.07	.04
	WaningGibbous	-.07	.028	1	.353	-.15	.02
	ThirdQuarterMoon	-.01	.017	1	1.000	-.07	.04
	WaningCrescent	-.08	.033	1	.432	-.18	.03
WaningGibbous	NewMoon	.02	.031	1	1.000	-.08	.11
	WaxingCrescent	.04	.037	1	1.000	-.07	.15
	FirstQuarterMoon	.06	.030	1	.572	-.03	.16
	WaxingGibbous	.05	.031	1	.913	-.04	.15
	FullMoon	.07	.028	1	.353	-.02	.15
	ThirdQuarterMoon	.05	.031	1	.928	-.04	.15
	WaningCrescent	-.01	.043	1	1.000	-.14	.12
ThirdQuarterMoon	NewMoon	-.04	.022	1	.951	-.10	.03
	WaxingCrescent	-.01	.029	1	1.000	-.10	.08
	FirstQuarterMoon	.01	.020	1	1.000	-.05	.07
	WaxingGibbous	.00	.022	1	1.000	-.07	.07
	FullMoon	.01	.017	1	1.000	-.04	.07
	WaningGibbous	-.05	.031	1	.928	-.15	.04
	WaningCrescent	-.06	.036	1	.905	-.18	.05
WaningCrescent	NewMoon	.03	.036	1	1.000	-.08	.14
	WaxingCrescent	.05	.041	1	.999	-.08	.18
	FirstQuarterMoon	.07	.035	1	.604	-.03	.18
	WaxingGibbous	.06	.036	1	.891	-.05	.18
	FullMoon	.08	.033	1	.432	-.03	.18
	WaningGibbous	.01	.043	1	1.000	-.12	.14
	ThirdQuarterMoon	.06	.036	1	.905	-.05	.18

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable PresSAbs

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Hyperoodon group size – GEE linear regression

Pairwise Comparisons

(I) Lunarphase	(J) Lunarphase	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference Lower	Upper
NewMoon	WaxingCrescent	.3086[a]	.06970	1	.000	.0914	.5258
	FirstQuarterMoon	.1140	.06070	1	.825	-.0751	.3032
	WaxingGibbous	.2516	.29375	1	1.000	-.6638	1.1671
	FullMoon	.0305	.06334	1	1.000	-.1669	.2279
	WaningGibbous	.3676	.12749	1	.105	-.0297	.7649
	ThirdQuarterMoon	-.0786	.14915	1	1.000	-.5435	.3862
	WaningCrescent	.0947	.08372	1	1.000	-.1662	.3556
WaxingCrescent	NewMoon	-.3086[a]	.06970	1	.000	-.5258	-.0914
	FirstQuarterMoon	-.1946[a]	.03426	1	.000	-.3014	-.0878
	WaxingGibbous	-.0570	.28944	1	1.000	-.9590	.8451
	FullMoon	-.2782[a]	.03874	1	.000	-.3989	-.1574
	WaningGibbous	.0590	.11723	1	1.000	-.3064	.4243
	ThirdQuarterMoon	-.3873	.14048	1	.151	-.8251	.0506
	WaningCrescent	-.2139[a]	.06707	1	.039	-.4230	-.0049
FirstQuarterMoon	NewMoon	-.1140	.06070	1	.825	-.3032	.0751
	WaxingCrescent	.1946[a]	.03426	1	.000	.0878	.3014
	WaxingGibbous	.1376	.28741	1	1.000	-.7581	1.0333
	FullMoon	-.0836[a]	.01809	1	.000	-.1399	-.0272
	WaningGibbous	.2535	.11211	1	.489	-.0958	.6029
	ThirdQuarterMoon	-.1927	.13624	1	.992	-.6173	.2319
	WaningCrescent	-.0193	.05766	1	1.000	-.1990	.1604
WaxingGibbous	NewMoon	-.2516	.29375	1	1.000	-1.1671	.6638
	WaxingCrescent	.0570	.28944	1	1.000	-.8451	.9590
	FirstQuarterMoon	-.1376	.28741	1	1.000	-1.0333	.7581
	FullMoon	-.2212	.28798	1	1.000	-1.1187	.6763
	WaningGibbous	.1159	.30850	1	1.000	-.8455	1.0774
	ThirdQuarterMoon	-.3303	.31807	1	1.000	-1.3215	.6610
	WaningCrescent	-.1569	.29314	1	1.000	-1.0705	.7566
FullMoon	NewMoon	-.0305	.06334	1	1.000	-.2279	.1669
	WaxingCrescent	.2782[a]	.03874	1	.000	.1574	.3989
	FirstQuarterMoon	.0836[a]	.01809	1	.000	.0272	.1399
	WaxingGibbous	.2212	.28798	1	1.000	-.6763	1.1187
	WaningGibbous	.3371	.11356	1	.080	-.0168	.6910
	ThirdQuarterMoon	-.1091	.13744	1	1.000	-.5374	.3192
	WaningCrescent	.0642	.06043	1	1.000	-.1241	.2526
WaningGibbous	NewMoon	-.3676	.12749	1	.105	-.7649	.0297
	WaxingCrescent	-.0590	.11723	1	1.000	-.4243	.3064
	FirstQuarterMoon	-.2535	.11211	1	.489	-.6029	.0958
	WaxingGibbous	-.1159	.30850	1	1.000	-1.0774	.8455
	FullMoon	-.3371	.11356	1	.080	-.6910	.0168
	ThirdQuarterMoon	-.4462	.17644	1	.275	-.9961	.1036
	WaningCrescent	-.2729	.12607	1	.579	-.6658	.1200
ThirdQuarterMoon	NewMoon	.0786	.14915	1	1.000	-.3862	.5435
	WaxingCrescent	.3873	.14048	1	.151	-.0506	.8251
	FirstQuarterMoon	.1927	.13624	1	.992	-.2319	.6173
	WaxingGibbous	.3303	.31807	1	1.000	-.6610	1.3215
	FullMoon	.1091	.13744	1	1.000	-.3192	.5374
	WaningGibbous	.4462	.17644	1	.275	-.1036	.9961
	WaningCrescent	.1733	.14794	1	1.000	-.2877	.6344
WaningCrescent	NewMoon	-.0947	.08372	1	1.000	-.3556	.1662
	WaxingCrescent	.2139[a]	.06707	1	.039	.0049	.4230
	FirstQuarterMoon	.0193	.05766	1	1.000	-.1604	.1990
	WaxingGibbous	.1569	.29314	1	1.000	-.7566	1.0705
	FullMoon	-.0642	.06043	1	1.000	-.2526	.1241
	WaningGibbous	.2729	.12607	1	.579	-.1200	.6658
	ThirdQuarterMoon	-.1733	.14794	1	1.000	-.6344	.2877

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable LgGrsz

a. The mean difference is significant at the .05 level.

Goodness of Fit[a]

	Value
Quasi Likelihood under Independence Model Criterion (QIC)[b]	19.277
Corrected Quasi Likelihood under Independence Model Criterion (QICC)[b]	18.364

Dependent Variable: LgGrsz
Model: (Intercept), Lunarphase[a]

a. Information criteria are in smaller-is-better form.

b. Computed using the full log quasi-likelihood function.

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
(Intercept)	354.678	1	.000
Lunarphase	64.590	7	.000

Dependent Variable: LgGrsz
Model: (Intercept), Lunarphase

Estimates

Lunarphase	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
NewMoon	.9591	.06070	.8402	1.0781
WaxingCrescent	.6505	.03426	.5834	.7177
FirstQuarterMoon	.8451	.00000	.8451	.8451
WaxingGibbous	.7075	.28741	.1442	1.2708
FullMoon	.9287	.01809	.8932	.9641
WaningGibbous	.5915	.11211	.3718	.8113
ThirdQuarterMoon	1.0378	.13624	.7707	1.3048
WaningCrescent	.8644	.05766	.7514	.9774

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Ziphiidae group size GEE linear regression

Pairwise Comparisons

(I) Lunarphase	(J) Lunarphase	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference Lower	Upper
NewMoon	WaxingCrescent	-.2303[a]	.06974	1	.027	-.4476	-.0129
	FirstQuarterMoon	.0052	.08630	1	1.000	-.2638	.2741
	WaxingGibbous	-.0224	.11847	1	1.000	-.3916	.3468
	FullMoon	.0408	.07329	1	1.000	-.1876	.2693
	WaningGibbous	.0296	.06829	1	1.000	-.1832	.2425
	ThirdQuarterMoon	.0399	.09296	1	1.000	-.2498	.3296
	WaningCrescent	.2287	.11616	1	.755	-.1333	.5908
WaxingCrescent	NewMoon	.2303[a]	.06974	1	.027	.0129	.4476
	FirstQuarterMoon	.2354	.08990	1	.220	-.0448	.5156
	WaxingGibbous	.2079	.12112	1	.920	-.1696	.5853
	FullMoon	.2711[a]	.07750	1	.013	.0296	.5126
	WaningGibbous	.2599[a]	.07279	1	.010	.0331	.4867
	ThirdQuarterMoon	.2702	.09631	1	.132	-.0300	.5703
	WaningCrescent	.4590[a]	.11886	1	.003	.0885	.8294
FirstQuarterMoon	NewMoon	-.0052	.08630	1	1.000	-.2741	.2638
	WaxingCrescent	-.2354	.08990	1	.220	-.5156	.0448
	WaxingGibbous	-.0276	.13136	1	1.000	-.4370	.3818
	FullMoon	.0357	.09269	1	1.000	-.2532	.3245
	WaningGibbous	.0245	.08878	1	1.000	-.2522	.3012
	ThirdQuarterMoon	.0347	.10891	1	1.000	-.3047	.3741
	WaningCrescent	.2236	.12928	1	.914	-.1793	.6265
WaxingGibbous	NewMoon	.0224	.11847	1	1.000	-.3468	.3916
	WaxingCrescent	-.2079	.12112	1	.920	-.5853	.1696
	FirstQuarterMoon	.0276	.13136	1	1.000	-.3818	.4370
	FullMoon	.0632	.12320	1	1.000	-.3207	.4472
	WaningGibbous	.0520	.12029	1	1.000	-.3229	.4269
	ThirdQuarterMoon	.0623	.13583	1	1.000	-.3610	.4856
	WaningCrescent	.2511	.15265	1	.948	-.2246	.7268
FullMoon	NewMoon	-.0408	.07329	1	1.000	-.2693	.1876
	WaxingCrescent	-.2711[a]	.07750	1	.013	-.5126	-.0296
	FirstQuarterMoon	-.0357	.09269	1	1.000	-.3245	.2532
	WaxingGibbous	-.0632	.12320	1	1.000	-.4472	.3207
	WaningGibbous	-.0112	.07620	1	1.000	-.2487	.2263
	ThirdQuarterMoon	-.0009	.09892	1	1.000	-.3092	.3073
	WaningCrescent	.1879	.12098	1	.972	-.1892	.5649
WaningGibbous	NewMoon	-.0296	.06829	1	1.000	-.2425	.1832
	WaxingCrescent	-.2599[a]	.07279	1	.010	-.4867	-.0331
	FirstQuarterMoon	-.0245	.08878	1	1.000	-.3012	.2522
	WaxingGibbous	-.0520	.12029	1	1.000	-.4269	.3229
	FullMoon	.0112	.07620	1	1.000	-.2263	.2487
	ThirdQuarterMoon	.0103	.09527	1	1.000	-.2866	.3072
	WaningCrescent	.1991	.11802	1	.932	-.1687	.5669
ThirdQuarterMoon	NewMoon	-.0399	.09296	1	1.000	-.3296	.2498
	WaxingCrescent	-.2702	.09631	1	.132	-.5703	.0300
	FirstQuarterMoon	-.0347	.10891	1	1.000	-.3741	.3047
	WaxingGibbous	-.0623	.13583	1	1.000	-.4856	.3610
	FullMoon	.0009	.09892	1	1.000	-.3073	.3092
	WaningGibbous	-.0103	.09527	1	1.000	-.3072	.2866
	WaningCrescent	.1888	.13382	1	.992	-.2282	.6059
WaningCrescent	NewMoon	-.2287	.11616	1	.755	-.5908	.1333
	WaxingCrescent	-.4590[a]	.11886	1	.003	-.8294	-.0885
	FirstQuarterMoon	-.2236	.12928	1	.914	-.6265	.1793
	WaxingGibbous	-.2511	.15265	1	.948	-.7268	.2246
	FullMoon	-.1879	.12098	1	.972	-.5649	.1892
	WaningGibbous	-.1991	.11802	1	.932	-.5669	.1687
	ThirdQuarterMoon	-.1888	.13382	1	.992	-.6059	.2282

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable LgGrsz

a. The mean difference is significant at the .05 level.

Goodness of Fit[a]

	Value
Quasi Likelihood under Independence Model Criterion (QIC)[b]	32.288
Corrected Quasi Likelihood under Independence Model Criterion (QICC)[b]	31.808

Dependent Variable: LgGrsz
Model: (Intercept), Lunarphase[a]

a. Information criteria are in smaller-is-better form.

b. Computed using the full log quasi-likelihood function.

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
(Intercept)	480.280	1	.000
Lunarphase	24.457	7	.001

Dependent Variable: LgGrsz
Model: (Intercept), Lunarphase

Estimates

Lunarphase	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
NewMoon	.5979	.04598	.5078	.6880
WaxingCrescent	.8282	.05243	.7254	.9309
FirstQuarterMoon	.5927	.07303	.4496	.7359
WaxingGibbous	.6203	.10919	.4063	.8343
FullMoon	.5571	.05708	.4452	.6689
WaningGibbous	.5683	.05049	.4693	.6672
ThirdQuarterMoon	.5580	.08079	.3997	.7164
WaningCrescent	.3692	.10668	.1601	.5783

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Physeter presence – GLM binary logistic regression

Categorical Variable Information

			N	Percent
Dependent Variable	PresSAbs	Absent	2172	83.1%
		Present	441	16.9%
		Total	2613	100.0%
Factor	Lunar	NewMoon	655	25.1%
		WaxingCrescent	154	5.9%
		FirstQuarterMoon	243	9.3%
		WaxingGibbous	255	9.8%
		FullMoon	637	24.4%
		WaningGibbous	235	9.0%
		ThirdQuarterMoon	239	9.1%
		WaningCrescent	195	7.5%
		Total	2613	100.0%

Case Processing Summary

	N	Percent
Included	2613	100.0%
Excluded	0	0.0%
Total	2613	100.0%

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
(Intercept)	72.142	1	.000
Lunar	25.760	7	.001

Dependent Variable: PresSAbs
Model: (Intercept), Lunar, offset = offsetdur

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Offset	offsetdur	2613	-3.00	1.85	-1.1100	.36603

Goodness of Fit[a]

	Value	df	Value/df
Deviance	18.200	0	.
Scaled Deviance	18.200	0	
Pearson Chi-Square	18.680	0	.
Scaled Pearson Chi-Square	18.680	0	
Log Likelihood[b]	2.387		
Akaike's Information Criterion (AIC)	11.226		
Finite Sample Corrected AIC (AICC)	11.282		
Bayesian Information Criterion (BIC)	58.172		
Consistent AIC (CAIC)	66.172		

Dependent Variable: PresSAbs
Model: (Intercept), Lunar, offset = offsetdur[a]

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Estimates

Lunar	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
NewMoon	.35	.025	.30	.40
WaxingCrescent	.40	.050	.31	.50
FirstQuarterMoon	.40	.040	.32	.48
WaxingGibbous	.21	.038	.14	.29
FullMoon	.35	.025	.31	.40
WaningGibbous	.48	.038	.40	.55
ThirdQuarterMoon	.41	.040	.33	.49
WaningCrescent	.44	.044	.36	.53

Pairwise comparison lunar phases & Physeter presence

Pairwise Comparisons

(I) Lunar	(J) Lunar	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference Lower	Upper
NewMoon	WaxingCrescent	-.05	.056	1	1.000	-.22	.12
	FirstQuarterMoon	-.05	.047	1	1.000	-.19	.10
	WaxingGibbous	.14ª	.045	1	.038	.00	.29
	FullMoon	.00	.035	1	1.000	-.11	.11
	WaningGibbous	-.13	.046	1	.150	-.27	.02
	ThirdQuarterMoon	-.05	.047	1	1.000	-.20	.09
	WaningCrescent	-.09	.051	1	.905	-.25	.07
WaxingCrescent	NewMoon	.05	.056	1	1.000	-.12	.22
	FirstQuarterMoon	.01	.064	1	1.000	-.19	.20
	WaxingGibbous	.20ª	.063	1	.050	.00	.39
	FullMoon	.05	.056	1	1.000	-.12	.22
	WaningGibbous	-.08	.063	1	.999	-.27	.12
	ThirdQuarterMoon	.00	.064	1	1.000	-.20	.20
	WaningCrescent	-.04	.067	1	1.000	-.25	.17
FirstQuarterMoon	NewMoon	.05	.047	1	1.000	-.10	.19
	WaxingCrescent	-.01	.064	1	1.000	-.20	.19
	WaxingGibbous	.19ª	.055	1	.016	.02	.36
	FullMoon	.04	.047	1	1.000	-.10	.19
	WaningGibbous	-.08	.055	1	.989	-.25	.09
	ThirdQuarterMoon	-.01	.057	1	1.000	-.18	.17
	WaningCrescent	-.04	.060	1	1.000	-.23	.14
WaxingGibbous	NewMoon	-.14ª	.045	1	.038	-.29	.00
	WaxingCrescent	-.20ª	.063	1	.050	-.39	.00
	FirstQuarterMoon	-.19ª	.055	1	.016	-.36	-.02
	FullMoon	-.15ª	.045	1	.037	-.29	.00
	WaningGibbous	-.27ª	.054	1	.000	-.44	-.10
	ThirdQuarterMoon	-.20ª	.055	1	.009	-.37	-.03
	WaningCrescent	-.23ª	.058	1	.002	-.41	-.05
FullMoon	NewMoon	.00	.035	1	1.000	-.11	.11
	WaxingCrescent	-.05	.056	1	1.000	-.22	.12
	FirstQuarterMoon	-.04	.047	1	1.000	-.19	.10
	WaxingGibbous	.15ª	.045	1	.037	.00	.29
	WaningGibbous	-.13	.046	1	.158	-.27	.02
	ThirdQuarterMoon	-.05	.047	1	1.000	-.20	.09
	WaningCrescent	-.09	.051	1	.912	-.25	.07
WaningGibbous	NewMoon	.13	.046	1	.150	-.02	.27
	WaxingCrescent	.08	.063	1	.999	-.12	.27
	FirstQuarterMoon	.08	.055	1	.989	-.09	.25
	WaxingGibbous	.27ª	.054	1	.000	.10	.44
	FullMoon	.13	.046	1	.158	-.02	.27
	ThirdQuarterMoon	.07	.055	1	.997	-.10	.24
	WaningCrescent	.04	.058	1	1.000	-.14	.22
ThirdQuarterMoon	NewMoon	.05	.047	1	1.000	-.09	.20
	WaxingCrescent	.00	.064	1	1.000	-.20	.20
	FirstQuarterMoon	.01	.057	1	1.000	-.17	.18
	WaxingGibbous	.20ª	.055	1	.009	.03	.37
	FullMoon	.05	.047	1	1.000	-.09	.20
	WaningGibbous	-.07	.055	1	.997	-.24	.10
	WaningCrescent	-.04	.060	1	1.000	-.22	.15
WaningCrescent	NewMoon	.09	.051	1	.905	-.07	.25
	WaxingCrescent	.04	.067	1	1.000	-.17	.25
	FirstQuarterMoon	.04	.060	1	1.000	-.14	.23
	WaxingGibbous	.23ª	.058	1	.002	.05	.41
	FullMoon	.09	.051	1	.912	-.07	.25
	WaningGibbous	-.04	.058	1	1.000	-.22	.14
	ThirdQuarterMoon	.04	.060	1	1.000	-.15	.22

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable PresSAbs

a. The mean difference is significant at the ,05 level.

Grampus sightings – GLM negative binomial regression

Categorical Variable Information

			N	Percent
Factor	Lunar	NewMoon	505	24.1%
		WaxingCrescent	128	6.1%
		FirstQuarterMoon	189	9.0%
		WaxingGibbous	200	9.5%
		FullMoon	527	25.1%
		WaningGibbous	194	9.2%
		ThirdQuarterMoon	189	9.0%
		WaningCrescent	166	7.9%
		Total	2098	100.0%
	Seastate recoded	calm	365	17.4%
		light	1490	71.0%
		moderate	171	8.2%
		rough	72	3.4%
		Total	2098	100.0%
	WindDirClass	N	232	11.1%
		NE	175	8.3%
		E	347	16.5%
		SE	391	18.6%
		S	80	3.8%
		SW	298	14.2%
		W	415	19.8%
		NW	153	7.3%
		Varied	7	0.3%
		Total	2098	100.0%

Case Processing Summary

	N	Percent
Included	2098	80.3%
Excluded	515	19.7%
Total	2613	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2099.336	2078	1.010
Scaled Deviance	2099.336	2078	
Pearson Chi-Square	2620.425	2078	1.261
Scaled Pearson Chi-Square	2620.425	2078	
Log Likelihood[b]	-2642.848		
Akaike's Information Criterion (AIC)	5325.696		
Finite Sample Corrected AIC (AICC)	5326.101		
Bayesian Information Criterion (BIC)	5438.671		
Consistent AIC (CAIC)	5458.671		

Dependent Variable: sightings
Model: (Intercept), Lunar, Seastate recoded, WindDirClass, Cloudcover in %, offset = offsetdur[a]

  a. Information criteria are in smaller-is-better form.

  b. The full log likelihood function is displayed and used in computing information criteria.

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	sightings	2098	0	16	.87	1.462
Covariate	Cloudcover in %	2098	0	100	57.17	31.969
Offset	offsetdur	2098	-3.00	1.85	-1.1138	.36109

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
(Intercept)	58.903	1	.000
Lunar	18.411	7	.010
Seastate recoded	65.324	3	.000
WindDirClass	10.905	8	.207
Cloudcover in %	4.107	1	.043

Dependent Variable: sightings
Model: (Intercept), Lunar, Seastate recoded, WindDirClass, Cloudcover in %, offset = offsetdur

Estimates

Lunar	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
NewMoon	2.18	.237	1.76	2.70
WaxingCrescent	2.44	.373	1.81	3.30
FirstQuarterMoon	2.46	.326	1.90	3.19
WaxingGibbous	2.07	.285	1.58	2.71
FullMoon	1.61	.182	1.29	2.01
WaningGibbous	1.97	.278	1.50	2.60
ThirdQuarterMoon	2.13	.303	1.61	2.81
WaningCrescent	1.80	.270	1.34	2.41

Covariates appearing in the model are fixed at the following values: Cloudcover in %=57.17

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Parameter Estimates lunar phases & Grampus sightings

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	.470	.5746	-.656	1.596	.669	1	.413	1.600	.519	4.934
[Lunar=1]	.193	.1376	-.077	.463	1.963	1	.161	1.213	.926	1.588
[Lunar=2]	.308	.1762	-.038	.653	3.047	1	.081	1.360	.963	1.921
[Lunar=3]	.316	.1606	.001	.631	3.877	1	.049	1.372	1.001	1.880
[Lunar=4]	.143	.1604	-.172	.457	.791	1	.374	1.153	.842	1.579
[Lunar=5]	-.107	.1402	-.382	.168	.585	1	.444	.898	.683	1.182
[Lunar=6]	.095	.1628	-.224	.414	.339	1	.560	1.100	.799	1.513
[Lunar=7]	.171	.1637	-.150	.492	1.088	1	.297	1.186	.861	1.635
[Lunar=8]	0[a]	.	.	.	.	.	.	1	.	.
[Seastate recoded=0]	1.417	.2590	.909	1.924	29.920	1	.000	4.123	2.482	6.850
[Seastate recoded=1]	.914	.2515	.421	1.407	13.215	1	.000	2.495	1.524	4.084
[Seastate recoded=2]	.545	.2802	-.004	1.094	3.784	1	.052	1.725	.996	2.986
[Seastate recoded=3]	0[a]	.	.	.	.	.	.	1	.	.
[WindDirClass=1]	-.494	.5058	-1.485	.498	.953	1	.329	.610	.226	1.645
[WindDirClass=2]	-.619	.5112	-1.621	.383	1.466	1	.226	.538	.198	1.467
[WindDirClass=3]	-.511	.5032	-1.498	.475	1.033	1	.309	.600	.224	1.608
[WindDirClass=4]	-.576	.5022	-1.560	.408	1.315	1	.251	.562	.210	1.504
[WindDirClass=5]	-.571	.5235	-1.597	.455	1.189	1	.276	.565	.203	1.576
[WindDirClass=6]	-.612	.5044	-1.600	.377	1.470	1	.225	.543	.202	1.458
[WindDirClass=7]	-.338	.5013	-1.321	.644	.455	1	.500	.713	.267	1.905
[WindDirClass=8]	-.644	.5135	-1.650	.363	1.572	1	.210	.525	.192	1.437
[WindDirClass=9]	0[a]	.	.	.	.	.	.	1	.	.
Cloudcover in %	-.002	.0010	-.004	-6.813E-5	4.107	1	.043	.998	.996	1.000
(Scale)	1[b]									
(Negative binomial)	1[b]									

Dependent Variable: sightings

Model: (Intercept), Lunar, Seastate recoded, WindDirClass, Cloudcover in %, offset = offsetdur

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

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Pairwise comparison lunar phases & Grampus sightings

Pairwise Comparisons

(I) Lunar	(J) Lunar	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
NewMoon	WaxingCrescent	-.26	.344	1	1.000	-1.34	.81
	FirstQuarterMoon	-.29	.296	1	1.000	-1.21	.64
	WaxingGibbous	.11	.259	1	1.000	-.70	.91
	FullMoon	.56	.189	1	.076	-.02	1.15
	WaningGibbous	.20	.259	1	1.000	-.60	1.01
	ThirdQuarterMoon	.05	.278	1	1.000	-.82	.91
	WaningCrescent	.38	.262	1	.987	-.43	1.20
WaxingCrescent	NewMoon	.26	.344	1	1.000	-.81	1.34
	FirstQuarterMoon	-.02	.407	1	1.000	-1.29	1.25
	WaxingGibbous	.37	.380	1	1.000	-.81	1.56
	FullMoon	.83	.338	1	.328	-.22	1.88
	WaningGibbous	.47	.379	1	.999	-.71	1.65
	ThirdQuarterMoon	.31	.391	1	1.000	-.91	1.53
	WaningCrescent	.65	.383	1	.932	-.55	1.84
FirstQuarterMoon	NewMoon	.29	.296	1	1.000	-.64	1.21
	WaxingCrescent	.02	.407	1	1.000	-1.25	1.29
	WaxingGibbous	.39	.338	1	1.000	-.66	1.45
	FullMoon	.85	.290	1	.089	-.05	1.75
	WaningGibbous	.49	.338	1	.989	-.56	1.54
	ThirdQuarterMoon	.33	.352	1	1.000	-.76	1.43
	WaningCrescent	.67	.341	1	.761	-.39	1.73
WaxingGibbous	NewMoon	-.11	.259	1	1.000	-.91	.70
	WaxingCrescent	-.37	.380	1	1.000	-1.56	.81
	FirstQuarterMoon	-.39	.338	1	1.000	-1.45	.66
	FullMoon	.46	.248	1	.847	-.31	1.23
	WaningGibbous	.10	.305	1	1.000	-.85	1.05
	ThirdQuarterMoon	-.06	.323	1	1.000	-1.07	.95
	WaningCrescent	.28	.309	1	1.000	-.69	1.24
FullMoon	NewMoon	-.56	.189	1	.076	-1.15	.02
	WaxingCrescent	-.83	.338	1	.328	-1.88	.22
	FirstQuarterMoon	-.85	.290	1	.089	-1.75	.05
	WaxingGibbous	-.46	.248	1	.847	-1.23	.31
	WaningGibbous	-.36	.246	1	.986	-1.13	.40
	ThirdQuarterMoon	-.52	.267	1	.782	-1.35	.32
	WaningCrescent	-.18	.246	1	1.000	-.95	.58
WaningGibbous	NewMoon	-.20	.259	1	1.000	-1.01	.60
	WaxingCrescent	-.47	.379	1	.999	-1.65	.71
	FirstQuarterMoon	-.49	.338	1	.989	-1.54	.56
	WaxingGibbous	-.10	.305	1	1.000	-1.05	.85
	FullMoon	.36	.246	1	.986	-.40	1.13
	ThirdQuarterMoon	-.16	.319	1	1.000	-1.15	.84
	WaningCrescent	.18	.306	1	1.000	-.78	1.13
ThirdQuarterMoon	NewMoon	-.05	.278	1	1.000	-.91	.82
	WaxingCrescent	-.31	.391	1	1.000	-1.53	.91
	FirstQuarterMoon	-.33	.352	1	1.000	-1.43	.76
	WaxingGibbous	.06	.323	1	1.000	-.95	1.07
	FullMoon	.52	.267	1	.782	-.32	1.35
	WaningGibbous	.16	.319	1	1.000	-.84	1.15
	WaningCrescent	.33	.322	1	1.000	-.67	1.34
WaningCrescent	NewMoon	-.38	.262	1	.987	-1.20	.43
	WaxingCrescent	-.65	.383	1	.932	-1.84	.55
	FirstQuarterMoon	-.67	.341	1	.761	-1.73	.39
	WaxingGibbous	-.28	.309	1	1.000	-1.24	.69
	FullMoon	.18	.246	1	1.000	-.58	.95
	WaningGibbous	-.18	.306	1	1.000	-1.13	.78
	ThirdQuarterMoon	-.33	.322	1	1.000	-1.34	.67

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable sightings

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Delphinids sightings – GLM negative binominal regression

Categorical Variable Information

			N	Percent
Factor	Seastate recoded	calm	365	17.4%
		light	1490	71.0%
		moderate	172	8.2%
		rough	72	3.4%
		Total	2099	100.0%
	WindDirClass	N	233	11.1%
		NE	175	8.3%
		E	347	16.5%
		SE	391	18.6%
		S	80	3.8%
		SW	298	14.2%
		W	415	19.8%
		NW	153	7.3%
		Varied	7	0.3%
		Total	2099	100.0%
	Lunar	NewMoon	505	24.1%
		WaxingCrescent	128	6.1%
		FirstQuarterMoon	189	9.0%
		WaxingGibbous	201	9.6%
		FullMoon	527	25.1%
		WaningGibbous	194	9.2%
		ThirdQuarterMoon	189	9.0%
		WaningCrescent	166	7.9%
		Total	2099	100.0%

Case Processing Summary

	N	Percent
Included	2099	80.3%
Excluded	514	19.7%
Total	2613	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2078.424	2078	1.000
Scaled Deviance	2078.424	2078	
Pearson Chi-Square	2955.795	2078	1.422
Scaled Pearson Chi-Square	2955.795	2078	
Log Likelihood[b]	-2487.960		
Akaike's Information Criterion (AIC)	5017.921		
Finite Sample Corrected AIC (AICC)	5018.366		
Bayesian Information Criterion (BIC)	5136.554		
Consistent AIC (CAIC)	5157.554		

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Visibility in %, Lunar, offset = offsetdur[a]

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	sightings	2099	0	15	.78	1.420
Covariate	Cloudcover in %	2099	0	100	57.14	31.986
	Visibility in %	2099	30	100	96.02	8.301
Offset	offsetdur	2099	-3.00	1.85	-1.1138	.36101

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
(Intercept)	6.856	1	.009
Seastate recoded	67.916	3	.000
WindDirClass	26.993	8	.001
Cloudcover in %	9.569	1	.002
Visibility in %	12.175	1	.000
Lunar	24.140	7	.001

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Visibility in %, Lunar, offset = offsetdur

Estimates

Lunar	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
NewMoon	2.16	.243	1.74	2.69
WaxingCrescent	2.07	.333	1.51	2.84
FirstQuarterMoon	1.65	.241	1.23	2.19
WaxingGibbous	1.40	.213	1.04	1.89
FullMoon	1.83	.212	1.46	2.30
WaningGibbous	1.42	.214	1.06	1.91
ThirdQuarterMoon	2.22	.318	1.67	2.93
WaningCrescent	1.43	.228	1.04	1.95

Covariates appearing in the model are fixed at the following values:
Cloudcover in %=57.14; Visibility in %=96.02

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Pairwise comparison lunar phases & Delphinids sightings

Pairwise Comparisons

(I) Lunar	(J) Lunar	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference Lower	Upper
NewMoon	WaxingCrescent	.09	.314	1	1.000	-.89	1.07
	FirstQuarterMoon	.52	.251	1	.670	-.26	1.30
	WaxingGibbous	.76[a]	.230	1	.025	.05	1.48
	FullMoon	.33	.193	1	.921	-.27	.93
	WaningGibbous	.74[a]	.234	1	.041	.01	1.47
	ThirdQuarterMoon	-.05	.285	1	1.000	-.94	.84
	WaningCrescent	.74	.241	1	.062	-.02	1.49
WaxingCrescent	NewMoon	-.09	.314	1	1.000	-1.07	.89
	FirstQuarterMoon	.43	.343	1	.999	-.64	1.50
	WaxingGibbous	.67	.329	1	.688	-.35	1.70
	FullMoon	.24	.306	1	1.000	-.71	1.19
	WaningGibbous	.65	.331	1	.754	-.38	1.68
	ThirdQuarterMoon	-.14	.371	1	1.000	-1.30	1.01
	WaningCrescent	.65	.337	1	.798	-.41	1.70
FirstQuarterMoon	NewMoon	-.52	.251	1	.670	-1.30	.26
	WaxingCrescent	-.43	.343	1	.999	-1.50	.64
	WaxingGibbous	.25	.258	1	1.000	-.56	1.05
	FullMoon	-.19	.235	1	1.000	-.92	.55
	WaningGibbous	.22	.260	1	1.000	-.59	1.03
	ThirdQuarterMoon	-.57	.320	1	.885	-1.57	.43
	WaningCrescent	.22	.268	1	1.000	-.62	1.05
WaxingGibbous	NewMoon	-.76[a]	.230	1	.025	-1.48	-.05
	WaxingCrescent	-.67	.329	1	.688	-1.70	.35
	FirstQuarterMoon	-.25	.258	1	1.000	-1.05	.56
	FullMoon	-.43	.212	1	.693	-1.09	.23
	WaningGibbous	-.02	.238	1	1.000	-.76	.72
	ThirdQuarterMoon	-.82	.305	1	.190	-1.77	.13
	WaningCrescent	-.03	.249	1	1.000	-.80	.75
FullMoon	NewMoon	-.33	.193	1	.921	-.93	.27
	WaxingCrescent	-.24	.306	1	1.000	-1.19	.71
	FirstQuarterMoon	.19	.235	1	1.000	-.55	.92
	WaxingGibbous	.43	.212	1	.693	-.23	1.09
	WaningGibbous	.41	.214	1	.799	-.26	1.08
	ThirdQuarterMoon	-.38	.274	1	.993	-1.24	.47
	WaningCrescent	.40	.225	1	.877	-.30	1.10
WaningGibbous	NewMoon	-.74[a]	.234	1	.041	-1.47	-.01
	WaxingCrescent	-.65	.331	1	.754	-1.68	.38
	FirstQuarterMoon	-.22	.260	1	1.000	-1.03	.59
	WaxingGibbous	.02	.238	1	1.000	-.72	.76
	FullMoon	-.41	.214	1	.799	-1.08	.26
	ThirdQuarterMoon	-.79	.305	1	.230	-1.74	.16
	WaningCrescent	-.01	.250	1	1.000	-.78	.77
ThirdQuarterMoon	NewMoon	.05	.285	1	1.000	-.84	.94
	WaxingCrescent	.14	.371	1	1.000	-1.01	1.30
	FirstQuarterMoon	.57	.320	1	.885	-.43	1.57
	WaxingGibbous	.82	.305	1	.190	-.13	1.77
	FullMoon	.38	.274	1	.993	-.47	1.24
	WaningGibbous	.79	.305	1	.230	-.16	1.74
	WaningCrescent	.79	.311	1	.275	-.18	1.76
WaningCrescent	NewMoon	-.74	.241	1	.062	-1.49	.02
	WaxingCrescent	-.65	.337	1	.798	-1.70	.41
	FirstQuarterMoon	-.22	.268	1	1.000	-1.05	.62
	WaxingGibbous	.03	.249	1	1.000	-.75	.80
	FullMoon	-.40	.225	1	.877	-1.10	.30
	WaningGibbous	.01	.250	1	1.000	-.77	.78
	ThirdQuarterMoon	-.79	.311	1	.275	-1.76	.18

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable sightings

a. The mean difference is significant at the .05 level.

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Appendix VII: Chi-Square outcomes lunar cycle

Grampus' behaviour & lunar phases – Chi-square outcomes

Behaviour * Lunar_cycle Crosstabulation

			Lunar_cycle				Total
			New Moon	Waxing Moon	Full Moon	Waning Moon	
Behaviour	Travelling	Count	329a, b	322b	274a, b	348a	1273
		Expected Count	329.3	350.2	269.1	324.4	1273.0
		% within Behaviour	25.8%	25.3%	21.5%	27.3%	100.0%
		% within Lunar_cycle	53.7%	49.4%	54.7%	57.6%	53.7%
		% of Total	13.9%	13.6%	11.6%	14.7%	53.7%
	Foraging	Count	33a	29a	16a, b	13b	91
		Expected Count	23.5	25.0	19.2	23.2	91.0
		% within Behaviour	36.3%	31.9%	17.6%	14.3%	100.0%
		% within Lunar_cycle	5.4%	4.4%	3.2%	2.2%	3.8%
		% of Total	1.4%	1.2%	0.7%	0.5%	3.8%
	Socialising	Count	58a	59a, b	38a, b	38b	193
		Expected Count	49.9	53.1	40.8	49.2	193.0
		% within Behaviour	30.1%	30.6%	19.7%	19.7%	100.0%
		% within Lunar_cycle	9.5%	9.0%	7.6%	6.3%	8.1%
		% of Total	2.4%	2.5%	1.6%	1.6%	8.1%
	Resting	Count	193a	242b	173a, b	205a, b	813
		Expected Count	210.3	223.7	171.9	207.2	813.0
		% within Behaviour	23.7%	29.8%	21.3%	25.2%	100.0%
		% within Lunar_cycle	31.5%	37.1%	34.5%	33.9%	34.3%
		% of Total	8.1%	10.2%	7.3%	8.6%	34.3%
Total		Count	613	652	501	604	2370
		Expected Count	613.0	652.0	501.0	604.0	2370.0
		% within Behaviour	25.9%	27.5%	21.1%	25.5%	100.0%
		% within Lunar_cycle	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	25.9%	27.5%	21.1%	25.5%	100.0%

Each subscript letter denotes a subset of Lunar_cycle categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	21.186[a]	9	.012
Likelihood Ratio	21.775	9	.010
Linear-by-Linear Association	.564	1	.453
N of Valid Cases	2370		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 19.24.

Delphinids behaviour & lunar phases – Chi-square outcomes

Behaviour * Lunar_cycle Crosstabulation

			Lunar_cycle				Total
			New Moon	Waxing Moon	Full Moon	Waning Moon	
Behaviour	Travelling	Count	439a, b	335b	376b	423a	1573
		% within Behaviour	27.9%	21.3%	23.9%	26.9%	100.0%
		% within Lunar_cycle	74.2%	69.8%	71.2%	77.6%	73.3%
		% of Total	20.5%	15.6%	17.5%	19.7%	73.3%
	Foraging	Count	75a	87b	89b, c	71a, c	322
		% within Behaviour	23.3%	27.0%	27.6%	22.0%	100.0%
		% within Lunar_cycle	12.7%	18.1%	16.9%	13.0%	15.0%
		% of Total	3.5%	4.1%	4.1%	3.3%	15.0%
	Socialising	Count	12a	12a	17a	8a	49
		% within Behaviour	24.5%	24.5%	34.7%	16.3%	100.0%
		% within Lunar_cycle	2.0%	2.5%	3.2%	1.5%	2.3%
		% of Total	0.6%	0.6%	0.8%	0.4%	2.3%
	Resting	Count	66a	46a	46a	43a	201
		% within Behaviour	32.8%	22.9%	22.9%	21.4%	100.0%
		% within Lunar_cycle	11.1%	9.6%	8.7%	7.9%	9.4%
		% of Total	3.1%	2.1%	2.1%	2.0%	9.4%
Total		Count	592	480	528	545	2145
		% within Behaviour	27.6%	22.4%	24.6%	25.4%	100.0%
		% within Lunar_cycle	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	27.6%	22.4%	24.6%	25.4%	100.0%

Each subscript letter denotes a subset of Lunar_cycle categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.873[a]	9	.037
Likelihood Ratio	17.783	9	.038
Linear-by-Linear Association	3.614	1	.057
N of Valid Cases	2145		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.97.

Appendix VIII: GLM outcomes tidal cycle

Grampus sightings - GLM negative binominal regression

Categorical Variable Information

			N	Percent
Factor	Seastate recoded	calm	365	17.4%
		light	1490	71.0%
		moderate	171	8.2%
		rough	72	3.4%
		Total	2098	100.0%
	WindDirClass	N	232	11.1%
		NE	175	8.3%
		E	347	16.5%
		SE	391	18.6%
		S	80	3.8%
		SW	298	14.2%
		W	415	19.8%
		NW	153	7.3%
		Varied	7	0.3%
		Total	2098	100.0%
	Tides2	High Tide	531	25.3%
		Descending Tide	525	25.0%
		Low Tide	630	30.0%
		Rising Tide	412	19.6%
		Total	2098	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	sightings	2098	0	16	.87	1.462
Covariate	Cloudcover in %	2098	0	100	57.17	31.969
Offset	offsetdur	2098	-3.00	1.85	-1.1138	.36109

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2105.653	2082	1.011
Scaled Deviance	2105.653	2082	
Pearson Chi-Square	2671.040	2082	1.283
Scaled Pearson Chi-Square	2671.040	2082	
Log Likelihood[b]	-2646.007		
Akaike's Information Criterion (AIC)	5324.013		
Finite Sample Corrected AIC (AICC)	5324.275		
Bayesian Information Criterion (BIC)	5414.393		
Consistent AIC (CAIC)	5430.393		

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Tides2, offset = offsetdur[a]

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Case Processing Summary

	N	Percent
Included	2098	80.3%
Excluded	515	19.7%
Total	2613	100.0%

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
(Intercept)	61.009	1	.000
Seastate recoded	65.591	3	.000
WindDirClass	12.131	8	.145
Cloudcover in %	5.575	1	.018
Tides2	12.147	3	.007

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Tides2, offset = offsetdur

Estimates

Tides2	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
High Tide	1.72	.190	1.39	2.14
Descending Tide	1.97	.218	1.58	2.44
Low Tide	2.33	.243	1.90	2.86
Rising Tide	2.15	.244	1.72	2.68

Covariates appearing in the model are fixed at the following values:
Cloudcover in %=57,17

Pairwise Comparisons

(I) Tides2	(J) Tides2	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
High Tide	Descending Tide	-.24	.179	1	.680	-.72	.23
	Low Tide	-.61[a]	.188	1	.007	-1.11	-.12
	Rising Tide	-.42	.201	1	.195	-.95	.11
Descending Tide	High Tide	.24	.179	1	.680	-.23	.72
	Low Tide	-.37	.192	1	.290	-.87	.14
	Rising Tide	-.18	.207	1	.948	-.72	.37
Low Tide	High Tide	.61[a]	.188	1	.007	.12	1.11
	Descending Tide	.37	.192	1	.290	-.14	.87
	Rising Tide	.19	.210	1	.937	-.36	.74
Rising Tide	High Tide	.42	.201	1	.195	-.11	.95
	Descending Tide	.18	.207	1	.948	-.37	.72
	Low Tide	-.19	.210	1	.937	-.74	.36

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable sightings

a. The mean difference is significant at the ,05 level.

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Delphinids sightings - GLM negative binominal regression

Categorical Variable Information

			N	Percent
Factor	Seastate recoded	calm	365	17.4%
		light	1490	71.0%
		moderate	172	8.2%
		rough	72	3.4%
		Total	2099	100.0%
	WindDirClass	N	233	11.1%
		NE	175	8.3%
		E	347	16.5%
		SE	391	18.6%
		S	80	3.8%
		SW	298	14.2%
		W	415	19.8%
		NW	153	7.3%
		Varied	7	0.3%
		Total	2099	100.0%
	Tides2	High Tide	531	25.3%
		Descending Tide	526	25.1%
		Low Tide	630	30.0%
		Rising Tide	412	19.6%
		Total	2099	100.0%

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	sightings	2099	0	15	.78	1.420
Covariate	Cloudcover in %	2099	0	100	57.14	31.986
	Visibility in %	2099	30	100	96.02	8.301
Offset	offsetdur	2099	-3.00	1.85	-1.1138	.36101

Case Processing Summary

	N	Percent
Included	2099	80.3%
Excluded	514	19.7%
Total	2613	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2087.957	2082	1.003
Scaled Deviance	2087.957	2082	
Pearson Chi-Square	3030.693	2082	1.456
Scaled Pearson Chi-Square	3030.693	2082	
Log Likelihood[b]	-2492.727		
Akaike's Information Criterion (AIC)	5019.454		
Finite Sample Corrected AIC (AICC)	5019.748		
Bayesian Information Criterion (BIC)	5115.490		
Consistent AIC (CAIC)	5132.490		

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Tides2, Visibility in %, offset = offsetdur[a]

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
(Intercept)	6.445	1	.011
Seastate recoded	64.088	3	.000
WindDirClass	27.232	8	.001
Cloudcover in %	10.847	1	.001
Tides2	14.790	3	.002
Visibility in %	11.893	1	.001

Dependent Variable: sightings
Model: (Intercept), Seastate recoded, WindDirClass, Cloudcover in %, Tides2, Visibility in %, offset = offsetdur

Estimates

Tides2	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
High Tide	1.78	.203	1.42	2.23
Descending Tide	1.56	.182	1.24	1.96
Low Tide	2.18	.236	1.77	2.70
Rising Tide	1.71	.209	1.35	2.18

Covariates appearing in the model are fixed at the following values:
Cloudcover in %=57,14; Visibility in %=96,02

Pairwise Comparisons

(I) Tides2	(J) Tides2	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference Lower	Upper
High Tide	Descending Tide	.22	.165	1	.683	-.21	.66
	Low Tide	-.40	.181	1	.148	-.88	.07
	Rising Tide	.07	.183	1	1.000	-.41	.55
Descending Tide	High Tide	-.22	.165	1	.683	-.66	.21
	Low Tide	-.63[a]	.179	1	.003	-1.10	-.16
	Rising Tide	-.16	.177	1	.937	-.62	.31
Low Tide	High Tide	.40	.181	1	.148	-.07	.88
	Descending Tide	.63[a]	.179	1	.003	.16	1.10
	Rising Tide	.47	.192	1	.087	-.04	.97
Rising Tide	High Tide	-.07	.183	1	1.000	-.55	.41
	Descending Tide	.16	.177	1	.937	-.31	.62
	Low Tide	-.47	.192	1	.087	-.97	.04

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable sightings

a. The mean difference is significant at the ,05 level.

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Estimated Marginal Means of the group size per species per sighting compared to the tidal phases; including Standard Deviation (SD), Pairwise Comparison (PC), Wald Chi-Square, Degree of Freedom (df) and Significance (p).

	Species							
Phase	**Balaenopteridae**	**Hyperoodon**	**Ziphiidae**	**Physeter**	**Globicephala**	**Grampus**	**Tursiops**	**Small Oceanic Delphinids**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
High Tide	0.116 ± 0.037	0.908 ± 0.036	0.667 ± 0.062	0.131 ± 0.022	0.905 ± 0.062	0.695 ± 0.024	1.041 ± 0.061	1.595 ± 0.032
Descending Tide	0.063 ± 0.020	0.826 ± 0.080	0.586 ± 0.048	0.099 ± 0.015	0.811 ± 0.083	0.642 ± 0.025	1.118 ± 0.064	1.550 ± 0.038
Low Tide	0.094 ± 0.027	0.894 ± 0.099	0.576 ± 0.042	0.110 ± 0.014	0.962 ± 0.056	0.644 ± 0.020	1.076 ± 0.065	1.568 ± 0.028
Rising Tide	0.073 ± 0.019	0.684 ± 0.080	0.564 ± 0.051	0.115 ± 0.022	0.936 ± 0.073	0.734 ± 0.023	1.059 ± 0.077	1.632 ± 0.035
Wald Chi-square	2.018	6.894	1.947	1.463	2.364	12.728	0.814	3.284
df	3	3	3	3	3	3	3	3
p	0.569	0.075	0.583	0.691	0.500	0.005	0.846	0.350

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Appendix IX: Chi-Square outcomes tidal cycle

Balaenopteridae behaviour & tidal phases – Chi-square outcomes

Behaviour * Tidal phase Crosstabulation

			High	Descending	Low	Rising	Total
			Tidal phase	
Behaviour	Travelling	Count	17a	29a, b	22a, b	28b	96
		Expected Count	22.2	28.1	22.9	22.9	96.0
		% within Behaviour	17.7%	30.2%	22.9%	29.2%	100.0%
		% within Tidal phase	56.7%	76.3%	71.0%	90.3%	73.8%
		% of Total	13.1%	22.3%	16.9%	21.5%	73.8%
	Foraging	Count	3a, b	2b	7a	2a, b	14
		Expected Count	3.2	4.1	3.3	3.3	14.0
		% within Behaviour	21.4%	14.3%	50.0%	14.3%	100.0%
		% within Tidal phase	10.0%	5.3%	22.6%	6.5%	10.8%
		% of Total	2.3%	1.5%	5.4%	1.5%	10.8%
	Resting	Count	10a	7a, b	2b, c	1c	20
		Expected Count	4.6	5.8	4.8	4.8	20.0
		% within Behaviour	50.0%	35.0%	10.0%	5.0%	100.0%
		% within Tidal phase	33.3%	18.4%	6.5%	3.2%	15.4%
		% of Total	7.7%	5.4%	1.5%	0.8%	15.4%
Total		Count	30	38	31	31	130
		Expected Count	30.0	38.0	31.0	31.0	130.0
		% within Behaviour	23.1%	29.2%	23.8%	23.8%	100.0%
		% within Tidal phase	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	23.1%	29.2%	23.8%	23.8%	100.0%

Each subscript letter denotes a subset of Tidal phase categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Monte Carlo Sig. (2-sided) Significance	Monte Carlo Sig. (2-sided) 99% Confidence Interval Lower Bound	Monte Carlo Sig. (2-sided) 99% Confidence Interval Upper Bound	Monte Carlo Sig. (1-sided) Significance	Monte Carlo Sig. (1-sided) 99% Confidence Interval Lower Bound	Monte Carlo Sig. (1-sided) 99% Confidence Interval Upper Bound
Pearson Chi-Square	19.140[a]	6	.004	.003[b]	.002	.005			
Likelihood Ratio	18.827	6	.004	.007[b]	.005	.010			
Fisher's Exact Test	17.234			.005[b]	.003	.007			
Linear-by-Linear Association	11.565[c]	1	.001	.000[b]	.000	.001	.000[b]	.000	.001
N of Valid Cases	130								

a. 7 cells (58.3%) have expected count less than 5. The minimum expected count is 3.23.

b. Based on 10000 sampled tables with starting seed 624387341.

c. The standardized statistic is -3.401.

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Grampus' behaviour & tidal phases – Chi-square outcomes

Behaviour * Tidal phase Crosstabulation

			Tidal phase				Total
			High	Descending	Low	Rising	
Behaviour	Travelling	Count	260a	278a	463a	272b	1273
		Expected Count	276.6	294.9	461.4	240.1	1273.0
		% within Behaviour	20.4%	21.8%	36.4%	21.4%	100.0%
		% within Tidal phase	50.5%	50.6%	53.9%	60.9%	53.7%
		% of Total	11.0%	11.7%	19.5%	11.5%	53.7%
	Foraging	Count	5a	28b	42b	16b	91
		Expected Count	19.8	21.1	33.0	17.2	91.0
		% within Behaviour	5.5%	30.8%	46.2%	17.6%	100.0%
		% within Tidal phase	1.0%	5.1%	4.9%	3.6%	3.8%
		% of Total	0.2%	1.2%	1.8%	0.7%	3.8%
	Socialising	Count	44a	40a	66a	43a	193
		Expected Count	41.9	44.7	70.0	36.4	193.0
		% within Behaviour	22.8%	20.7%	34.2%	22.3%	100.0%
		% within Tidal phase	8.5%	7.3%	7.7%	9.6%	8.1%
		% of Total	1.9%	1.7%	2.8%	1.8%	8.1%
	Resting	Count	206a	203a, b	288b	116c	813
		Expected Count	176.7	188.3	294.7	153.3	813.0
		% within Behaviour	25.3%	25.0%	35.4%	14.3%	100.0%
		% within Tidal phase	40.0%	37.0%	33.5%	26.0%	34.3%
		% of Total	8.7%	8.6%	12.2%	4.9%	34.3%
Total		Count	515	549	859	447	2370
		Expected Count	515.0	549.0	859.0	447.0	2370.0
		% within Behaviour	21.7%	23.2%	36.2%	18.9%	100.0%
		% within Tidal phase	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	21.7%	23.2%	36.2%	18.9%	100.0%

Each subscript letter denotes a subset of Tidal phase categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	39.338[a]	9	.000
Likelihood Ratio	44.073	9	.000
Linear-by-Linear Association	17.995	1	.000
N of Valid Cases	2370		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.16.

Appendix X: Density maps
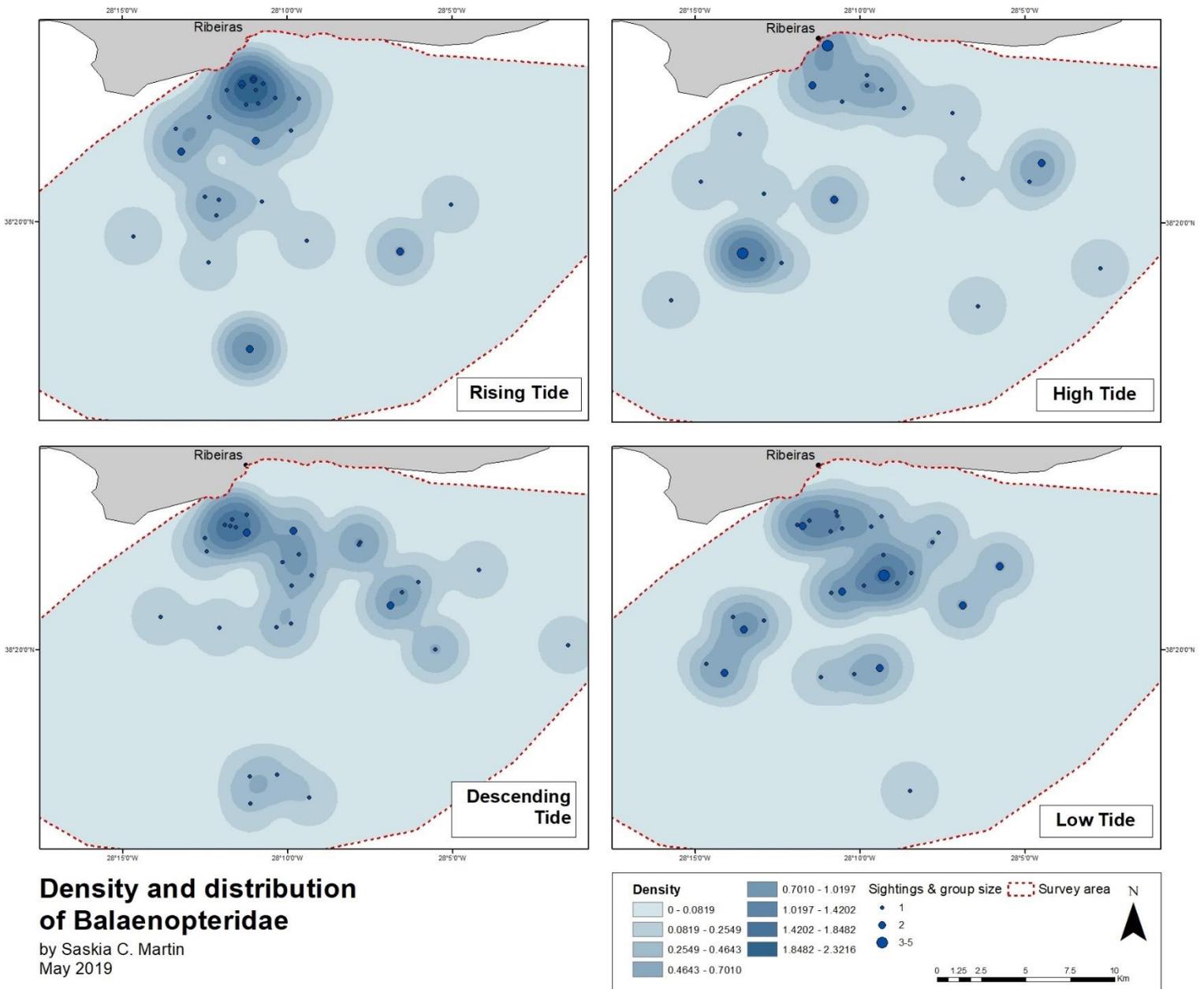
**Density and distribution
of Balaenopteridae**

by Saskia C. Martin
May 2019

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Density and distribution of Hyperoodon
by Saskia C. Martin
May 2019

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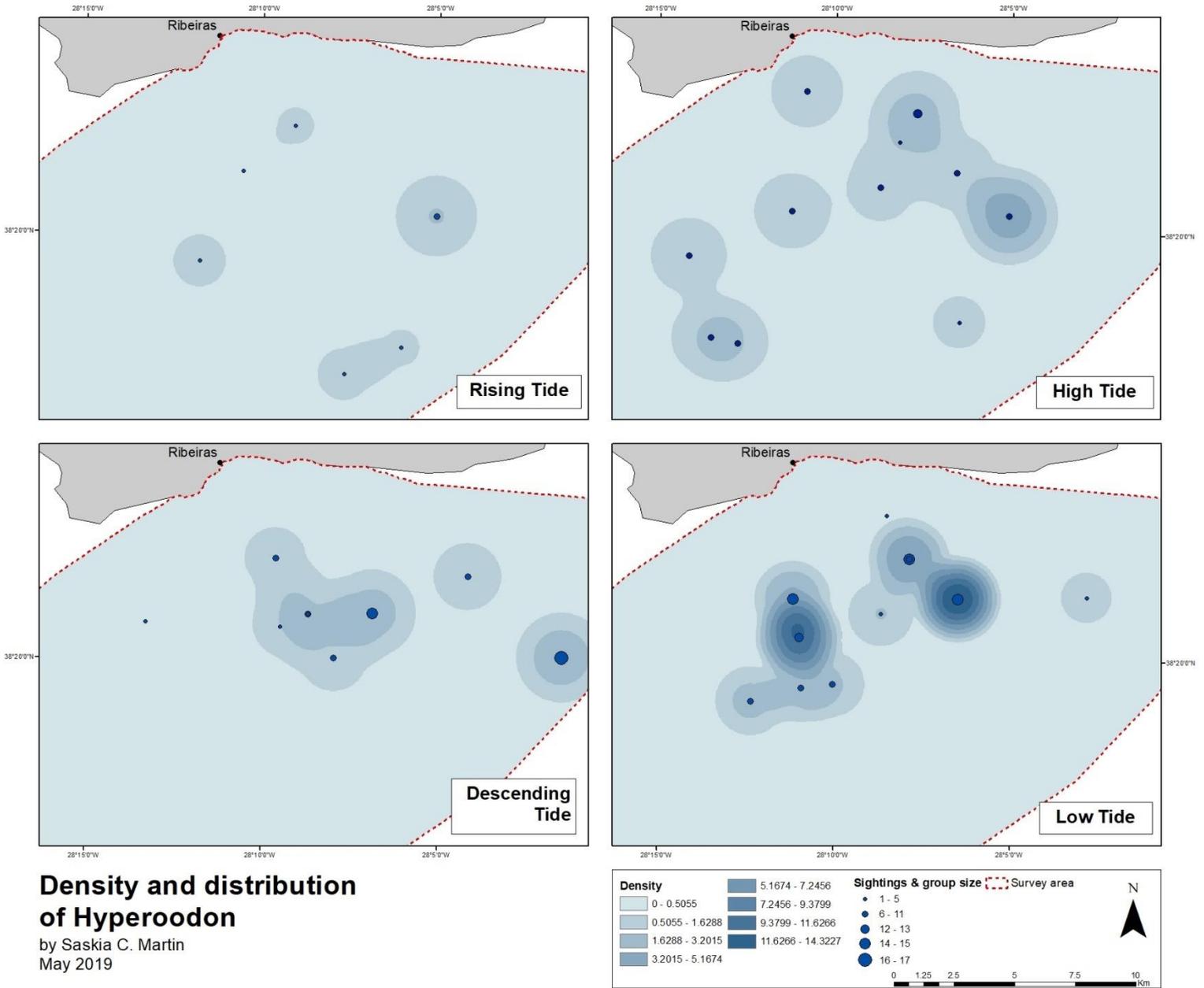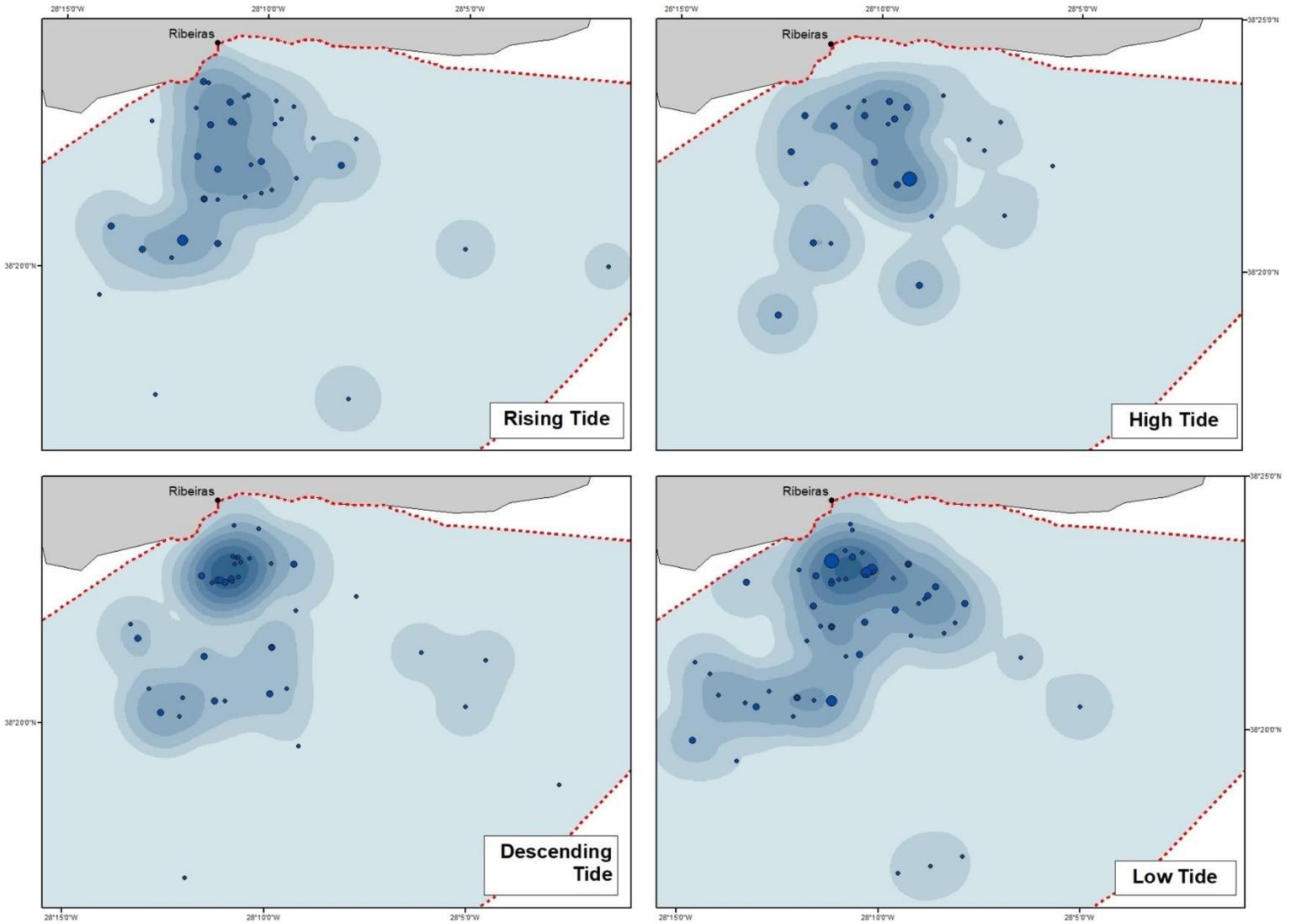
**Density and distribution
of Ziphiidae**

by Saskia C. Martin
May 2019

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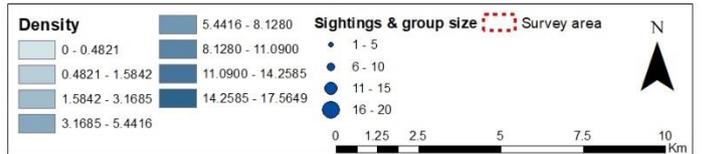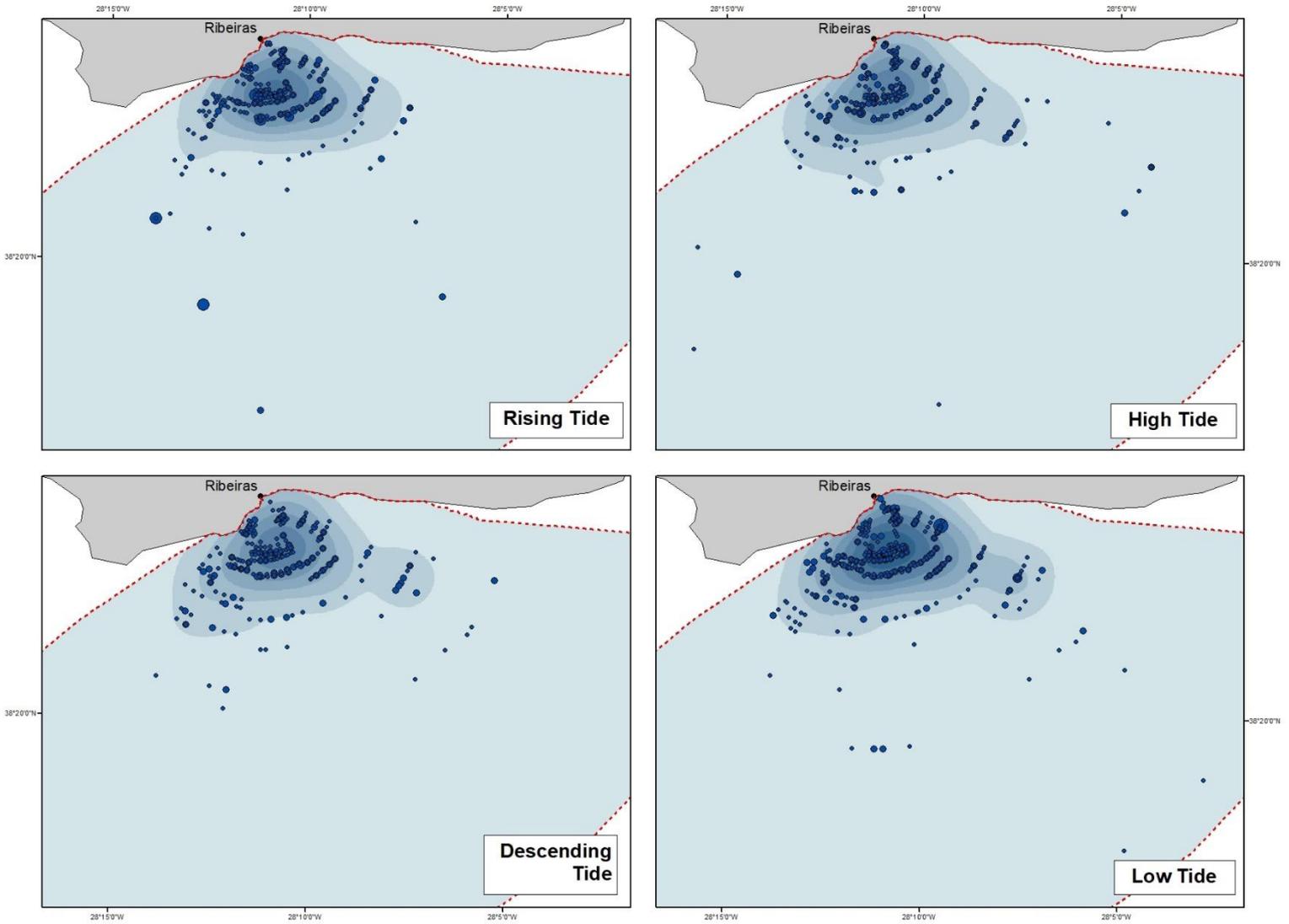
Density and distribution of Grampus
by Saskia C. Martin
May 2019

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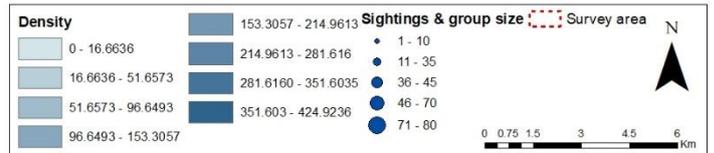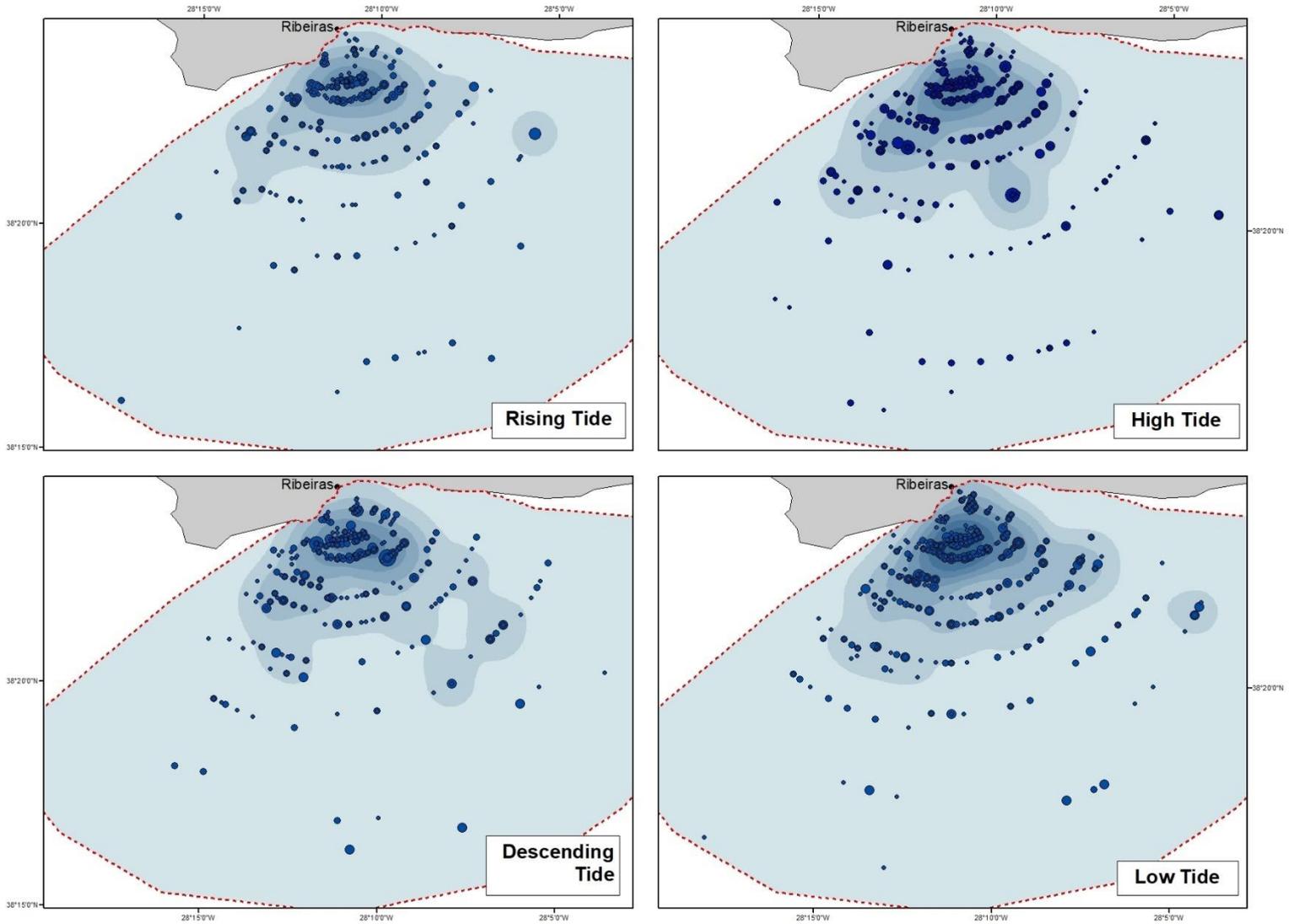
Density and distribution of Small Oceanic Delphinids

by Saskia C. Martin
May 2019