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MARINE MAMMAL

ATLAS

OF

OMAN

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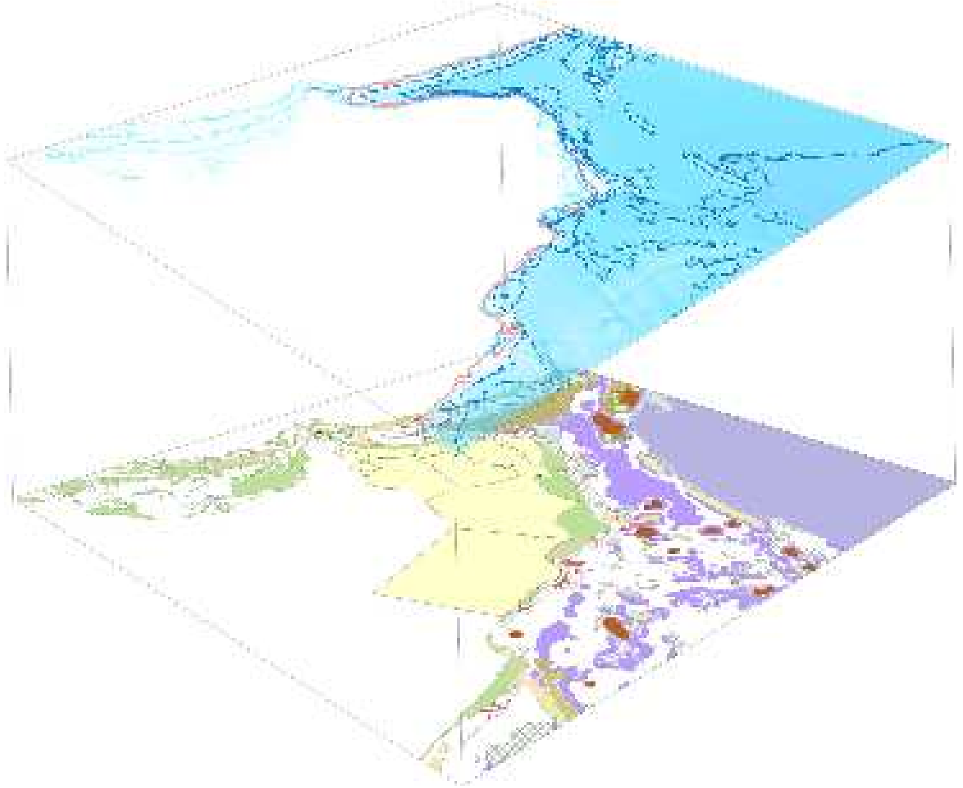
2021



MARINE MAMMAL ATLAS OF OMAN

FOREWORD

THE RENAISSANCE WHALE AND DOLPHIN RESEARCH PROJECT is the flagship initiative of our company's support for Environment Society of Oman (ESO). The importance of ESO work in marine conservation is visible in the wonder, beauty and knowledge captured in these pages of the Marine Mammal Atlas of Oman.

People, Planet and Profits are not mutually exclusive. They are complementary and inter-dependent. There is moral purpose for private sector to support biodiversity conservation and raise awareness. Commitment to the global Environment, Social and Governance (ESG) agenda is commitment to a balanced approach to ethical, legal and commercial obligations to all stakeholders.

Our Corporate Social Responsibility (CSR) initiatives include focus on people and human potential. But everything is connected. Environmental initiatives have consequence and benefit for people too: Not just the imperative of sustainability, but as in the case of Oman's marine mammals, positive implications for the fishing industry, tourism and jobs.

Oman's private sector commitment to the ESG agenda is required to attract international finance and investment into the economy. Disclosures in Sustainability Reports must be auditable. ESO provides accountable evidence of every expenditure, to prove the application and value of your support.

The rewards are greater than the sum of the investment. However quiet we expected our role to be, within the scope of our own disclosures; Renaissance support for ESO has appeared on national and international television, newspapers, magazines, websites and other social media. This included recognition in the BBC prime time documentary, charting the amazing scientific outcomes of the project, for the story of the Arabian Sea Humpback Whale.

The journey continues in this beautiful volume. Every time you enjoy opening Marine Mammal Atlas of Oman, I hope it may inspire you to encourage private sector and others to support ESO and similar causes, to conserve the biodiversity of Oman and our home of Planet Earth.

Stephen R. Thomas OBE
CEO
Renaissance Services SAOG

FOREWORD

BEFORE OIL, BEFORE COMMERCIAL FARMING, BEFORE AIRPLANES, OUR LIVES AND LIVELIHOODS DEPENDED ON THE OCEAN.

Trade winds connected us to global markets, we built fleets that explored and traded, we welcomed people from the other side of the planet, and we feasted on the rich seemingly bottomless bounty of the ocean.

As we grow and race through the 21st century, our impact on our oceans has become considerable. What we thought was an inexhaustible resource, here for the taking, is now struggling under our negligent management. It is heating up, resulting in ever stronger storms, it is contaminated with plastic and other pollutants we flush into it daily, its rich life is under threat of extinction on many fronts.

The first step in addressing these problems is to describe and quantify them.

For over 15 years ESO has been observing, and sharing its findings. Armed with reliable data the authorities can act in the knowledge that they are doing the right thing and can measure their successes.

There are 20 species of marine mammals living off Oman's coast. These intelligent creatures are at the top of their food webs and their primary threat comes from us. They are a barometer of the state of our oceans and the survival of all the rest of the flora and fauna therein. It is imperative we use our knowledge, curiosity and problem solving skills to obliterate this huge blind spot we have maintained. It is time to close this chapter, the chapter of our misguided belief, that the ocean is too big to be affected by our unfettered exploitation.

It is our responsibility to carefully manage the precious life sustaining resources of our oceans and I would like to thank those who collaborated to produce this Atlas, as they are providing us with vital data and solutions to move forward.

His Highness Tarik bin Shabib Al Said
Patron,
Environment Society of Oman

FOREWORD

OVER THE PAST 20 YEARS, *the global community of whale and dolphin scientists has come to recognise Oman as a country of great importance to this group of marine mammals. It was once considered likely that the extreme corner of the North Western Indian Ocean in which Oman is situated, would have an impoverished cetacean fauna. Today, however, Oman is known for its remarkable and rich cetacean biodiversity. Rich, not just in terms of numbers of species (Oman hosts almost a quarter of the world's cetacean species) but also in terms of the biodiversity within species. And this is the really fascinating part: almost all species in Oman which have been studied in enough detail to date – the Indian Ocean Blue Whale, Bryde's Whale, Arabian Sea Humpback Whale, Indian Ocean Humpback Dolphin, Spinner Dolphin, Indo-Pacific Common Dolphin and the two species of Bottlenose Dolphins - have been revealed to be subtly, and sometimes not-so-subtly, different to those elsewhere in the world, so much so that some may yet turn out to be separate subspecies or even new species unique to the region.*

Such variability exists in other parts of the world, but rarely so universally, for Oman owns unique biogeographical status. It occupies an unusual space on the planet where there is a kind of ocean cul-de-sac, with migration to polar feeding grounds to the north made impossible by the Asian land mass and the distance to the south too great for regular migration, and yet where food is in plentiful supply thanks to a powerful seasonal upwelling the likes of which occurs in just four other locations globally. This monsoonal upwelling is the source of nutrients that turn Oman's southern seas bottle green every summer, powering a food web that sustains even the largest of whales.

Consequently, the whales and dolphins of Oman are both diverse and, mostly, numerous and many do not leave the region, choosing instead to remain in these rich waters year round and becoming genetically isolated in the process.

This Atlas provides the most comprehensive insight yet into our knowledge of whales and dolphins in Oman gained through decades of dedicated research. The field element of the research has involved countless sun-exposed hours on small vessels, punctuated by moments of awe and excitement during active encounters. This fieldwork is nevertheless only a fraction of the work required to raise funds, plan and prepare field campaigns, process and interpret data, analyse samples and finally publish and disseminate results. This Atlas attempts to summarise many of these results, releasing previously unpublished information from databases and visually highlighting data that are often difficult to find and decipher in the labyrinth of scientific journals.

All of this work is important not only to our knowledge of Oman's whales and dolphins, but also to our understanding of the wider marine realm. Ultimately, this is of great value to the Omani people - the prolific end-users, economic beneficiaries and custodians of the Sultanate's seas.

Robert Baldwin
CEO,
Five Oceans Environmental Services LLC.

A C K N O W L E D G E M E N T S

The funding, commissioning and production of this Atlas are the result of determined endeavour by Renaissance Services SAOG (Renaissance), the Environment Society of Oman (ESO) and Five Oceans Environmental Services LLC (5OES), respectively. Dedicated teams within each of these organisations, in the case of 5OES additionally supported by interns, have worked hard to bring this Atlas to publication over the past year and each of these organisations has also played a pivotal role in acquiring much of the recent research data behind it.

Renaissance first began funding whale and dolphin research in Oman in 2011 and the culmination of their support is this Atlas itself. ESO has played the focal role of managing and coordinating whale and dolphin research in Oman from the very beginning of the organisation's history which dates back to 2004. Also since its official establishment in 2004, 5OES has been leading the field research, data processing and scientific analysis, as well as working closely with ESO to help develop detailed guidance for the conservation management of whales, dolphins and their habitats in Oman.

None of this work would have been possible without sanction by the Environment Authority in Oman (formerly the Ministry of Environment and Climate Affairs), representatives of which have always enthusiastically processed and approved research permit applications and many have also joined field research teams, committing valuable time and energy to the programme. Some have now become specialists in the subject of whales and dolphins in their own right. The support of the Ministry of Agriculture, Fisheries and Water Resources (formerly the Ministry of Agriculture and Fisheries Wealth) is also gratefully acknowledged.

For the full complement of data on which this Atlas is based there are many additional organisations and people to thank. In the 1970s, the cataloguing of records of whales and dolphins in Oman was initiated at the Oman Natural History Museum, where a Whale Hall brings to life some of the archival store of specimens that provide scientists with reference material for study.

In the 1980's, a database created as part of the IUCN Oman Coastal Zone Management Project, under the auspices of the former Ministry of Commerce and Industry, lead to expansion of the list of documented records, and gave rise, in the early 1990's, to the Oman Cetacean Database (OMCD). This database, now managed by ESO and a number of dedicated volunteers, remains the central storage facility for cetacean records in Oman and has provided the majority of the data on which this Atlas is based. Since its establishment, the OMCD has been populated by records collected by many Omani and expatriate volunteers who have reported sightings and strandings of whales and dolphins throughout the Sultanate.

It is thanks to the support of Renaissance Services SAOG, that some of the more cutting-edge scientific research in Oman has been made possible. Satellite tracking, passive acoustic monitoring, drone surveys, DNA sampling and analysis, and other advanced techniques, have resulted in some ground-breaking discoveries, the results of which have been published in leading international peer-reviewed scientific journals. Individuals from many organisations around the world have lent their expertise to such work, consistently providing technical advice, equipment and materials, funding, and a leading hand in fieldwork. Particular acknowledgment is due to the Wildlife Conservation Society, the International Whaling Commission Scientific Committee, the US National Oceanic and Atmospheric Administration, the International Union for the Conservation of Nature, the United Nations Convention on the Conservation of Migratory Species of Wild Animals, World Wildlife Fund-Emirates Nature, Durham University, University of Exeter, Five Oceans Environmental Services LLC, Megaptera Marine Conservation, Peruvian Centre for Cetacean Research (CEPEC), New England Aquarium, African Aquatic Conservation Fund, Smithsonian Institution, Aarhus Institute of Advanced Studies, Cape Peninsula University of Technology, Centre for Dolphin Studies (South Africa), Clear Blue Photo Inc. and a range of scientific journals, including the Aquatic Mammals journal.

The continuation of the work on which this Atlas is based will always rely on the dedication of individuals and is absolutely essential. With increasing pressures on the marine environment, we must continue to study and monitor Oman's whales and dolphins, endeavour to better understand the role they play in marine ecosystems, investigate and address the threats they face and promote action to realise the economic benefits they could provide, whilst all the time seeking to protect this valuable component of Oman's natural heritage. We thank all those who have played their part in creating the basis for such endeavours to date.

HOW TO USE THIS ATLAS

THE MARINE MAMMAL ATLAS OF OMAN provides a detailed biogeographical account of all of the marine mammals that have been recorded in the country to date. All of these are whales and dolphins, with the exception of a single Southern Elephant Seal (*Mirounga leonina*) that was recorded in Oman in 1988. As a one-off vagrant, this marine mammal is not considered part of the mammalian fauna of the country and is not covered here. The information in this is Atlas is derived from evidence that has been assembled and assessed through scientific process, including records of whales and dolphins collected during dedicated scientific field surveys, as well as opportunistic and incidental records from third parties. Whether you are a whale and dolphin enthusiast, scientist, environmental consultant, policymaker/public servant or developer, this Atlas will provide you with the correct tools to compliment and build your existing knowledge of cetaceans (the collective name for whales and dolphins) with a primary aim of guiding your activities towards a sustainable future for this remarkable group of marine mammals.

To use this Atlas, we have divided the book into five main chapters: **Chapter One** introduces the whales and dolphins found in Oman's waters, highlighting their spatial distribution in Oman and their occurrence in the context of the wider Northern Indian Ocean region. **Chapter Two** presents species profiles for different regions of Oman and any associated Important Marine Mammal Areas (IMMAs) as defined by international organisations based on a detailed peer review process. **Chapter Three** discusses the natural and anthropogenic factors that threaten the health, well-being and survival of cetaceans in Oman, with a focus on 1) ship strike, 2) underwater noise, 3) offshore oil and gas activities, 4) fisheries threats including bycatch and overfishing 5) whale and dolphin tourism, 6) pollution, 7) coastal development, 8) climate change, and 9) biotoxins and disease. **Chapter Four** addresses threat specific mitigation options for ship strike, underwater noise, fisheries, and whale and dolphin watching in Oman. Lastly, **Chapter Five** discusses the various international and national conservation frameworks, organisations and activities relevant to cetaceans in Oman and the wider region.

The Atlas is specifically designed as a digital product and we highly recommend taking the time to zoom in on the maps presented for a more comprehensive experience. It is not intended as a species identification guide, and we recommend other references for this purpose as listed below.

T.Collins

OTHER REFERENCES

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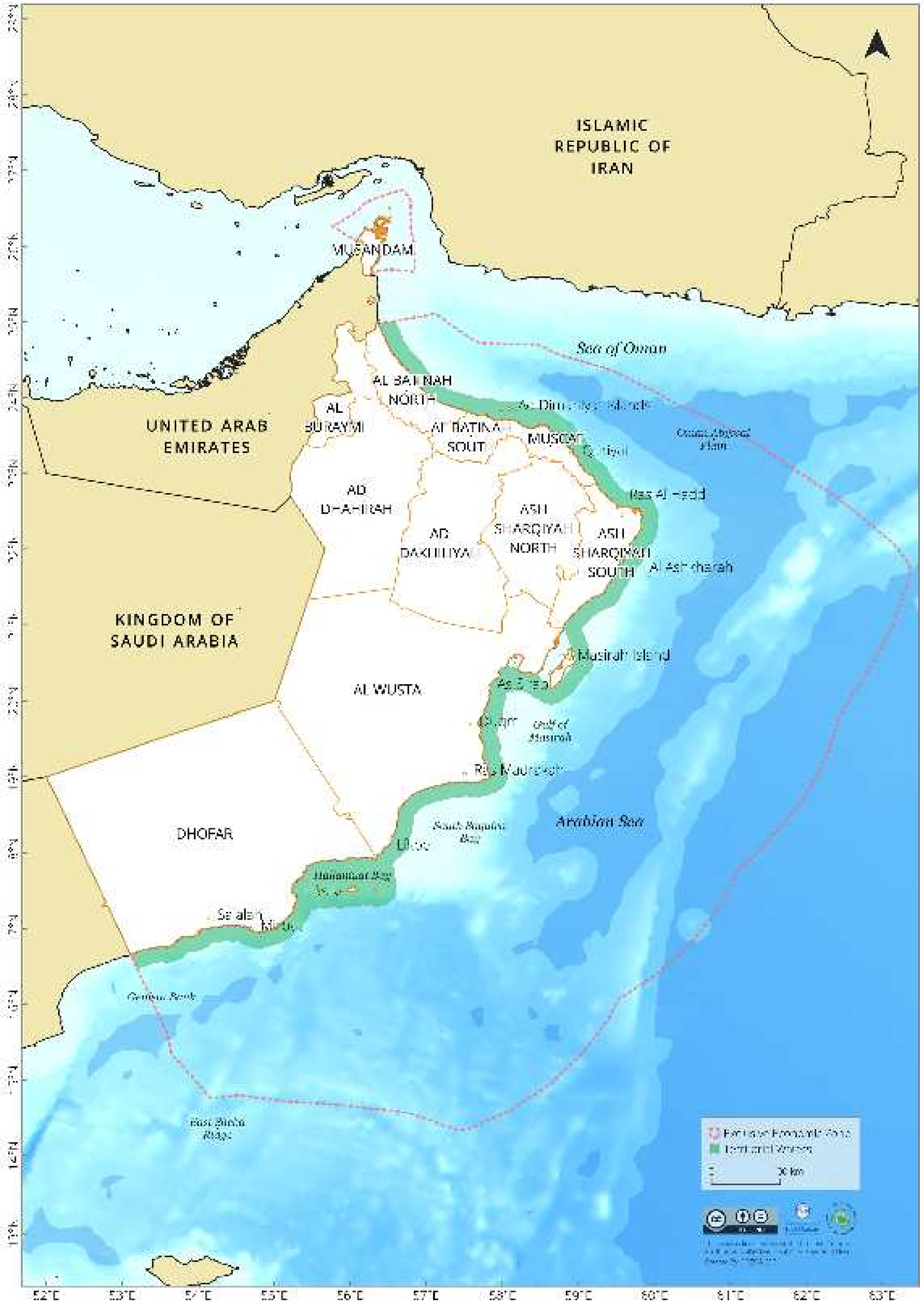
Note: Look out too for the forthcoming 'Field Guide to Mammals of Oman', by Andrew Spalton, Gareth Whittington Jones, Robert Baldwin and Hadi al Hickmani which will be published in 2021 and includes all of Oman's whales and dolphins.

CONTENTS

INTRODUCTION

OCEANOGRAPHY
SURVEY APPROACH
SURVEY EFFORT
BIODIVERSITY

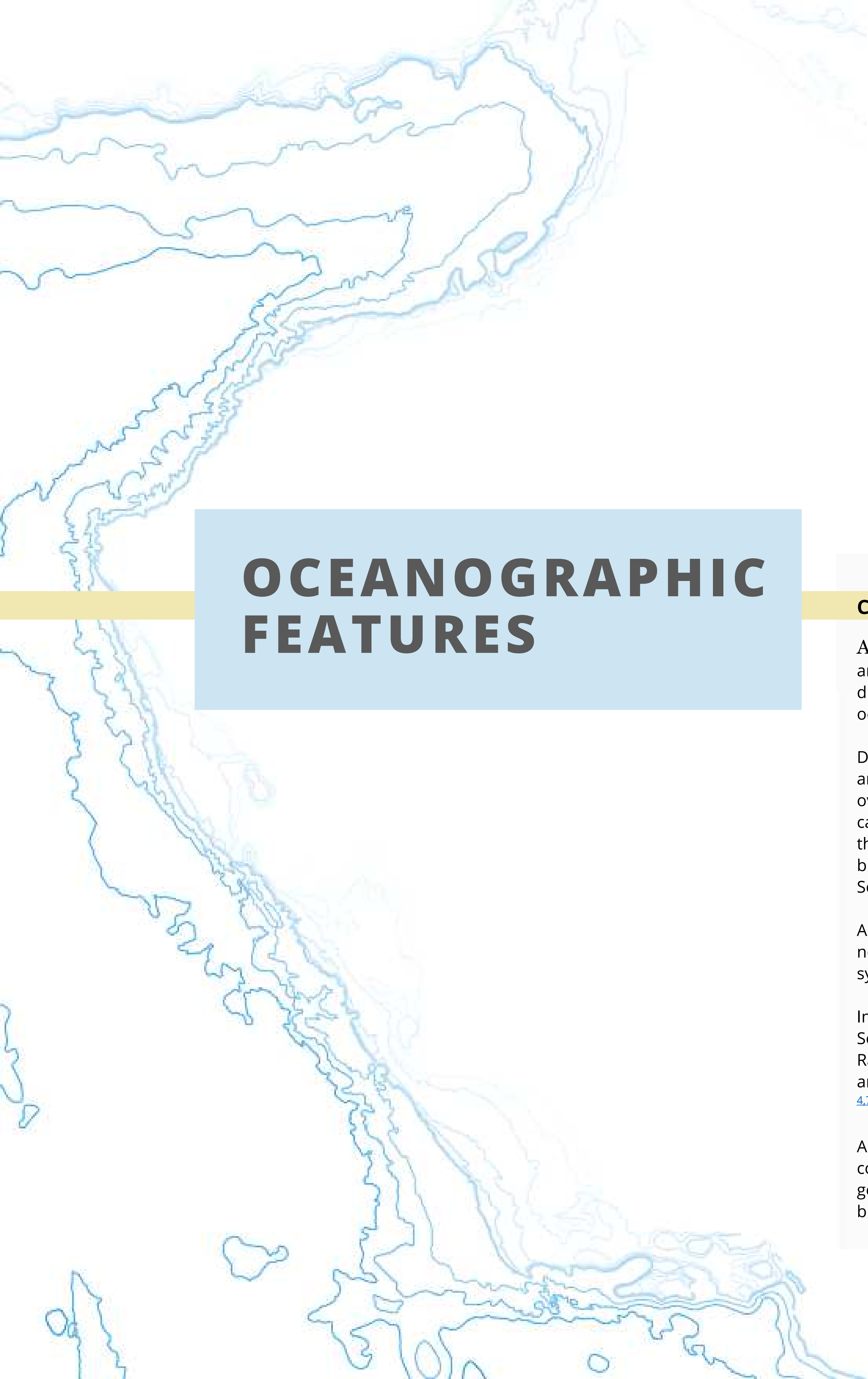


INTRODUCTION

THE SULTANATE OF OMAN is divided into 11 governorates with a coastline stretching some 3,165km bordering the Arabian Sea, the Sea of Oman and the Arabian Gulf, the latter defined by a relatively small area of the territorial waters around the Musandam governorate [1]. The Exclusive Economic Zone (EEZ) of Oman, including an area of approximately 537,841km^2, extends 200 nautical miles from shore and is represented by the red dotted line in the adjacent map. Within the EEZ are the territorial waters of Oman (12NM zone - shaded in teal) encompassing an area of approximately 51,358km^2.

The first section of this chapter presents a summary of a range of physical oceanographic features of Oman which play a central part in the definition of marine mammal habitats, including bathymetry and slope profile, sea surface temperature, and net primary productivity. The second section provides a brief overview of the scientific study methods and strategy employed during dedicated cetacean surveys from which much of the sightings data in this Atlas is derived. This includes explanation of where and when surveys were conducted and introduces the concept of 'survey effort' which is necessary contextual information to understand the reporting of sightings in subsequent chapters of the Atlas.

The results of surveys are presented for five main areas: 1) Muscat, 2) Ras Al Hadd, 3) Gulf of Masirah, 4) South Saquira Bay, and 5) Dhofar. The Gulf of Masirah includes waters that surround Masirah Island and the waters north of Ras Madrakah in Al Wusta. South Saquira Bay stretches south of Ras Madrakah to the boundary between Dhofar and Al Wusta. While the Gulf of Masirah and South Saquira Bay lie within the Al Wusta governorate, these areas are differentiated in the analysis in this Atlas due to a large variance in survey effort.



OCEANOGRAPHIC FEATURES

CURRENTS

AS IN ALL OCEANS, THE CURRENTS OF THE NORTHERN INDIAN OCEAN are influenced by wind patterns over large temporal and spatial scales. However, unlike the Pacific and Atlantic Oceans, the direction of predominant Indian Ocean currents reverses annually in response to changes in monsoonal winds, causing complex oceanographic conditions around Oman.

During the summer, an area of low pressure is generated over the Indian subcontinent due to the heating of the land, whilst an area of high pressure occurs on the other side of the Indian Ocean, over Australia. As a result, strong south-westerly winds form over the northern Indian Ocean [2]. These winds generate the Southwest Monsoon Current and the southerly Somali Current, and cause the North Equatorial Current to flow from west to east [3,4]. In the winter, as the land cools, the area of low pressure over the Indian subcontinent dissipates and is replaced with a high-pressure system. This causes the monsoonal winds to reverse and blow in a north-easterly direction [3,4,5], thus creating the east-west North Equatorial Current and a periodic cessation of the Somali Current.

Around Oman, surface currents in the winter flow out of the Arabian Gulf via the Strait of Hormuz. They continue along the north-east coast of Oman, around Ras Al Hadd and then southward along the south-east coast of Oman. In the summer, the system reverses and surface currents flow northward along the east coast of Oman and into the Arabian Gulf.

In summer, the outflow of high salinity deep water from the Arabian Gulf, coupled with the north-ward surface water flow of the Somali Current (extending into the East Arabian Current) produces a well-defined density front on the Oman coast, known as the Ras Al Hadd frontal zone [4,6]. This demarcates the boundary between the high salinity deep water originating in the Arabian Gulf and the lower salinity waters of the Sea of Oman: this frontal zone breaks down during the northeast (winter) monsoon period [4,7,8,9].

Along the southeast coast, there is strong and sustained seasonal upwelling between May and September associated with the continuation of the Somali Current into the East Arabian Current. During summer months, a dense field of mesoscale eddies is generated by convergence of the East Arabian Current and other currents of the Arabian Sea, creating high temporal variability, but spatial heterogeneity, of chlorophyll a (used as an indicator for biological productivity [10]) during the summer monsoon [11].

OCEANOGRAPHIC FEATURES

PRIMARY PRODUCTIVITY

PRIMARY PRODUCTIVITY (the rate at which new carbon is incorporated into organic matter via the process of photosynthesis [12]) is influenced by a complex interaction of physical, chemical and biological factors [13], which in their simplest terms include light intensity (irradiance), water, carbon dioxide and nutrient availability, and temperature [12]. Net primary productivity (NPP) is the total productivity (gross primary productivity) minus the rate of energy loss due to metabolism and maintenance. Of primary producers in the marine environment, the wide variety of phytoplankton species may contribute approximately 95% of marine primary productivity [14], with primary productivity often used as a proxy for phytoplankton growth rates.

Irradiance levels are high year-round in Oman; seasonal variation in irradiance is less distinct than at temperate latitudes, and light is generally not considered to be a limiting factor for primary production [15]. Although precipitation in Oman is generally low, periodic high rainfall can occur during extreme weather events, resulting in significant volumes of water flowing into coastal systems through wadi channels, carrying with it terrestrial-origin sediments and nutrient loading.

Nutrient levels in waters off Oman show correlation with monsoonal cycles and associated upwelling events [16,17,18]. Elevated nutrient concentrations are recorded during one or both of the monsoon periods as well as in areas of upwelling, either coastal/nearshore or up to several hundred kilometres offshore [16,18].

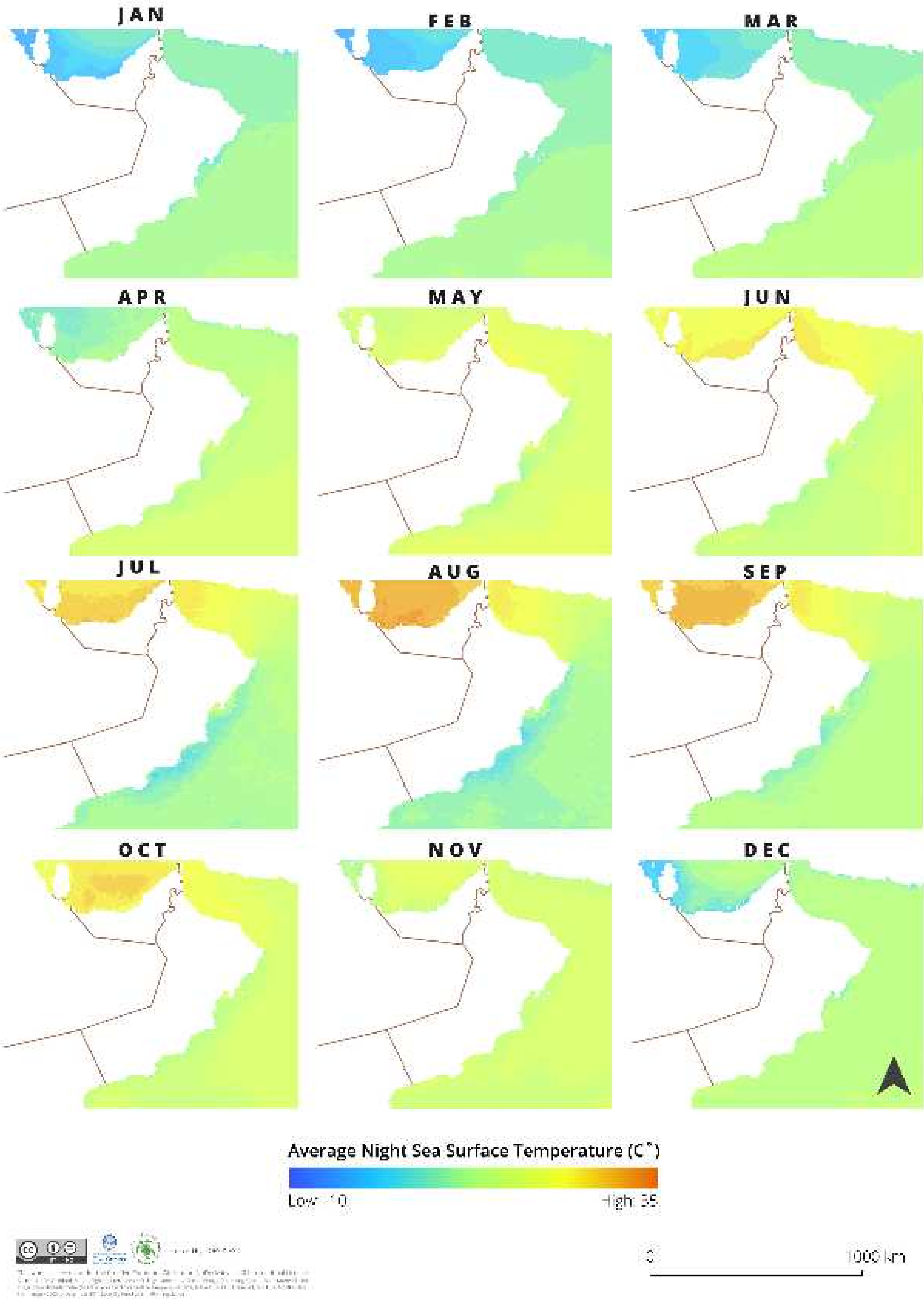
In nearshore coastal waters, a short time-series study of nutrient levels revealed clear seasonality, with nitrate and phosphate concentrations highest in January/February, coincident with the end of the northeast winter monsoon, and silicate concentrations highest in October, towards the end of the southwest summer monsoon [18].

Chlorophyll a measurements (as a proxy for phytoplankton biomass) may show one or two peaks each year, coincident with the monsoon periods, with timing and magnitude varying dependent on location; Sea of Oman coastline, or southwest Arabian Sea coastline (e.g. Masirah) [4]. Maximal chlorophyll A concentrations for the southwest are reported during the summer monsoon, whilst for the Sea of Oman maximal concentrations are generally recorded during the northeast winter monsoon period [4], although peaks during summer monsoon months have also been reported [18].

In Oman, an inverse relationship between mean NPP and average nightly sea surface temperature is evident [19]: In areas of lower average nightly sea surface temperatures, NPP levels are high, and vice versa. During the first three months of the year, NPP is high and concentrated along the northern areas of Oman's coastline when average nightly sea surface temperatures are lower. A change in the NPP distribution is apparent from July-September with a higher NPP in southern regions of Oman where sea surface temperatures are lower than in the northern areas.

BATHYMETRY

A NOTABLE FEATURE of the bathymetry profile of Oman is a narrow continental shelf between Muscat and Ras al Hadd and also in parts of Dhofar, where the 200m isobath is relatively close to shore. In the Muscat region, the coast is characterized by steep drop offs and canyons that are present between Muscat and Ras Al Hadd. Between Ras Al Hadd and Mirbat, the continental shelf is wider, and includes two distinct shallow bays: the Gulf of Masirah and South Saquira Bay.


JAN
FEB
MAR
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MAY
JUN
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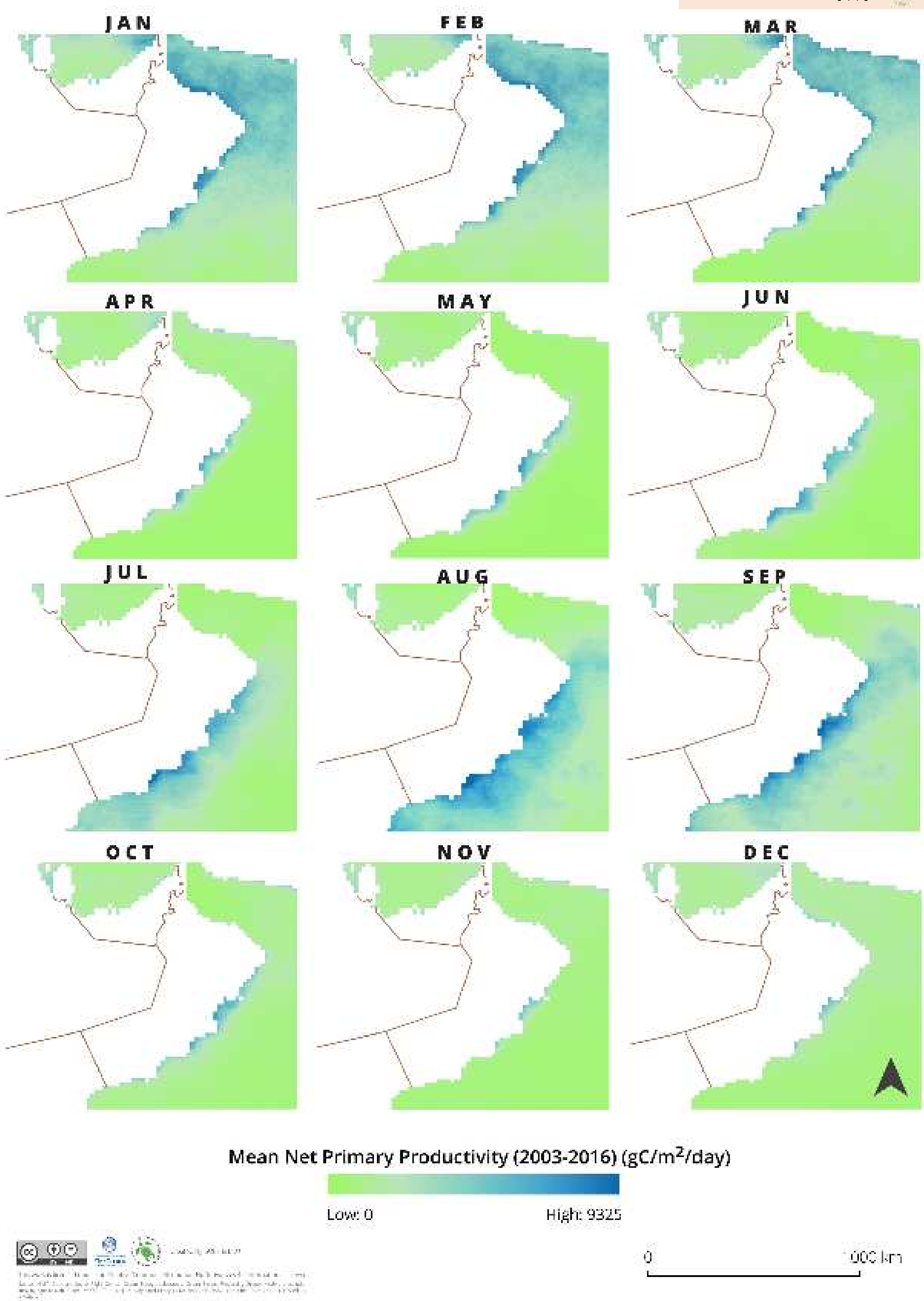
Average Night Sea Surface Temperature (C°)
High: 35
0
1000 km


JAN
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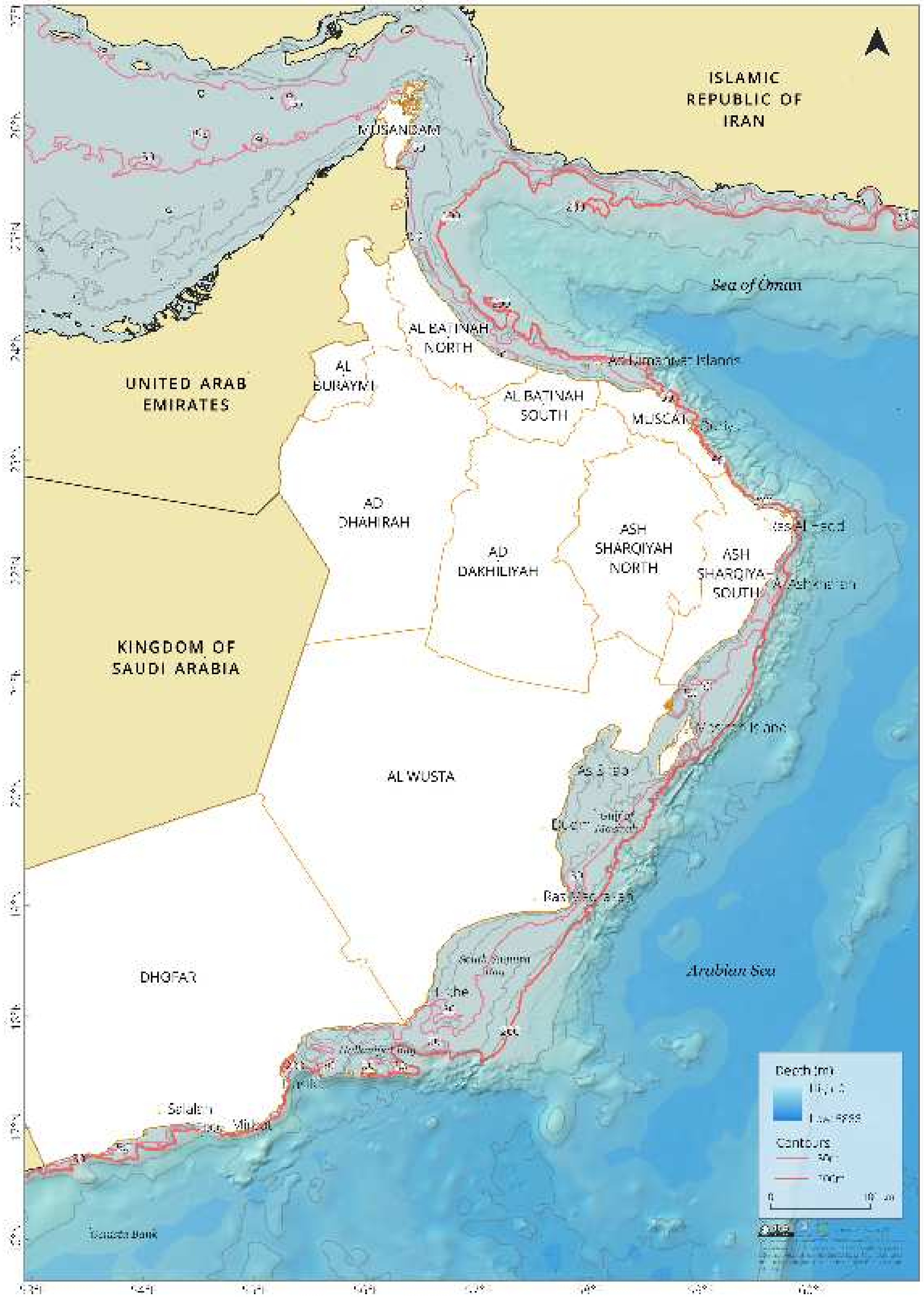
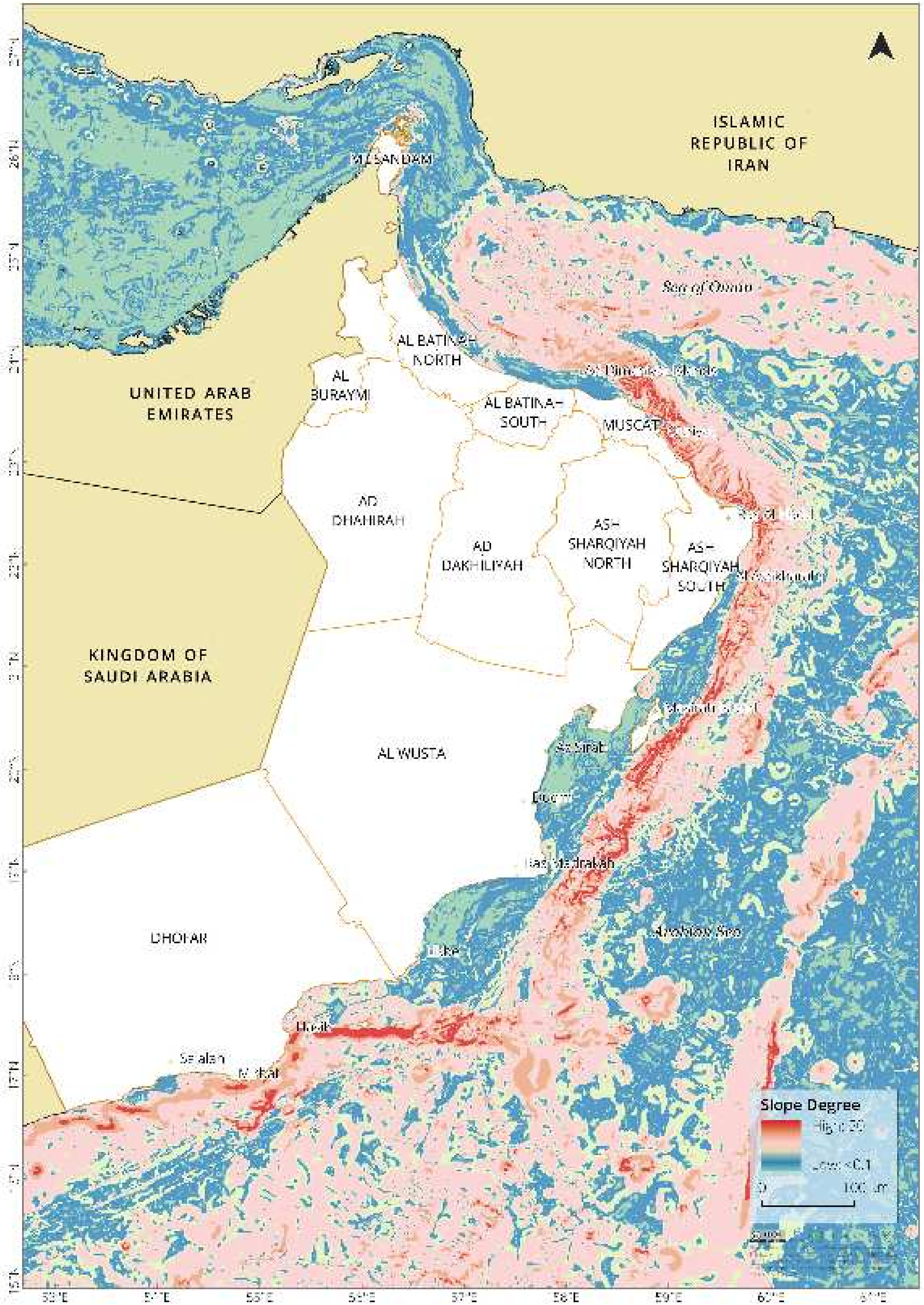
Mean Net Primary Productivity (2003-2016) (gC/m2/day)
Low: 0
High: 9325
0


ISLAMIC REPUBLIC OF IRAN
MUSANDAM
Sea of Oman
UNITED ARAB EMIRATES
AL BURAYMI
AL BATINAH NORTH
AL BATINAH SOUTH
MUSCAT
AD DHAHIRAH
AD DAKHILIYAH
ASH SHARQIYAH NORTH
ASH SHARQIYAH SOUTH
KINGDOM OF SAUDI ARABIA
AL WUSTA
DHOFAR
Arabian Sea
Ras Madrakah
Duqm
Salalah
Mirbat
Depth (m)
Contours


ISLAMIC REPUBLIC OF IRAN
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AL BURAYMI
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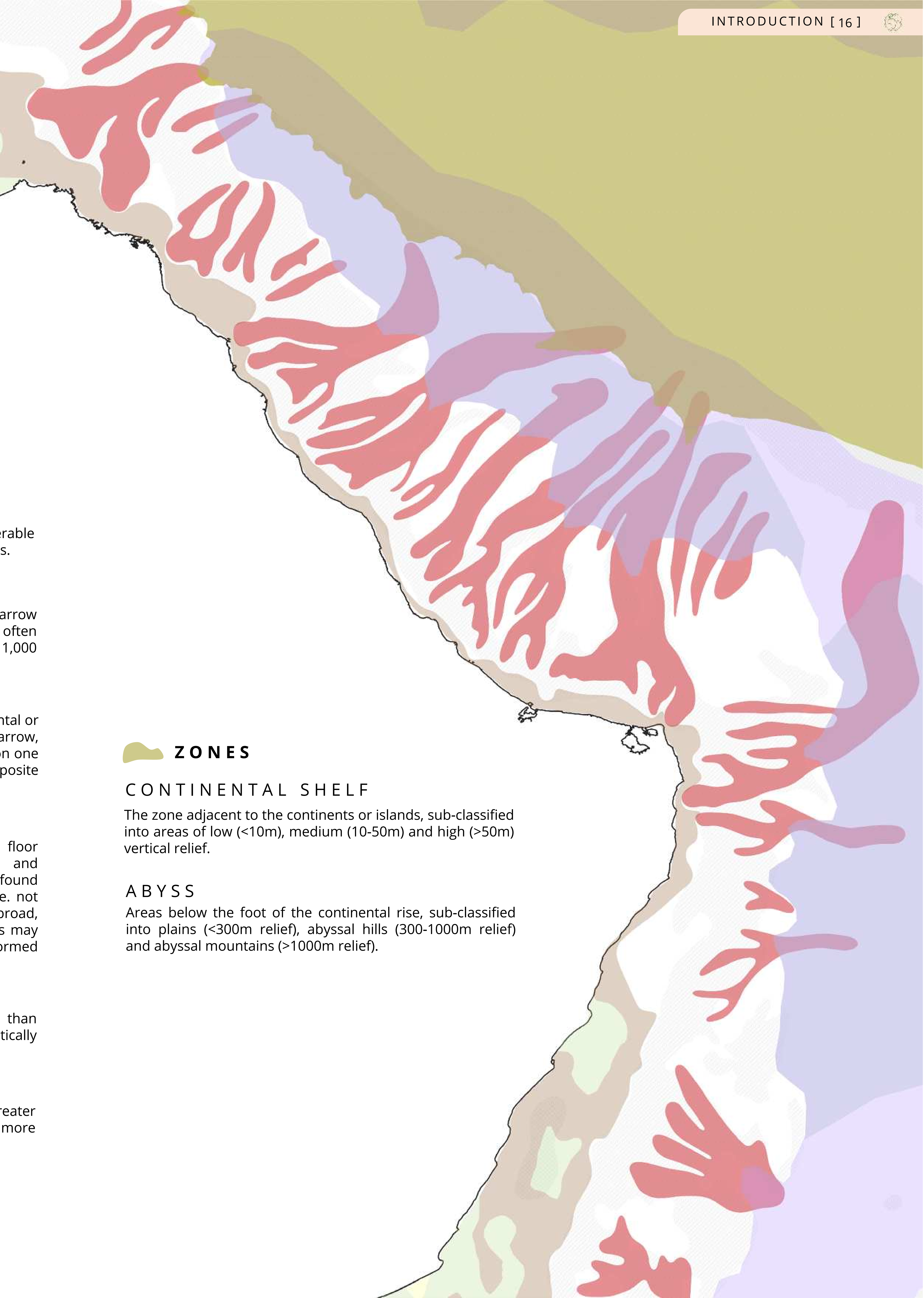
Salalah
Mirbat
Slope Degree



SEAFLOOR GEOMORPHOLOGY LEGEND

The following definitions of seafloor geomorphology features were retrieved from the dataset summary in ArcGIS, sourced from Geomorphology of the Oceans [20]. These seafloor geomorphology terms are used in species sighting maps in Chapter 2.

TERRAIN

BASINS

Basins are depressions in the sea floor that are more or less equi-dimensional in plan, of variable extent, and are restricted to seafloor depressions defined by closed bathymetric contours.

ESCARPMENTS

Escarpments are “an elongated, characteristically linear, steep slope separating horizontal or gently sloping sectors of the sea floor in non-shelf areas. Also abbreviated to scarp” [21]. Escarpments, like basins, overlay other features (i.e. other individual features may be partly or wholly covered by escarpments). Thus, features like the continental slope, seamounts, guyots, ridges and submarine canyons (for example) may be sub-classified in terms of their area of overlain escarpment.

FEATURES

CANYONS

Submarine canyons are defined as steep-walled, sinuous valleys with V-shaped cross sections, axes sloping outward as continuously as river-cut land canyons and relief comparable to even the largest of land canyons.

FANS

Fans are relatively smooth, fan-like, depositional featured normally sloping away from the outer termination of a canyon or canyon system. Fans overlay and comprise part of the continental rise and are located offshore from the base of the continental slope. Fans are inter-related with submarine canyons and sediment drift deposits; in cases where canyon axes extend across the rise, the canyon-channels may be flanked by sediment drift deposits, which have been grouped with fans in this study. Fans are defined in the present study by 100m isobaths that form a concentric series exhibiting an expanding spacing in a seaward direction away from the base of the slope, sometimes clearly associated with a canyon mouth, but also comprising low-relief ridges between canyon-channels on the abyssal plain.

PLATEAUS

Plateaus are flat or nearly flat elevations of considerable areal extent, dropping off abruptly on one or more sides.

RIDGES

Ridges are isolated or a group of elongated narrow elevations of varying complexity with steep sides, often separating basin features. Ridges have greater than 1,000 meters of relief.

TERRACES

Terraces an isolated or a group of relatively flat horizontal or gently inclined surface(s), sometimes long and narrow, which is (are) bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.

TROUGHS

Troughs are long depressions of the sea floor characteristically flat bottomed and steep sided and normally shallower than a trench. In this study we found that troughs are also commonly open at one end (i.e. not defined by closed bathymetric contours) and their broad, flat floors may exhibit a continuous gradient. Troughs may originate from glacial erosion processes or have formed through tectonic processes.

SEAMOUNTS

Seamounts are a single or group of peaks, greater than 1,000 meters in relief above the sea floor, characteristically of conical form.

SHELF VALLEYS

Shelf valleys are greater than 10 km in length and greater than 10 m in depth overall with an elongate shape more than 4 times greater in length than width.

ZONES

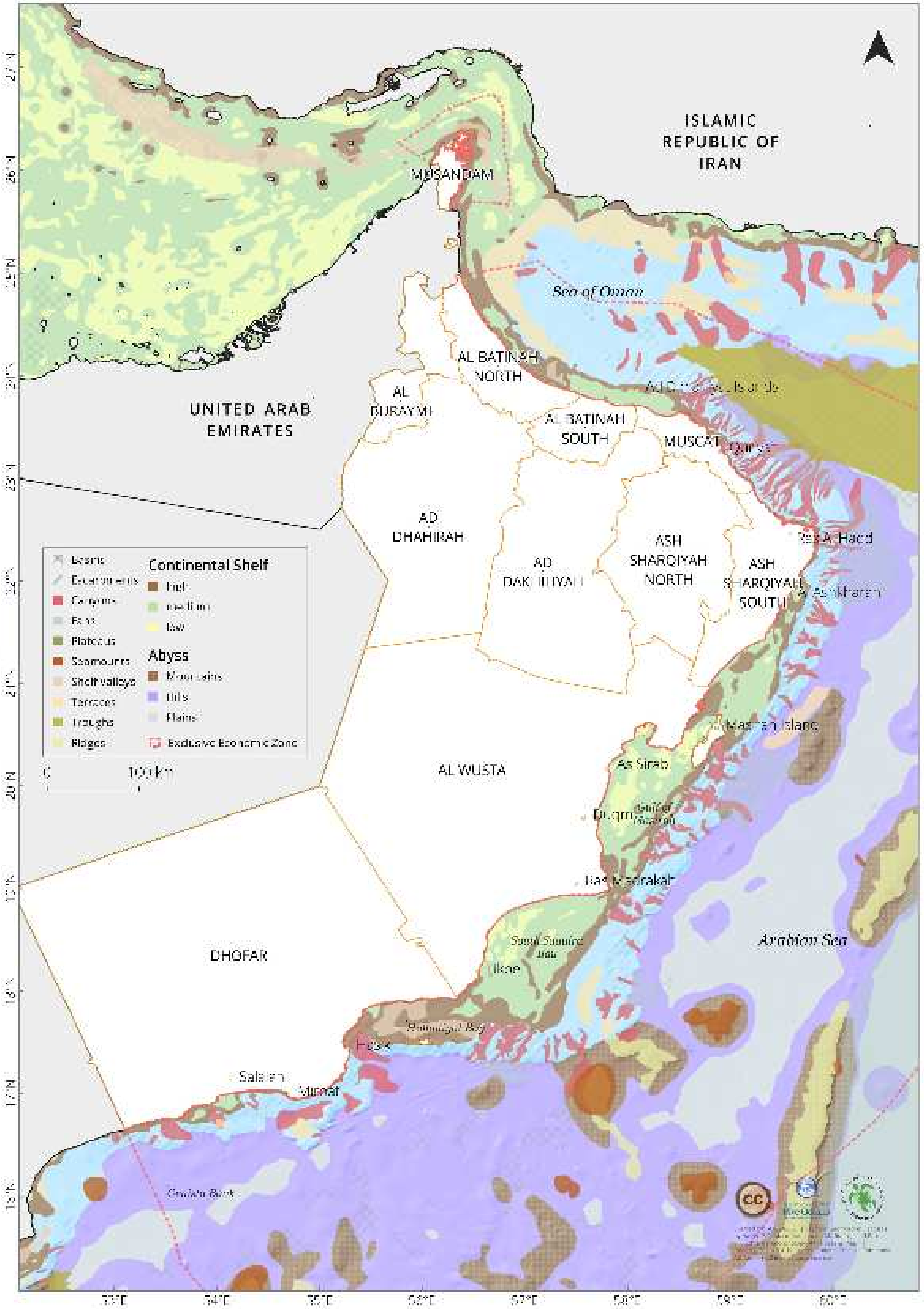
CONTINENTAL SHELF

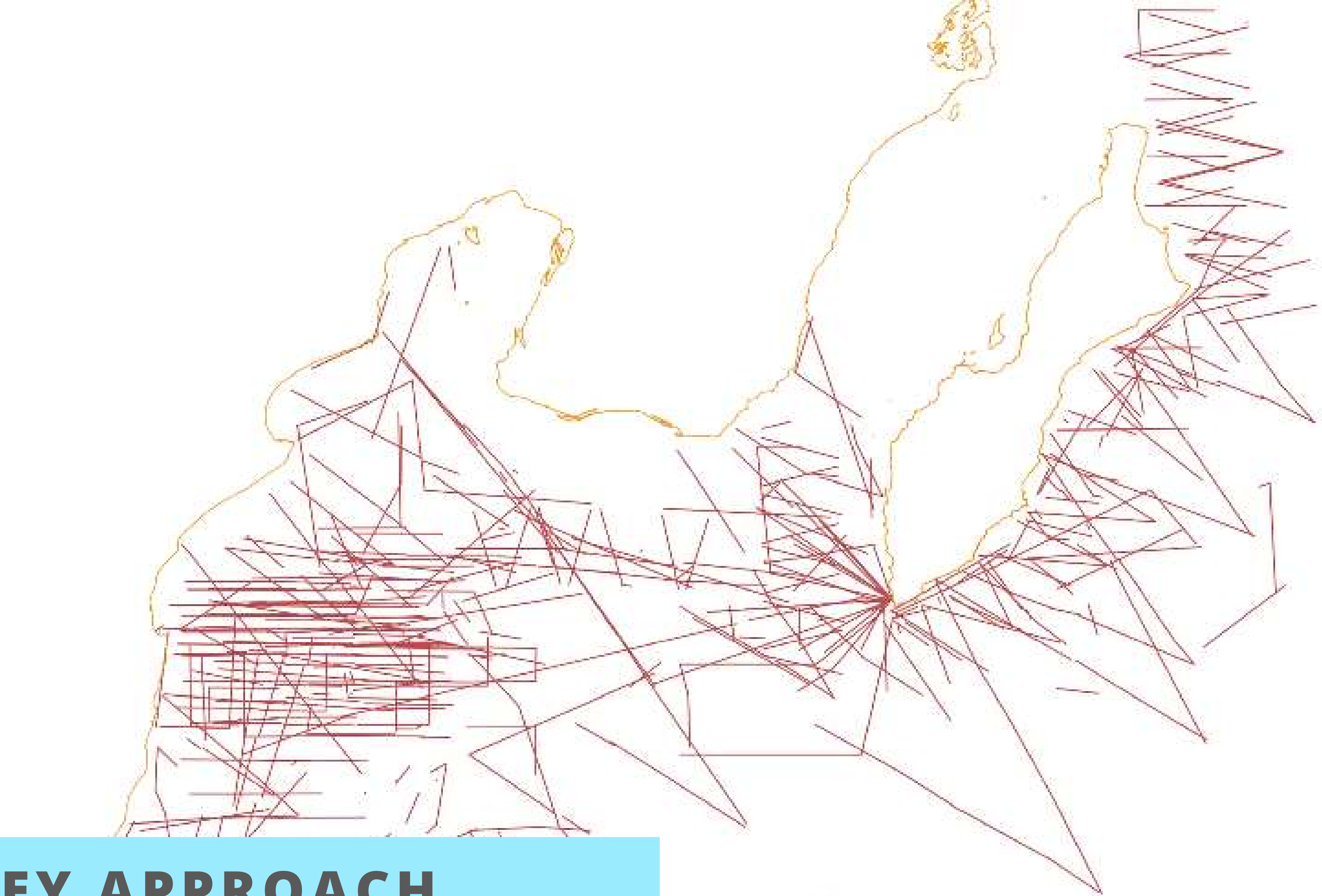
The zone adjacent to the continents or islands, sub-classified into areas of low (<10m), medium (10-50m) and high (>50m) vertical relief.

ABYSS

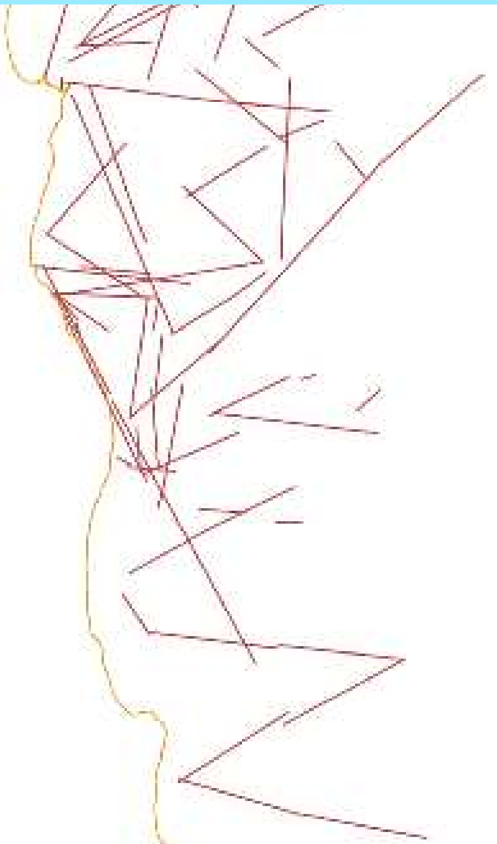
Areas below the foot of the continental rise, sub-classified into plains (<300m relief), abyssal hills (300-1000m relief) and abyssal mountains (>1000m relief).

SEAFLOOR GEOMORPHOLOGY





SURVEY APPROACH & METHODS

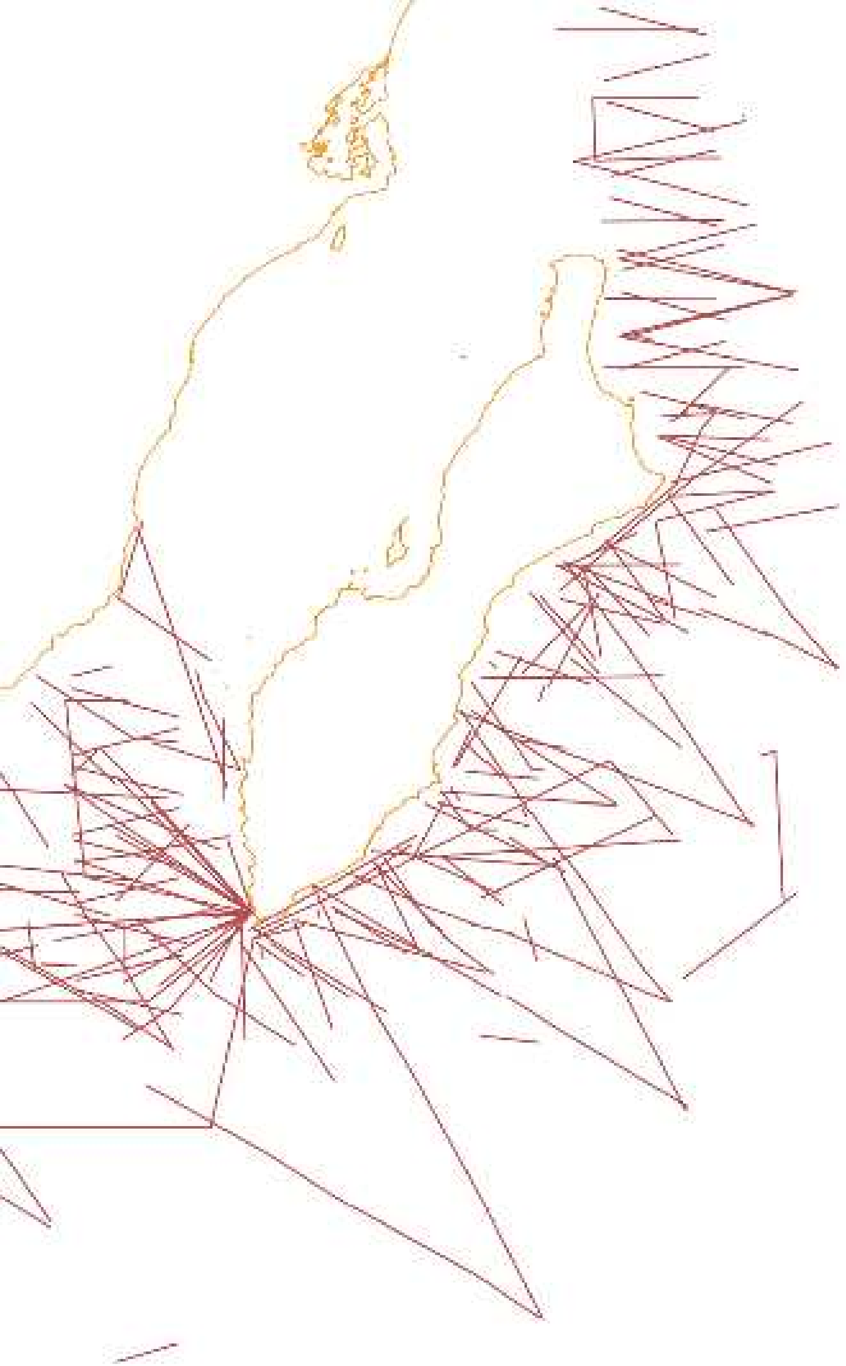


EVOLUTION OF SCIENTIFIC SURVEYS OF MARINE MAMMALS IN OMAN

THE CENTRAL DATA ARCHIVING PLATFORM for marine mammal records in the Sultanate is the Oman Cetacean Database (OMCD). Although the earliest record dates from 1961, the database was originally created in 1987 during the Oman Coastal Zone Management Project (CZMP) which was undertaken between 1986 and 1991 by IUCN under the auspices of the former Ministry of Commerce and Industry and subsequently the former Ministry of Environment. The database was designed to hold records of stranded and live sightings of cetaceans, which represent a collation of historical data from whaling records, opportunistic records made during the IUCN CZMP field surveys and incidental records from third parties. Over the years, the database has changed hands and form and is now hosted by the Environment Society of Oman (ESO) and continues to be updated on an online web-based platform called 'Flukebook'. This platform achieves discrete field records and photo data. A separate database specifically for strandings records was more recently established by the National Strandings Committee at the former Ministry of Environment and Climate Affairs (now the Environment Authority) and includes those strandings records that are curated in the OMCD. None of these strandings records are included in this version of the Atlas.

Although opportunistic surveys for cetaceans were conducted during the period between 1986 to 2000, resulting in documentation of species absence/presence as well as seasonal and spatial distribution, dedicated scientific surveys were only initiated in 2000. The basic survey approach and the methods employed are still used today, and are based on recognised scientific protocols and methods [22]. The objectives are driven by science, but often governed by conservation priorities, seasonal constraints imposed by weather conditions, funding opportunities and the capacity of the research team.

The research initiated in 2000, permitted by the Government of Oman, has benefited from a growing network of international partnerships including those with academic research institutions, NGOs and government bodies, as well as independent cetacean scientists. This has facilitated in-country training, supply of specialist equipment, data and sample processing and analysis, co-funding, and regular publication of results in peer-reviewed scientific journals. This support and collaboration has enabled an incremental development of scientific research capability in Oman that is reflected by the increase in research objectives and outputs over the years.



SURVEY APPROACH & METHODS

SURVEY DESIGN CONSTRAINTS

DEDICATED MARINE MAMMAL SURVEYS conducted since 2000 have predominantly been driven by objectives to study the Arabian Sea Humpback Whale, with other species forming the focus of periodic scientific attention (such as Spinner Dolphins, Bottlenose Dolphins and Indo-Pacific Common Dolphins) or benefitting from incidental study during Arabian Sea Humpback Whale research surveys. As is reflected in the survey effort data, historical records of Arabian Sea Humpback Whales guided early surveys to specific areas within the Arabian Sea, particularly the Gulf of Masirah and Hallaniyat Bay, and these areas continue to be focal areas for the study of this species in Oman today. In these areas, surveys are seasonally constrained by the Southwest Monsoon between May and September which generates sea-states that are not favourable for conducting the small vessel-based surveys that have been the main platform for research.

Cost limitations and the requirements of close encounter survey work with whales (for example to fulfil biopsy and satellite tagging objectives) has made small (6.5m) rigid hull inflatable boats the vessels of choice in Oman to date. Their light weight and seakeeping characteristics also make them the most suitable platform for deployment at remote locations along the coastline. However, among other limitations, their range is limited to survey locations relatively close to shore-based anchorages - a feature that limits survey capabilities largely to coastal waters. Cost constraints have also limited the number and duration of surveys conducted over the years. Vessel based surveys in Oman typically take place over one to four weeks and are seasonal (targeting November and March to coincide with Arabian Sea Humpback Whale activity in the Gulf of Masirah and Dhofar, respectively). Exceptions to these regular seasonal surveys include surveys conducted in Muscat, which may occur at any time of year.

The constraints imposed by seasonality, resource availability and vessel use have been addressed by employment of novel techniques for studying cetaceans in Oman. For example, deployment of moored passive acoustic monitoring arrays, which began in 2011 in the Gulf of Masirah and Hallaniyat Bay, have allowed for continuous year-round monitoring of whale song in these areas. The instrumentation of Arabian Sea Humpback Whales with satellite tags (from 2014 to 2017 inclusive) additionally presented the opportunity to understand the locations of whales (as well as other information, such as dive profiles) continuously for up to several months at a time, including in areas beyond the range of small vessel surveys.

SUMMARY OF MARINE BASED ACTIVITIES

1986-1999

- Dedicated focus on Arabian Sea Humpback Whales including analysis of historical records confirming key locations in Gulf of Masirah and Hallaniyat Bay
- Establishment of Oman Cetacean Database (OMCD); Opportunistic surveys focused on presence/absence of species and spatial/seasonal occurrence
- Early documentation of species list for Oman including 19 of the 20 species now known to occur

Shore based cliff-top observation surveys

Development of sightings records (including whale characteristics and behavior).

Development of an Arabian Sea Humpback Whale photo-database.

2000-2004

- Use of photos to evaluate health and impacts to whales, including ship strike, entanglement and skin disease.
- Understand population identity of Arabian Sea Humpback Whale and other species based on genetic analyses.
- Use of acoustic recording methods to determine spatial and seasonal extent of humpback whale song.

Vessel based line transect surveys

Formal photographic documentation of individuals encountered

Biopsy of whales using crossbow-based tissue sampling techniques.

Use of vessel-based drop-down hydrophones to detect marine mammal vocalisations, specifically humpback whale song.

2005-2008

- Dedicated study of Spinner Dolphin ecology and behaviour, including investigation of threats from emerging whale and dolphin watching tourism industry in the Muscat area

2011

- Investigation of the seasonal presence and distribution of Arabian Sea Humpback Whales engaged in song.

Use and deployment of shallow moored passive acoustic monitoring equipment.

objectives driving design of field surveys

milestones for methods developed

SUMMARY OF MARINE BASED ACTIVITIES

2012-2014

Detailed study of Bottlenose and Common Dolphins in Oman, with a focus on genetic analysis to evaluate the comparative biogeography the evolution of population structure in Oman and the wider region

Biopsy of small cetaceans using crossbow-based sampling techniques.

2014-2017

Study of the broadscale, localised and year-round horizontal and vertical movements of Arabian Sea Humpback Whales, using advanced satellite tracking techniques

Instrumentation of Arabian Sea Humpback Whales with satellite tracking tags.

2017-2020

Development and use of Key Ecological Attributes to evaluate and project the long-term health and status of Arabian Sea Humpback Whales

Understanding the dietary health of whales through investigating body condition (length/width ratios).

Understanding of population identity from humpback whale song.

Initial description of the song of Northern Indian Ocean Blue Whales

Initiation of behavioural observations and genetic sampling of Northern Indian Ocean Blue Whales in Dhofar

Development of ecological niche models for Arabian Sea Humpback Whales to project the distribution of the population across the North Indian Ocean

Use of unmanned aerial systems (drones) to provide and measurement of whales through use of photogrammetry techniques.

2020

Initial description of the song of Northern Indian Ocean Blue whales

Evaluating the risk of ship strike to Arabian Sea Humpback Whales from satellite telemetry and ship tracking data sources

Deployment of deep moored passive acoustic monitoring arrays in the Hallaniyat Bay and the Gulf of Masirah

objectives driving design of field surveys milestones for methods developed

SURVEY METHODS

PART ONE

INTRODUCTION

THE RESULTS OF SURVEYS PRESENTED IN THIS ATLAS have been obtained through use of field survey methods that are based on well-established, standardized, scientific methodologies and protocols [22]. The surveys include use of data record sheets which enable recording of observer activity ('effort'), details of individual sighting events, acoustic recordings, photographs, biopsies and more. In 2017, data recording transitioned from the use of hard copy record sheets to use of a customised digital app.

SHORE-BASED SURVEYS

Shore-based surveys are usually performed when circumstances are unsuitable for conducting vessel surveys or as additional support to vessel-based surveys. Survey locations are strategically planned to provide maximum vantage points, such as on coastal cliff top locations. During surveys, observers search using binoculars, recording the bearing and estimated distance to sightings whilst maintaining, and recording, consistent observation effort. Cameras with telephoto lenses in excess of 200mm are used to document sightings and confirm species identification. When within range, the behavior of the animal under observation can also be confirmed and documented. VHF radio communication allows shore-based observers to contact vessel-based observers, and vice versa, where appropriate.

SURVEY METHODS: PART TWO – VESSEL-BASED

SURVEY TRANSECTS

Survey transects at sea in Oman are typically confined to < 50nm from shore (equivalent to an approximate two hour journey time) or < 3,000m depth, due to constraints associated with small survey vessels [23]. Surveys are mostly conducted from a 6.5m RIB, crewed by a team of 2-5 observers and are conducted at speeds of between 12 and 15knots [24]. Transects follow pre-planned track lines that form an irregular sawtooth pattern with a minimum of 30 degrees internal angle between neighbouring transects. Survey activities are logged to the minute and track data are recorded by handheld GPS units. Survey effort is assigned to one of three categories as shown on the right.

1 | ON-EFFORT	Surveys conducted at speeds of 12-15 knots and sea-state < Beaufort force 4.
2 | SUB-OPTIMAL EFFORT	Surveys conducted with full observer attention but at elevated speeds or sea-state > Beaufort force 4.
3 | OFF-EFFORT	Surveys conducted without following necessary survey protocols

SIGHTINGS

As a minimum, for each sighting a record is made of the species identification, location, group size, behaviour and date/time of encounter with details of each record based on a consensus of classifications and categories [25,26,27,28,29,30]. Species identification is reported where sufficient distinguishing features are observed to allow confirmation, and if not, is noted to the closest taxonomic level. Confirmation is often supported with photographs. Typically, when a sighting is made the survey vessel will leave the current transect to investigate the sighting more closely. This enables documentation of behaviour and group characteristics (such as size of pod, size of animals, presence of juveniles and calves, etc.).

Close encounter work may also facilitate additional collection of information at the individual level (see below). Where more than one observation platform (vessel or shore-based station) is active in the same area, the observer platform responsible for the initial sighting is referred to as the 'primary' platform, and only this record is used in subsequent data analyses (such as effort-corrected density assessments).

INDIVIDUAL OBSERVATIONS

Detailed investigation of individuals encountered during surveys provides information on specific features of animals within a group (such as size and behavioural characteristics). Such close encounters also enable collection of additional information such as photographic records and tissue samples (described below). The records are often supported by annotated drawings of individual features to aid post-survey processing of data.

SURVEY METHODS: PART THREE – VESSEL-BASED

PHOTOGRAPHIC RECORDS

Photographic records are used to confirm and assist with taxonomic identification of animals as well as providing spatial and temporal markers of individual occurrence based on unique external features (known as 'photo-identification'). The most appropriate photographs for this purpose include left and right sides of the dorsal fin of each individual and, especially in some species (such as the Humpback Whale), the ventral (underside) surface of tail flukes [31]. During data processing, the most useful photos are selected and imported into a photo database with cross reference to the encounter and occurrence information. Photographs from reliable third-party sources are accepted for the database where they are supported by date/time and location data. When sufficient photographic records are acquired over the course of time, they can be used for population abundance estimation through use of mark-recapture assessment techniques, as has been achieved for the Arabian Sea Humpback Whale in Oman [32]. Photo archiving and management is supported by the 'Flukebook' web-based platform that allows for manual and automated methods of matching tail flukes. This work is undertaken by work personnel trained in photo identification techniques. Photographs are also used to evaluate the incidence of skin disease and interaction with vessels and fishing equipment for Arabian Sea Humpback Whales. Full details of the method can be found in Minton et al. 2020 [32].

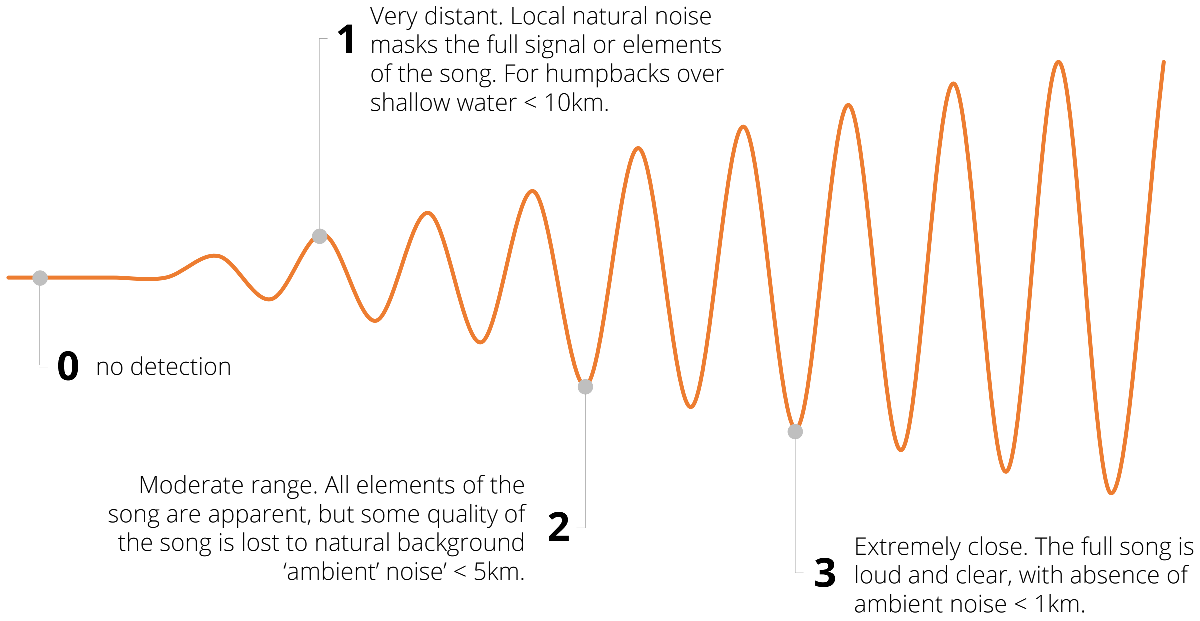
TISSUE SAMPLES

In Oman, tissue samples are primarily collected for genetic analysis, though have occasionally also been collected for pollutant assays. Genetic analyses to date have included study of DNA to investigate the sex of encountered animals, as well as more detailed questions related to population identity and structure. The DNA sequence also has value as an independent identification marker of individuals (to support mark-recapture population assessments). Tissue samples are obtained by one of two methods; **i)** *opportunistic collection* of sloughed skin from 'dive wells' (areas of disturbed water created as an individual dives beneath the surface) or following a breach [33] or **ii)** *active sampling* from the survey vessel using a crossbow with modified biopsy darts [34]. For Arabian Sea Humpback Whales, individuals are sampled once during every survey regardless of whether they have been sampled during previous surveys. Surveys conducted between 2001 and 2006 used salt saturated water with 20% dimethyl sulfoxide [35] as the preservative. Thereafter, samples have been stored in 80% water-buffered ethanol solution and archived in freezer storage units.

ACOUSTIC RECORDS

Omni-directional hydrophones lowered by hand from survey vessels have been used in Oman since October 2001. Hydrophones enable detection of whale and dolphin vocalisations and, where visual observations are absent, as an alert to observers that animals are present in the area. Typically, the hydrophones are deployed at predetermined acoustic stations during research surveys. These stations are strategically placed at approximately 5km intervals along vessel transect lines as well as at the beginning and end of transect lines. The hydrophone element is extended to a depth of approximately 10m below the water's surface for 5-10 minutes, and data is obtained by an operator on the surface using a headset and digital recording unit.

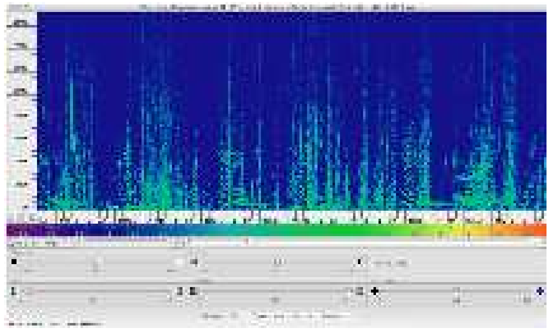
The results of acoustic recordings at each station are assigned a proximity scale according to the amplitude or signal-to-noise ratio of the detection. This is usually most relevant to Arabian Sea Humpback Whales, which are measured according to proximity on a scale of 0-3 (the detection scale is summarised to the right).



SURVEY METHODS: PART FOUR

MOORED ACOUSTIC ARRAYS

Autonomous archival acoustic recorders have also been used to record whale vocalisations at selected locations in Oman. This provides an alternative data collection platform to vessel-based surveys and can supply continuous and year-round monitoring at key sites of interest. The units consist of a hydrophone, a digital-to-audio converter processing unit (to transfer the signal from the hydrophone to memory cards) and batteries to power the device. This is all contained within a water-tight housing. The units are transported to a selected deployment site by boat and anchored to the seabed. After recovery the acoustic data is transferred to standard computer hard drives where it can be prepared for processing. The processing includes automated and manual screening of acoustic signatures using audiogram software. Arabian Sea Humpback Whale-focused deployments were made in Hallaniyat Bay between 2011 and 2012, as well as in the Gulf of Masirah in 2012 and 2013. Vocalisations of other species, such as the Northern Indian Ocean Blue Whale, have also been recorded. Additional details of the methods and results can be found in Cerchio et al., 2016 [36] and Cerchio et al., 2018 [37].



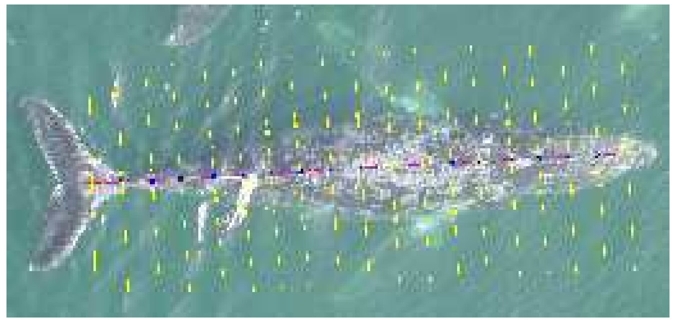
SATELLITE TAGGING

A satellite tagging study of Arabian Sea Humpback Whales was initiated in 2014 to better understand habitat use and distribution of this species owing to its precarious conservation status. The tags include a battery and electronic circuitry that transmits a radio frequency to the Argos satellite network system each time a tagged whale surfaces. The electronics are housed inside a surgical grade stainless steel housing that is carefully attached to a whale by experienced vessel-based tagging crew, following pre-determined protocols that have been subject to intensive scientific study and peer review. Once deployed, the signal from a tagging device may be picked up by one or more overhead satellites, and is relayed to a ground base station where computation is made on the location of the instrumented whale, expressed as latitude and longitude coordinates. Tags naturally detach from whales after a period ranging from a few days to several months. The near-real time information is archived and accessible over a web-based connection. Detailed methods for deployment can be found in Willson et al., 2014 [38]; Wilson et al., 2015 [39]; Wilson et al., 2016 [40] and Willson et al., 2018 [41].

SURVEY METHODS: PART FIVE

UNMANNED AERIAL SYSTEM PHOTO-GRAMMETRY

Use of unmanned aerial systems (UAS), or drones, was introduced as a survey method in Oman in November 2017. Deployed from the deck of a small survey vessel, the drones are typically used for two purposes: **i)** *sampling of whale blow to evaluate the microbiome of the respired condensate,* and **ii)** *taking scale referenced overhead images to obtain whale dimensions* (a process referred to as photogrammetry). Length-width measurements can be used to assess the relative health of individuals through comparison of these metrics with other samples taken from the entire population, and with samples from populations in other parts of the world. Both of these investigations are in their infancy in Oman, although further research is planned. Methods and results of the initial work can be found in Willson et al., 2018 [41].



OVERVIEW OF VESSEL-BASED

SURVEY RESULTS

THE FOLLOWING SECTION FOCUSES ON THE RESULTS OF SURVEYS AND PRESENTS INFORMATION ON SIGHTINGS, AND SIGHTINGS DENSITY IN MAPS FORMAT

The timing, location and vessels used for surveys are among factors that determine the success of detection and collection of data on cetaceans during scientific surveys.

Limitations related to capacity and funding have restricted survey work in Oman such that not all areas have been surveyed, and those which have, may not have been surveyed consistently over time. Where there are 'gaps' in the maps presented here, this does not necessarily mean no species occur in that area. Absence of evidence does not mean evidence of absence!

There is a pressing requirement to continue addressing these knowledge gaps.

VESSEL-BASED

SURVEY EFFORT

AS DESCRIBED IN THE PREVIOUS SECTION survey locations have been targeted as a result of research priorities and constraints. Five main areas of Oman feature in the survey effort data including Muscat, Ras al Hadd, Gulf of Masirah, South Saquira Bay and Dhofar. The results are presented as tables that show a summary of total vessel distance and survey travel time, specifically that conducted 'on-effort'. The data are also represented graphically, with maps of the 'on-effort' vessel track lines and the length of track lines summed into a hexagonal grid cell map representing vessel effort density as a unit of track distance per area (km/km^2).

Total survey time amounts to over 3,000 hours on the water and 32,000km under the keel since 2001. Surveys for Arabian Sea Humpback Whales were not conducted between 2007 and 2009. Dhofar and the Gulf of Masirah have been subject to the most concerted survey effort due to the importance of these areas to Arabian Sea Humpback Whales. Vessel track and density maps reveal that most of the effort in the Dhofar area has been conducted along the western side of the Hallaniyat Bay where encounters with Arabian Sea Humpback Whales were considered to be most likely. To the west of the Dhofar area, survey track lines are closer to the coast and demonstrate a linear 'coastal search' method used to detect coastal species such as the Indian Ocean Humpback Dolphins. The Gulf of Masirah is the area with the broadest survey coverage and most consistent survey effort across years. Survey effort in this area is distributed between Al Ashkharah in the north and Ras Madrakah in the South and has been serviced by field campsites in Masirah, Bar al Hikman, Sirab, Duqm, and other areas. In Muscat, surveys were regularly undertaken between 2001 and 2006, primarily targeting Spinner Dolphins, with no consistent surveys since then. In this area the survey effort was distributed between Quriyat and the Ad Dimaniyat Islands.

Very limited survey effort has been applied to the Ras al Hadd and Saquira Bay areas, and dedicated survey effort is largely absent along the Ash Sharqiyah South, Batinah North and Musandam coastlines. As previously described, survey constraints have also limited offshore survey work, and as such, much of the deeper water habitat of Oman's Exclusive Economic Zone is unexplored.

ON EFFORT

	REGION									
	Muscat		Ras Al Hadd		Gulf of Masirah		South Saquira Bay		Dhofar	
Year	*Hours*	*Distance (km)*	*Hours*	*Distance (km)*	*Hours*	*Distance (km)*	*Hours*	*Distance (km)*	*Hours*	*Distance (km)*
2001	11.58	247.38	6.02	99.41	53.32	1021.35			21.00	408.35
2002	27.16	474.83			19.30	341.66	36.15	411.06	57.67	831.91
2003	45.95	723.12							41.67	707.06
2004	2.17	49.85			6.37	157.87			81.17	475.85
2005	71.17	1643.70								
2006	20.52	496.78			37.93	876.47				
2009	3.20	65.04								
2010					17.85	386.24				
2011					20.00	355.90			56.08	974.94
2012					36.20	758.78			80.00	1021.50
2014									42.65	280.31
2015					39.63	554.10				
2017					59.73	958.77				
Total	181.75	3700.70	6.02	99.41	290.33	5411.13	36.15	411.06	380.23	4699.92

SURVEY EFFORT

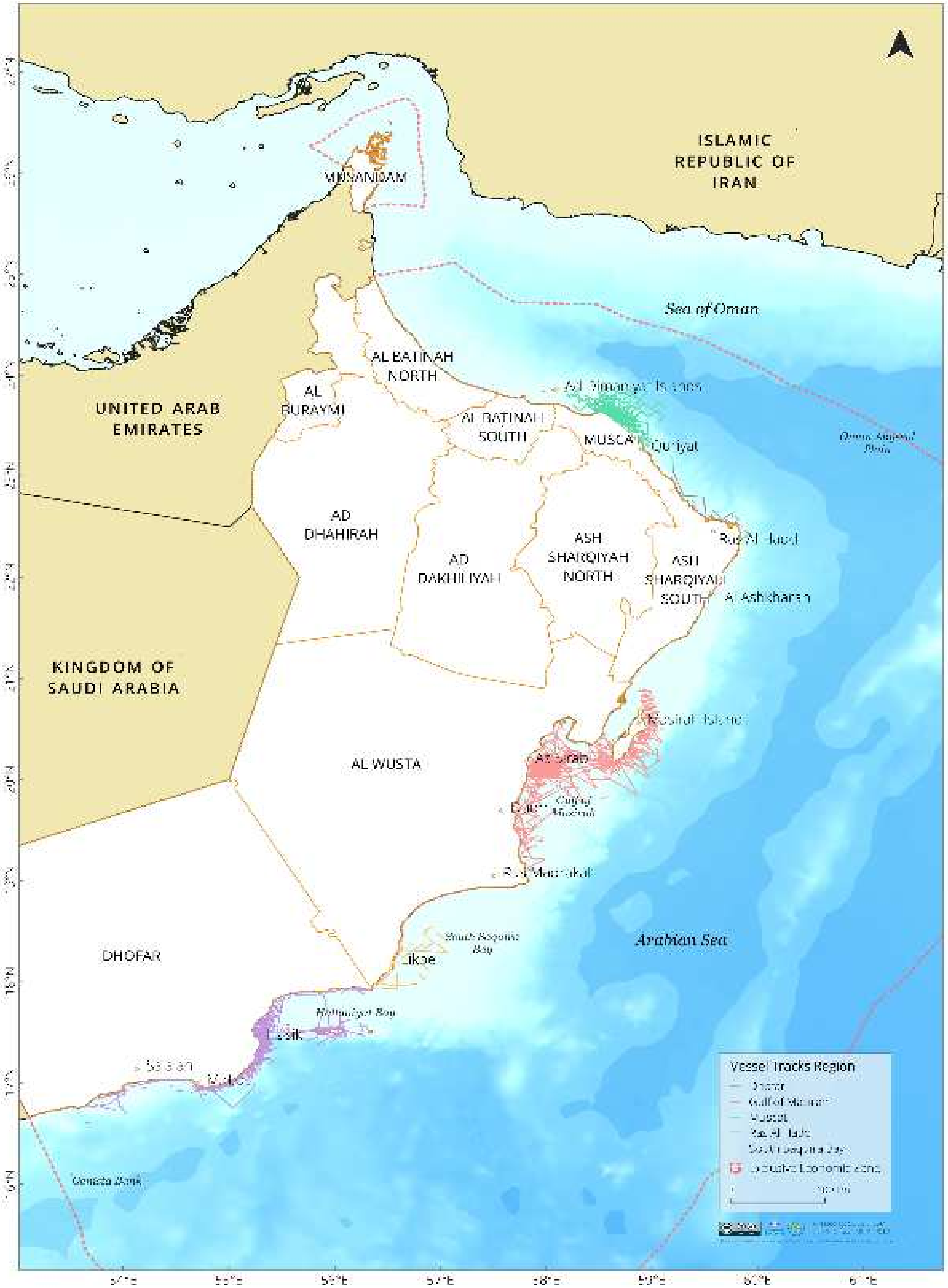
SUMMARY OF SURVEY EFFORT in 5 areas (Muscat, Ras Al Hadd, Gulf of Masirah, South Saquira Bay, and Dhofar) in Oman from 2001 to 2017 based on effort level (On-Effort or All-Effort) expressed in terms of number of hours and distance covered (km). Survey effort since this time is not included in this version of the Atlas.

The following page explores the vessel track and respective survey effort (km/km^2) undertaken since 2001. Results highlight areas in the Muscat region near the Ad Dimaniyat Islands, Masirah Island, the Gulf of Masirah and the coastal area of Mirbat in the Dhofar region to have been relatively well surveyed in comparison with other areas.

ALL EFFORT

	REGION									
	Muscat		Ras Al Hadd		Gulf of Masirah		South Saquira Bay		Dhofar	
Year	*Hours*	*Distance(km)*	*Hours*	*Distance(km)*	*Hours*	*Distance(km)*	*Hours*	*Distance(km)*	*Hours*	*Distance(km)*
2001	41.72	277.92	18.48	155.77	153.48	2294.50			69.60	847.86
2002	49.15	608.23			72.35	853.34	65.97	1008.17	155.42	1812.49
2003	67.34	872.98							163.12	1743.70
2004	38.47	542.84			123.22	2288.82			226.53	1077.10
2005	243.00	3489.42								
2006	58.43	969.68			121.27	1843.94				
2010			47.57	819.36	40.07	791.52				
2011					78.82	782.34			268.32	1495.46
2012					103.67	1823.14			309.48	2320.33
2014									153.37	774.01
2015					152.72	1332.39			253.23	8279.20
2017					238.85	2339.04				
Total	498.11	6761.07	66.05	975.12	1084.44	14349.04	65.97	1008.17	1599.06	18350.16

ALL EFFORT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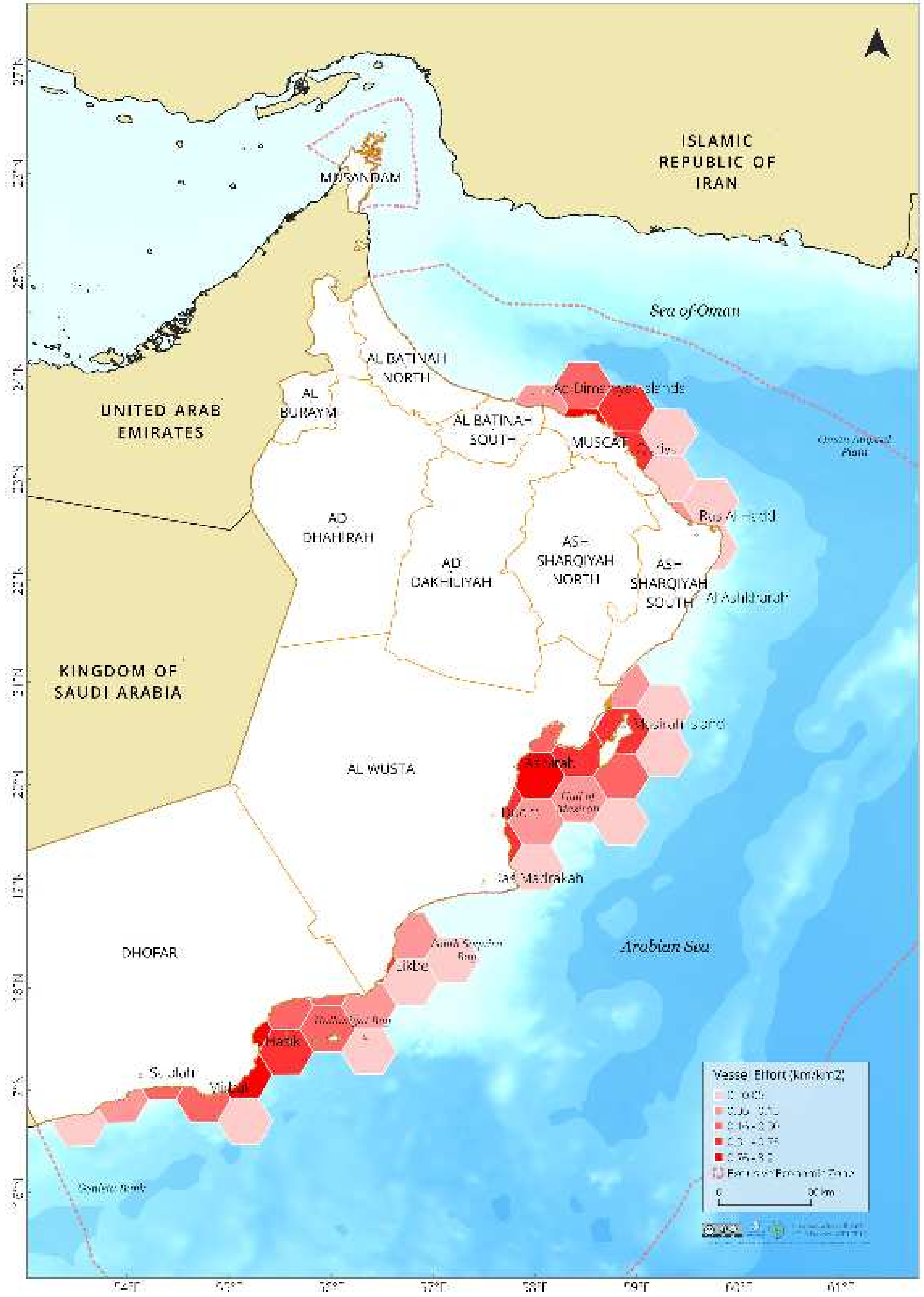
AL WUSTA
Ras Madrakah
DHOFAR
Arabian Sea
Hallaniyat Bay
Vessel Tracks Region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AL WUSTA
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DHOFAR
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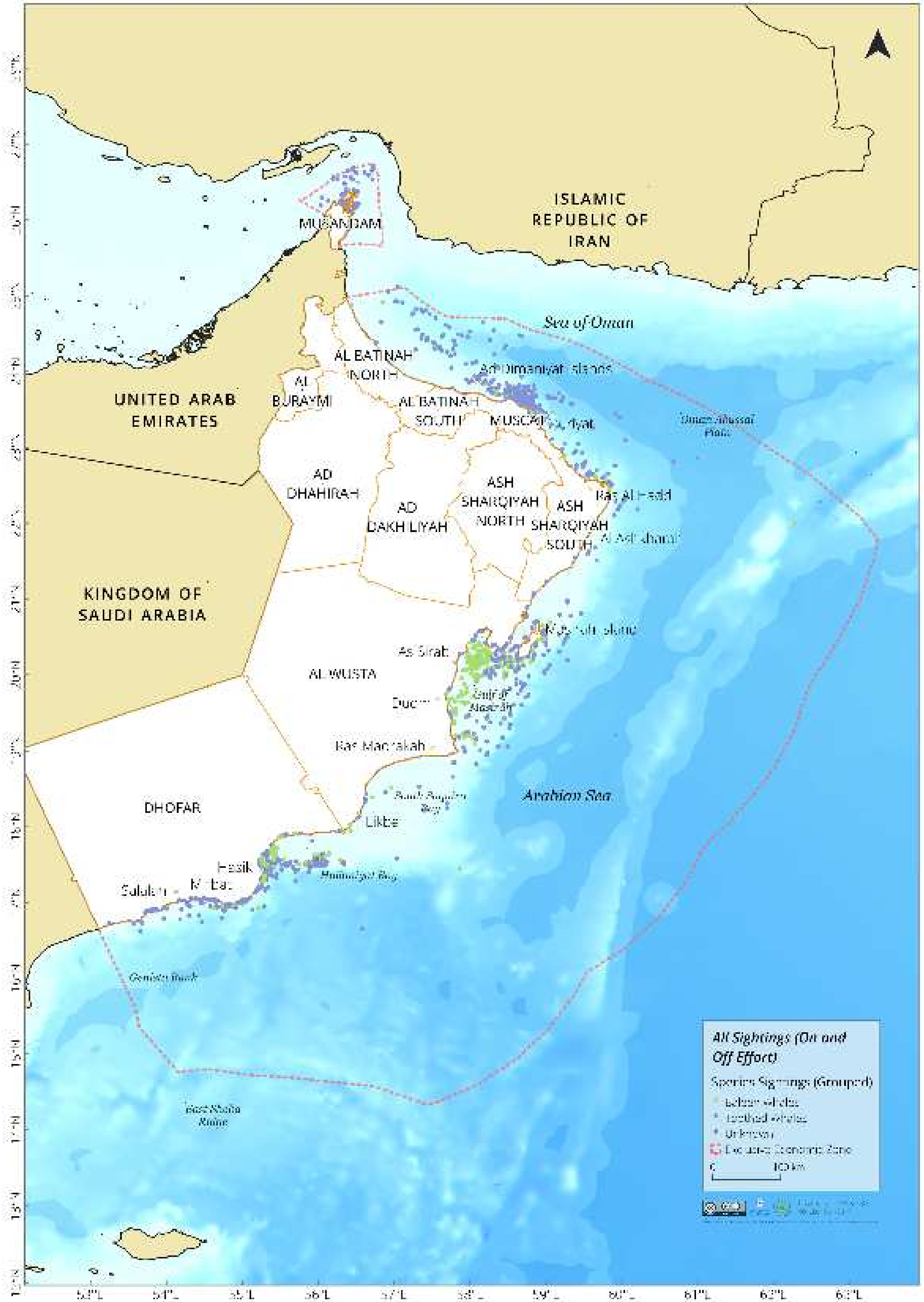
CETACEAN DISTRIBUTION IN OMAN WATERS

ALL SIGHTINGS (including both on-effort and all-effort) recorded from Jan 1961 to Nov 2017 within the EEZ total 1,929. Of these sightings records, 536 (27.8%) are baleen whales (Mysticeti) and 1,387 (71.9%) are toothed whales and dolphins (Odontoceti), whilst 6 (0.31%) were not identified to the level of taxonomic order. A large proportion of odontocete sightings are concentrated in the Muscat region, whereas the mysticete sightings are more evident in the Gulf of Masirah and Dhofar.

Assessing the occurrence of species in relation to survey effort reveals areas with the highest effort-corrected densities in Oman to be near Ras Al Hadd, the Gulf of Masirah, and Al Hallaniyah Island in the Hallaniyat Bay.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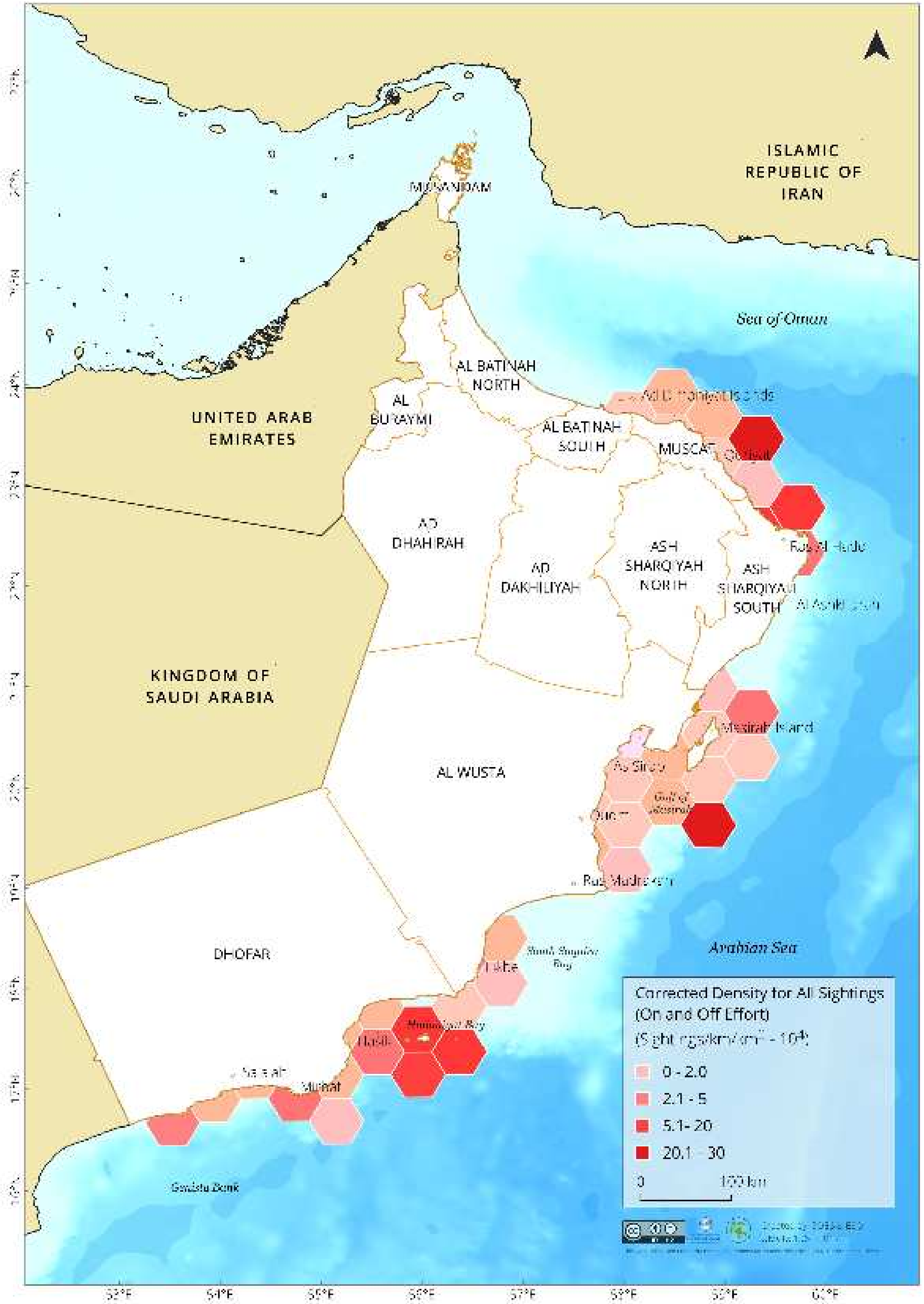
AL BURAYMI
AL BATINAH NORTH
AL BATINAH SOUTH
Ad Dimaniyat Islands
MUSCAT
AD DHAHIRAH
AD DAKHILIYAH
ASH SHARQIYAH NORTH
ASH SHARQIYAH SOUTH
Ras Al Hadd
Al Ashkharah
KINGDOM OF
SAUDI ARABIA
Masirah Island
As Sirab
AL WUSTA
Duqm
Gulf of Masirah
Ras Madrakah
Arabian Sea
DHOFAR
Likbe
Hasik
Mirbat
Salalah
Hallaniyat Bay
All Sightings (On and Off Effort)
Species Sightings (Grouped)
Baleen Whales
Toothed Whales
Unknown
Exclusive Economic Zone
0 100 km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AL BATINAH SOUTH
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AD DAKHILIYAH
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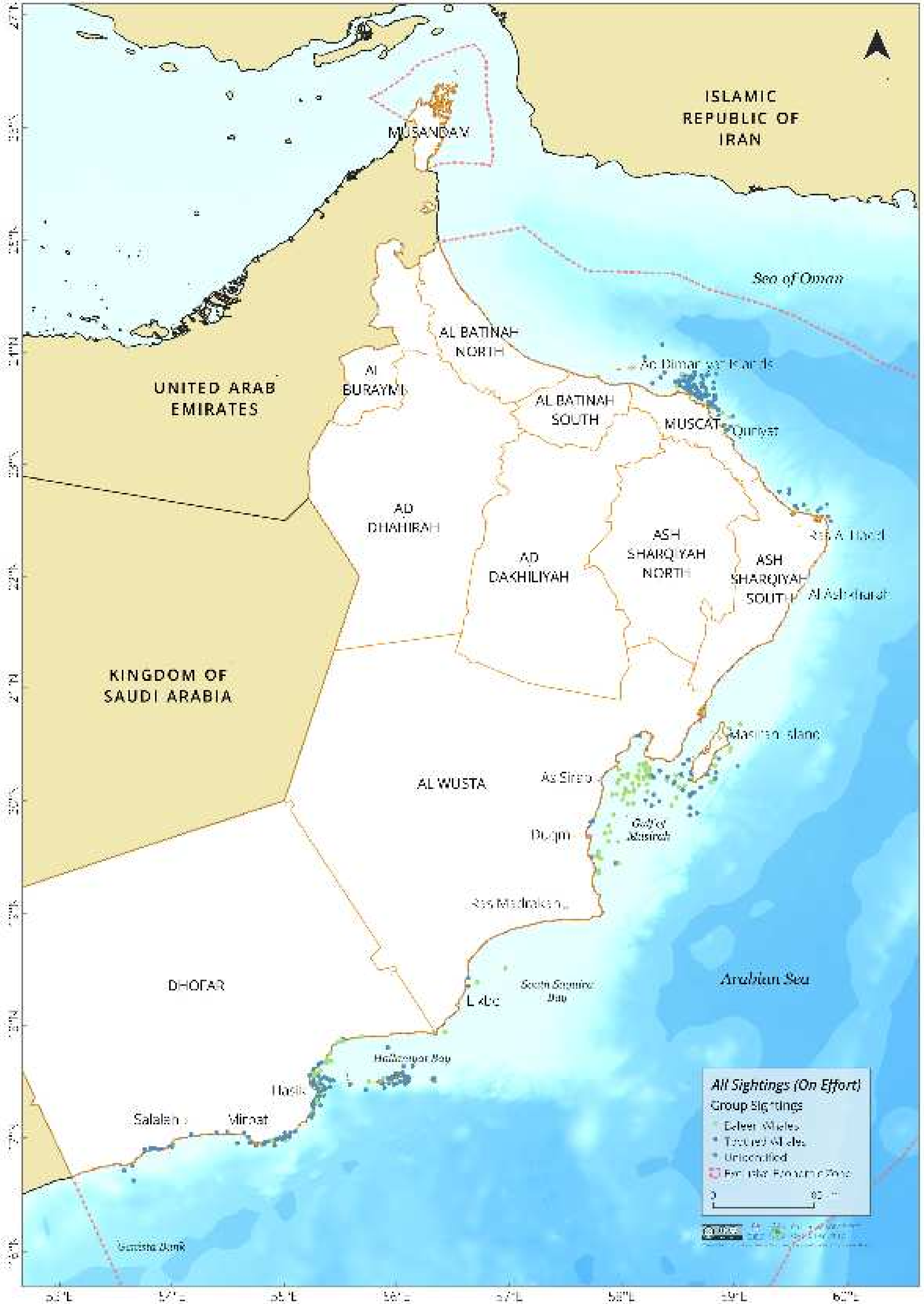
KINGDOM OF
SAUDI ARABIA
Masirah Island
As Sirab
AL WUSTA
Duqm
Ras Madrakah
Arabian Sea
DHOFAR
Likbe
Hasik
Mirbat
Salalah
Hallaniyat Bay
Corrected Density for All Sightings
(On and Off Effort)
0 - 2.0
2.1 - 5
5.1- 20
20.1 - 30
0 100 km

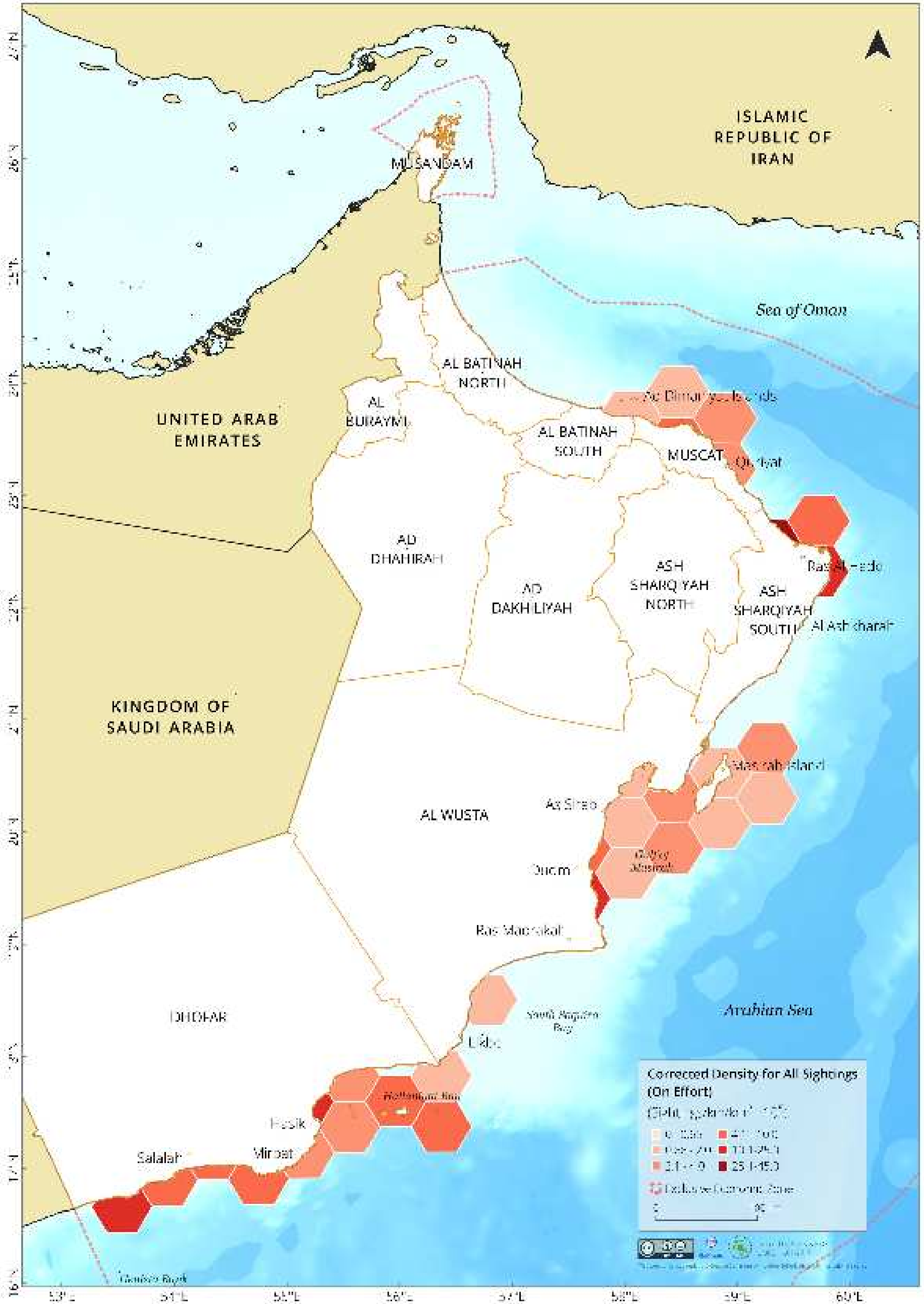
ON EFFORT

ON EFFORT MARINE MAMMAL SIGHTINGS WITH OPTIMAL OBSERVATION CONDITIONS, total 594 records between January 1996 and March 2017 within the Oman EEZ. Sightings since this time are not included in this version of the Atlas. A large proportion of reported sightings are of odontocetes (n=423, 71.2%), compared to 166 (27.9%) mysticetes, and 5 (0.84%) that were not recorded to the level of taxonomic order. The distribution of records follows a similar pattern to all-effort sightings where the majority are odontocetes in the Muscat region whilst mysticete sightings are concentrated in the Gulf of Masirah.

Assessment of the effort-corrected density of on-effort sightings reveals that waters off Ras Al Hadd, Duqm, Al Hallaniyah, and Salalah are areas of high concentration for all species recorded. Note that no on-effort surveys were conducted around Musandam

SIGHTINGS


ISLAMIC REPUBLIC OF IRAN
MUSANDAM
Sea of Oman
UNITED ARAB EMIRATES
AL BURAYMI
AL BATINAH NORTH
AL BATINAH SOUTH
MUSCAT
Quriyat
AD DHAHIRAH
AD DAKHILIYAH
ASH SHARQIYAH NORTH
ASH SHARQIYAH SOUTH
Al Ashkharah
KINGDOM OF SAUDI ARABIA
AL WUSTA
As Sirab
Duqm
Gulf of Masirah
DHOFAR
Arabian Sea
Hallaniyat Bay
Hasik
Salalah
Mirbat
All Sightings (On Effort)
Group Sightings
Unidentified


ISLAMIC REPUBLIC OF IRAN
MUSANDAM
Sea of Oman
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AL BURAYMI
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MUSCAT
AD DHAHIRAH
AD DAKHILIYAH
ASH SHARQIYAH NORTH
ASH SHARQIYAH SOUTH
Al Ashkharah
KINGDOM OF SAUDI ARABIA
AL WUSTA
As Sirab
Duqm
Ras Madrakah
DHOFAR
Arabian Sea
Hasik
Salalah
Mirbat
Corrected Density for All Sightings (On Effort)

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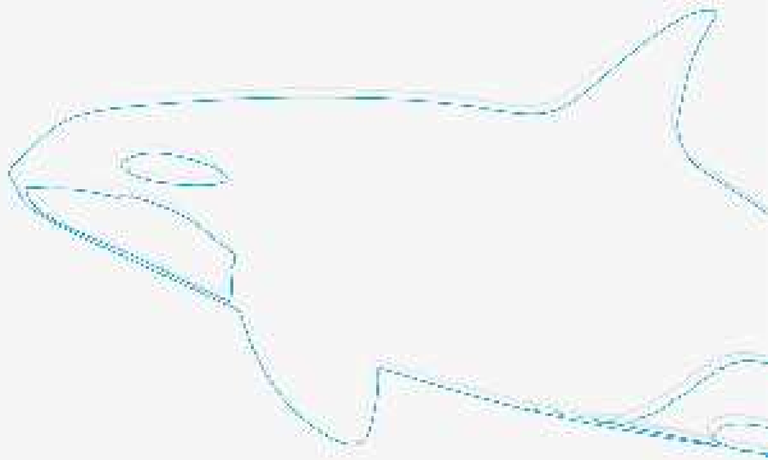

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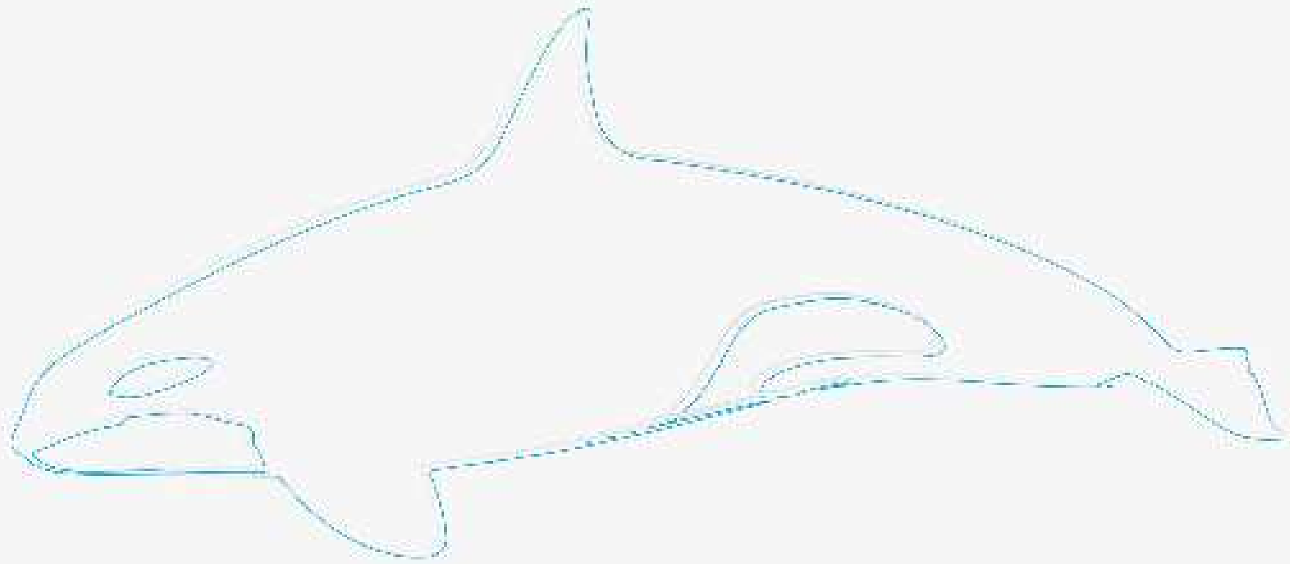


SPECIES

1

ACCOUNTS

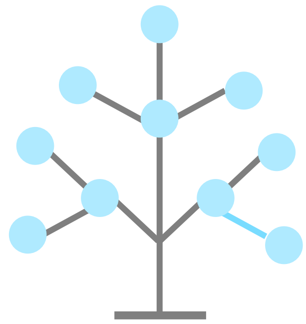
INTRODUCTION

CHAPTER 1 of the Atlas is a comprehensive review of the 20 species of marine mammals confirmed to occur in the waters of Oman, knowledge of which has been developed over many decades. This includes over 20 years of dedicated cetacean research undertaken since 2000 by an international collaboration of researchers, led in Oman by experts from Five Oceans Environmental Services LLC, under the administration of the Environment Society of Oman, and permitted by the former Ministry of Environment and Climate Affairs (now the Environment Authority).

The order in which the species are presented accords to phylogenetic groupings after Mcgowen et al. [1] whilst nomenclature follows that provided by The Society for Marine Mammalogy [2]. As an aid to visual differentiation, a unique colour has been assigned to each species which is used consistently throughout the Atlas (see Species Account Key). For each species, a description of the taxonomy, distribution, habitat preferences, feeding and breeding status, seasonality, sightings history, population status, conservation status, and group estimates are provided. When estimating numbers of animals in the field, the convention is to estimate a maximum, a minimum and a 'best guess' number. This serves to both enhance the accuracy of the estimate in the field by making the observer consider all three parameters, as well as to provide a range of figures useful in subsequent data analysis. Two detailed maps are also presented for each species; one showing all reported records and another showing sighting densities corrected for survey 'effort' (i.e. dedicated survey periods). Not all areas have been surveyed and some have been subjected to greater survey effort than others, potentially biasing our impression of cetacean distribution.

The effort-corrected distribution maps account for such bias and can therefore serve as a helpful indicator of the most likely distribution of species. Information on the spatial distribution of some species, however, is still lacking. We hope these gaps in the distribution of species, as well as other knowledge gaps, will be filled by further research that continues to improve our understanding of the marine mammals of Oman and leads to more complete future iterations of this Atlas.

Among the current data gaps is information on population status for all but one species. This one exception is the Arabian Sea Humpback Whale which has been the focus of more dedicated research effort than other species to date. The Arabian Sea Humpback Whale population in Oman is exceptionally low (less than 100 individuals) and it is officially classified as being at very high risk of extinction (Endangered) on the IUCN Red List of Threatened Species. Like the Arabian Sea Humpback Whale, all species in Oman face many threats at sea, both natural and anthropogenic, and several species are considered to be in urgent need of further research to help determine their status and to inform conservation requirements. For some species, some of the threats have been documented in Oman, whilst other threats are less well known or remain undetermined. To view the associated threats with each species, please click on the threats symbol found at top right corner of the species label. Further discussion of threats to marine mammals in Oman, threat mitigation options and the international and national conservation frameworks involved are discussed in Chapters 3, 4 and 5, respectively.

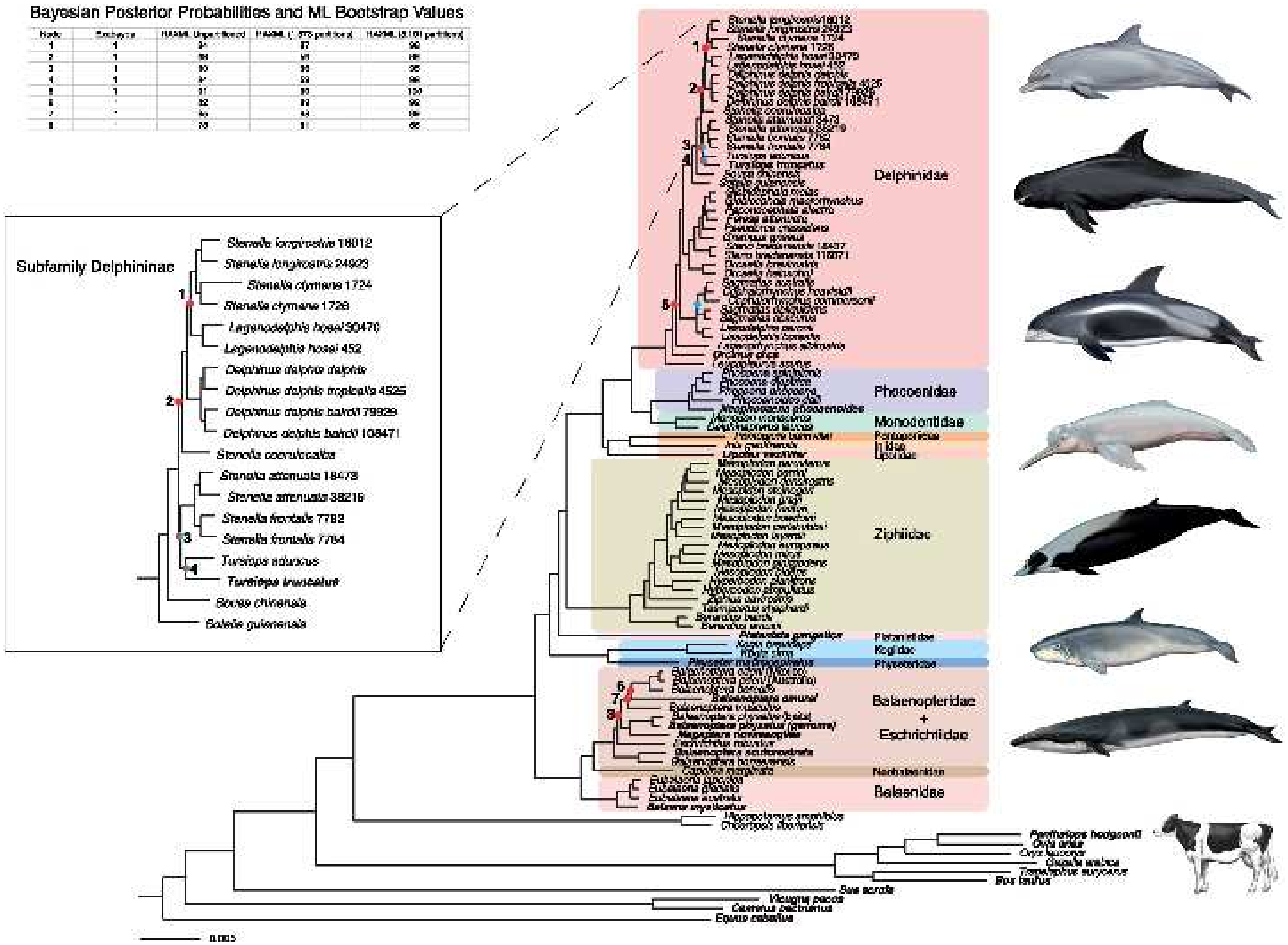


ORDERING AND CLASSIFYING OF THE ATLAS

TAXONOMY | *'theory and practice of identifying, describing and classifying organisms'* [3]

SYSTEMATICS | *'the study of kinds and diversity of organisms and the relationships among them'* [3]

THIS CHAPTER OF THE ATLAS is structured according to an internationally accepted approach towards systematically classifying marine mammals. It covers the infraorder Cetacea, including the whales and dolphins, which are the only marine mammals found in Oman. The cetaceans are broadly divided into two main parvorders; the Mysticeti, which includes all of the baleen whales (which lack teeth) and the Odontoceti (all toothed whales and dolphins). Taxonomy and systematics are evolving scientific disciplines and the methods that inform them are constantly improving. Years ago, taxonomic groupings were predominantly based on the external morphology of animals. Today, they are additionally informed by molecular genetics which use finer scale resolution to help explain population identity and structure within and between species. This enables identification of discrete populations of the same species, and where more significant differences are found, species are divided into sub-species or even entirely new species under a revised taxonomic structure. As genetic studies advance, so the taxonomy of cetaceans may continue to change and it is therefore important to cite the most recent taxonomic assessment of marine mammals when formally referring to species. *The Society for Marine Mammalogy* (Committee on Taxonomy) provides the latest information on the taxonomy of marine mammals worldwide, which is updated at least annually.



PHYLOGENOMIC RESOLUTION OF THE CETACEAN TREE OF LIFE USING TARGET SEQUENCE CAPTURE

Illustrations are by Carl Buell and represent (top to bottom) *Tursiops truncatus* (Common Bottlenose Dolphin), *Feresa attenuata* (Pygmy Killer Whale), *Lagenorhynchus albirostris* (White-beaked Dolphin), *Inia geoffrensis* (Amazon River Dolphin), *Mesoplodon layardii* (Strap-toothed Whale), *Kogia sima* (Dwarf Sperm Whale), *Balaenoptera bonaerensis* (Antarctic Minke Whale), and *Bos taurus* (Domestic Cow) [1].

n=20

SPECIES ACCOUNT KEY

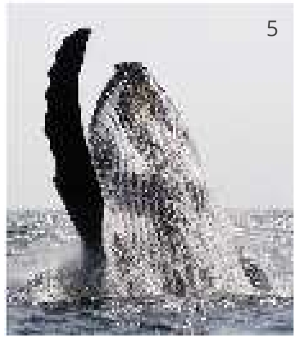
ARABIAN SEA HUMPBACK WHALE 1	NORTHERN INDIAN OCEAN BLUE WHALE 2	BRYDE'S WHALE 3	SPERM WHALE 4	DWARF SPERM WHALE 5
CUVIER'S BEAKED WHALE 6	KILLER WHALE 7	ROUGH-TOOTHED DOLPHIN 8	RISSO'S DOLPHIN 9	FALSE KILLER WHALE 10
MELON-HEADED WHALE 11	PYGMY KILLER WHALE 12	SHORT-FINNED PILOT WHALE 13	INDIAN OCEAN HUMPBACK DOLPHIN 14	COMMON BOTTLENOSE DOLPHIN 15
INDO-PACIFIC BOTTLENOSE DOLPHIN 16	PANTROPICAL SPOTTED DOLPHIN 17	STRIPED DOLPHIN 18	INDO-PACIFIC COMMON DOLPHIN 19	SPINNER DOLPHIN 20

1. *Megaptera novaeangliae* **2**. *Balaenoptera musculus indica* **3**. *Balaenoptera edeni* **4**. *Physeter macrocephalus* **5.** *Kogia sima* **6**. *Ziphius cavirostris* **7**. *Orcinus orcas* **8**. *Steno bredanensis* **9**. *Grampus griseus* **10**. *Pseudorca crassidens* **11**. *Peponocephala electra* **12**. *Feresa attenuata* **13**. *Globicephala macrorhynchus* **14**. *Sousa plumbea* **15**. *Tursiops truncatus* **16**. *Tursiops aduncus* **17.** *Stenella attenuata* **18.** *Stenella coeruleoalba* **19.** *Delphinus delphis tropicalis* **20**. *Stenella longirostris*

HISTORICAL ACCOUNTS AND OTHER SPECIES

The 20 cetaceans listed in this Atlas are the only confirmed marine mammal species that have been recorded in Oman to date*. There are unconfirmed records of additional species, such as Fin Whale (*Balaenoptera physalus*), Sei Whale (*Balaenoptera borealis*) and Common Minke Whale (*Balaenoptera acustorostrata*). In this Atlas, we only include those species where positive identification has been made in consultation with species experts, based on verified photographs, morphological evidence from strandings and/or confirmation from genetic studies. All evidence of previous records, including the species mentioned above, has been thoroughly investigated by experts and only the 20 species listed here are currently confirmed to occur in Oman. Additional species, especially deep water species, such as several of the beaked whales, are however, likely to occur and await discovery.

**Note: There is a confirmed record of a Southern Elephant Seal (Mirounga leonina) in Oman, which was killed by fishermen after it came ashore in Dhofar in 1988 [4]. This species has not been documented in Oman before or since and normally occurs only in the extreme south of the Indian Ocean. How an individual came to be in the region remains a mystery.*



ARABIAN SEA HUMPBACK WHALE

الحوت الأحدب [Al Hoot Al Ahdab]

Megaptera novaeangliae

length : *up to 15.5m*

36 000 KG

GLOBAL | *Least Concern* ***REGIONAL*** | *Endangered*

GROUP SIZE | *Minimum* 1 *Maximum* 6 *Best Estimate: Average* 1.66 *Standard Deviation* 1.58

THE ARABIAN SEA HUMPBACK WHALE of the family Balaenopteridae is not yet officially named. There are currently just three recognised subspecies of humpback whales globally: The North Atlantic Humpback Whale (*M. n. novaeangliae*), the Southern Humpback Whale (*M. n. australis*), and the North Pacific Humpback Whale (*M. n. kuzira*) [5]. The case for a fourth, the Arabian Sea Humpback Whale (*M. n. indica*), is currently being studied based on research in Oman which has already demonstrated that Humpback Whales in the Arabian Sea are geographically, demographically and genetically isolated [6]. Based on the strength of the latter, we nominally use Arabian Sea Humpback Whale in this Atlas.

Globally, the species is present in all five oceans, including in coastal waters, around island groups and archipelagos, and also in open oceanic waters. The general distribution in Oman follows this global pattern and includes all waters of Oman. However, the distribution is centred in the Arabian Sea, where Arabian Sea Humpback Whales exhibit a preference for habitats in the Gulf of Masirah and Dhofar, between which they regularly move according to results of satellite tracking studies [7,8,9].

Uniquely, Arabian Sea Humpback Whales are year-round residents of Oman [10,11,12,13], not undertaking the long-distance migrations of other subspecies between feeding areas at high latitudes and mating/calving areas at low latitudes [5]. This has led to a highly distinct population with photo-identifcation studies resulting in no matches outside of the Arabian Sea region [14], and acoustic studies revealing a highly distinctive song [15]. Estimates of gene flow and divergence times reveal a Southern Hemisphere origin, but indicate isolation in the Arabian Sea region for approximately 70,000 years [6]. This isolation, combined with evidence of a small population size [14] and multiple threats [12,16,17,18] has led to some authors recommending an amendment of the status of the population from Endangered to Critically Endangered on the IUCN Red List of Threatened Species [6].

The Arabian Sea Humpback Whale is a breeding resident of Oman. Whaling records indicate that the mating season is relatively short (January until May) with calving peaking in February/March [11]. Whaling records also reveal the diet to consist primarily of small shoaling fishes, such as chub, mackerel, scad, sardines, and euphausids [11,19]. It has long been speculated that the sustained seasonal upwelling in the Arabian Sea associated with the summer monsoon provides the basis for the food supply to support Arabian Sea Humpback Whales [20,21,22,23]. Humpback Whales are unique within the baleen group in that they exhibit cooperative feeding behaviour [24], which in Oman has been observed to include techniques such as use of 'bubble net' and 'bubble cloud' structures [25].

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of Arabian Sea Humpback Whales in Oman have been recorded throughout the year, except the month of July (Figure 1). Group sightings are more common in the Dhofar and North Al Wusta region. Most sightings are of individuals or pairs, with occasional records of larger groups of up to 5 or 6 individuals (and rare, anecdotal reports of much larger aggregations). Mother-calf pairs have been recorded on occasion, although sightings of calves are very rare. Out of a total of 355 sightings, only 30% were observed during on-effort surveys. Sightings records are strongly clustered in the Gulf of Masirah, and east of Mirbat in the Dhofar region. Sightings records are most numerous in November, followed by March and February, reflecting a temporal distribution that favours cooler months. Effort-corrected sightings records highlight South Saquira Bay, in the western part of the Hallaniyat Bay, as well as the Gulf of Masirah close to Duqm, as hot spots. The global population of Humpback Whales is estimated at ~84,000 and appears to be increasing [5]. However, some isolated populations, such as the Arabian Sea Humpback Whale population, are known to consist of much lower numbers of individuals. Passive acoustic monitoring work has documented the presence of southern hemisphere Humpback Whale song off thte coast of Oman, out of phase with the ASHW breeding season [28].The best estimate for the total population off Oman is 82 individuals (95% CI=60-111) based on photoidentification mark-recapture techniques [14], making the Arabian Sea Humpback Whale among the rarest whales in the world.

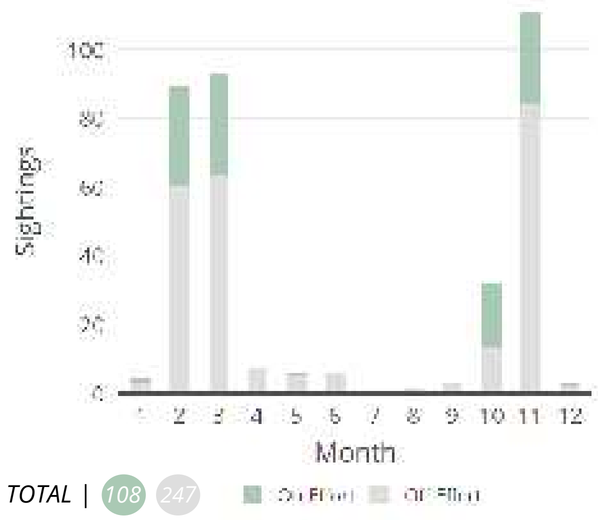
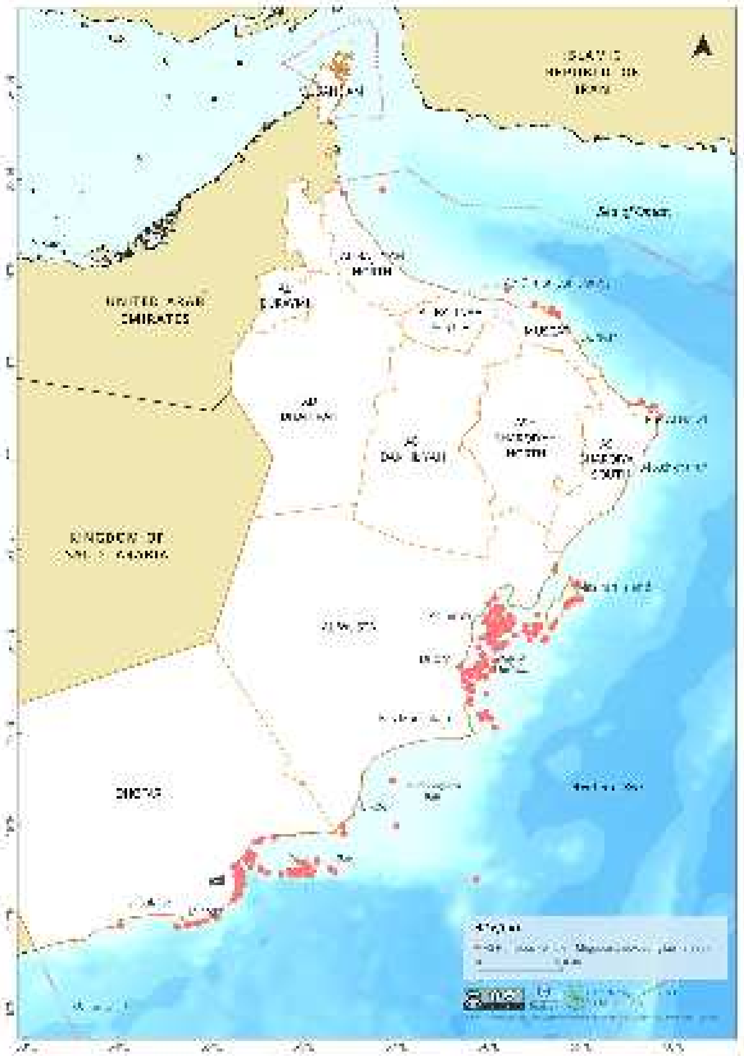
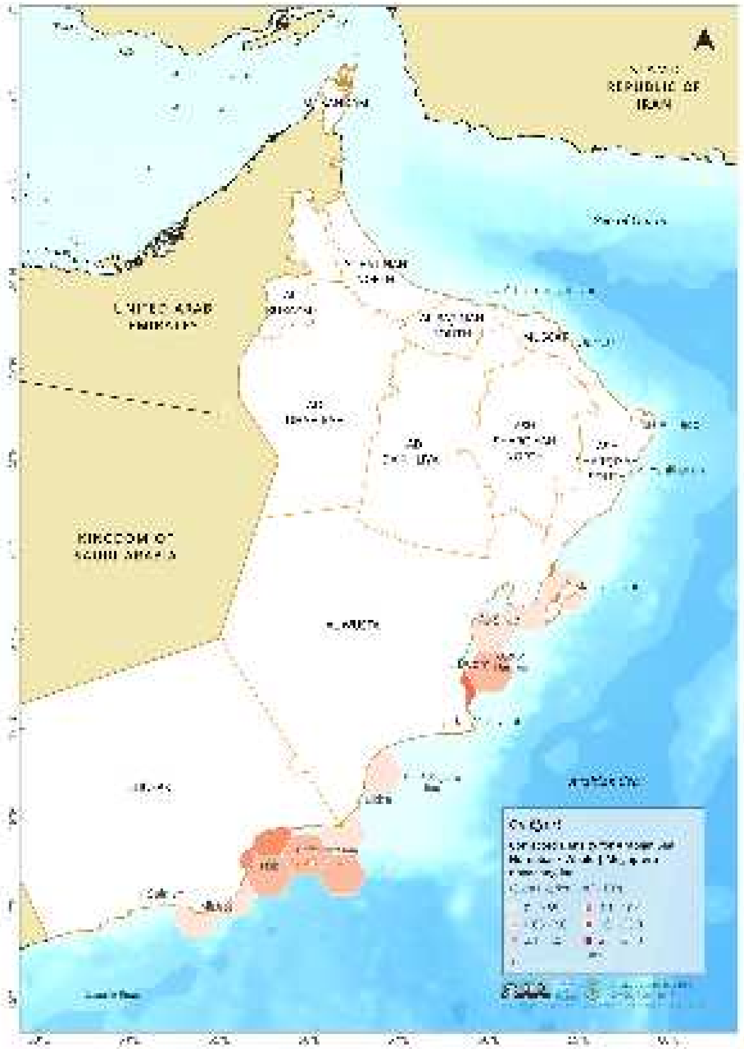


Figure 1) *ASHW (Megaptera novaeangliae) sightings from 1961 to 2017 by month. Sightings are categorized as On Effort (during active watch on surveys), or Off Effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*





NORTHERN INDIAN OCEAN BLUE WHALE

الحوت الأزرق [Al Hoot Al Azraq]

Balaenoptera musculus

length : *up to 24m*

90 000 KG

GLOBAL | Endangered ***REGIONAL*** | Not Evaluated

GROUP SIZE | *Minimum* 1 *Maximum* 3 *Best Estimate: Average* 1.25 *Standard Deviation* 0.68

THE BLUE WHALE, of the family Balaenopteridae, is only rarely encountered in Oman where it is represented by a Northern Indian Ocean subspecies, *Balaenoptera musculus indica* [2,12]. Three other named subspecies of Blue Whale are recognized globally: the Northern Blue Whale (*Balaenoptera musculus musculus*), Antarctic Blue Whale (*B. m. intermedia*), and Pygmy Blue Whale (*B. m. brevicauda*) [2]. The taxonomic distinction of the NIO Blue Whale is currently evidenced by its apparent year-round residence in the NIO [26], its Northern Hemisphere breeding cycle [27] and its song type [28].

Blue Whale populations can be identified through their unique song types. Recent evaluation of passive acoustic monitoring records has revealed song recorded off Oman to be different to that described elsewhere in the Northern Indian Ocean [28]. Further studies are required to distinguish the identity and population characteristics of Blue Whales found in the Indian Ocean. For this reason, we will continue to refer to whales encountered off Oman as 'Northern Indian Ocean Blue Whales' until further taxonomic work is completed.

The centre for distribution of the NIO Blue Whale in Oman is the Arabian Sea, where Soviet whaling fleets caught at least 1,294 individuals between 1964 and 1966 [11]. Data from these catches reveals two potential breeding seasons, with most calves being born in April or October [11]. Prey is dominated by euphausiid crustaceans, but dense swarms of other species may also be targeted: Faecal samples taken from aggregation sites off Sri Lanka have revealed animals feeding on sergestid shrimp [29]. Small shoaling fishes are also consumed in the Arabian Sea [11]. Feeding behaviour of NIO Blue Whales in Oman has been documented in Dhofar between the Hallaniyat Bay and Salalah [30].

Evidence suggests that NIO Blue Whales are present in the Arabian region year round and may be non-migratory [11,12,31], unlike populations elsewhere in the world which make long-distance seasonal movements between high latitude feeding grounds and low latitude winter breeding areas. Soviet whaling in Arabian Seas revealed three areas of aggregation; from the Gulf of Aden to the southern shores of the Arabian Peninsula, at the Maldives and Laccadive islands and at the equator north of the Seychelles [11]. It has been hypothesized that the movements of NIO blue whales around the Northern Indian Ocean may be linked to productivity and prey availability stimulated by the pulsing south west and north east monsoons [27].

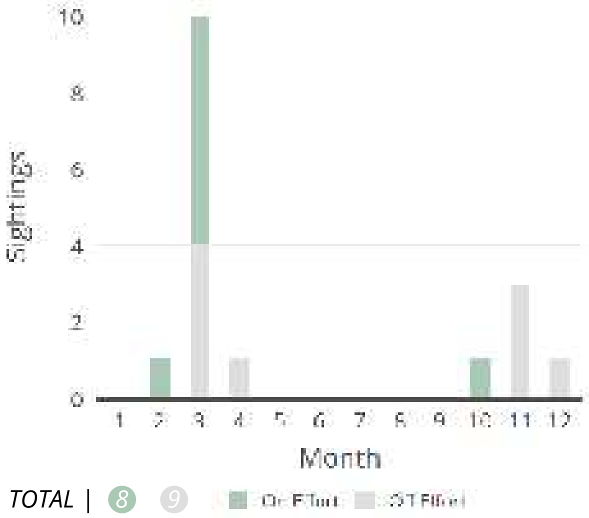
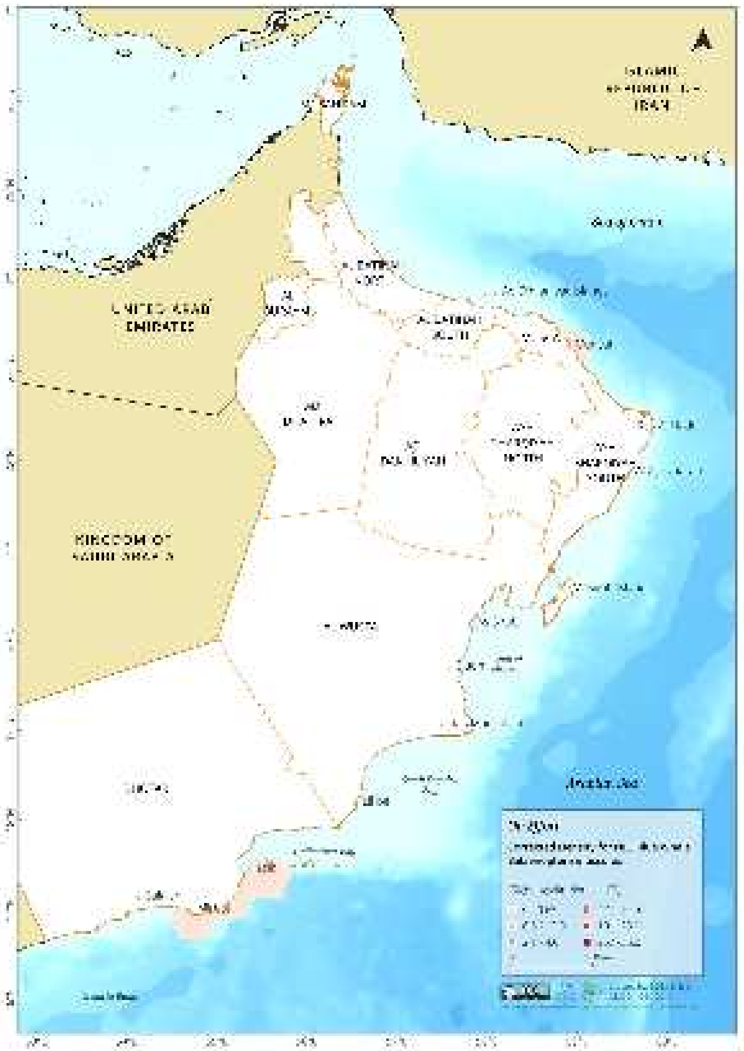
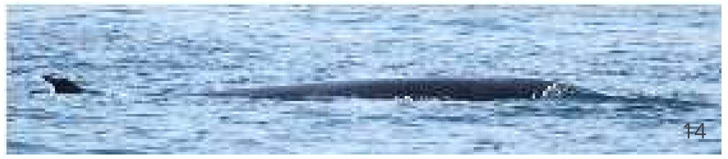


Figure 2) *Total number of NIO Blue Whale* (Balaenoptera musculus indica) *reported sightings from 1961 to 2017 by month. Sightings are categorized by On Effort (during active watch on surveys), or Off Effort (during survey but off watch or during another sighting, third party reports, shore-based observations).*

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of NIO Blue Whales in Oman have been recorded in six months of the year, between October and April, with the majority in March (Figure 2). Most sightings occur in coastal regions of Dhofar and Muscat, usually involving lone adults or lone juveniles. One record describes a sighting of 2 adults and 1 juvenile less than 1km from shore off Muscat Island. Out of a total of 17 records, 47% are categorized as on-effort sightings. When considering on-effort-corrected density records, important areas for this species are identified along the Mirbat coastline of Dhofar and a small stretch of the Muscat coast. There is currently no estimate of population abundance of NIO Blue Whales in Oman.



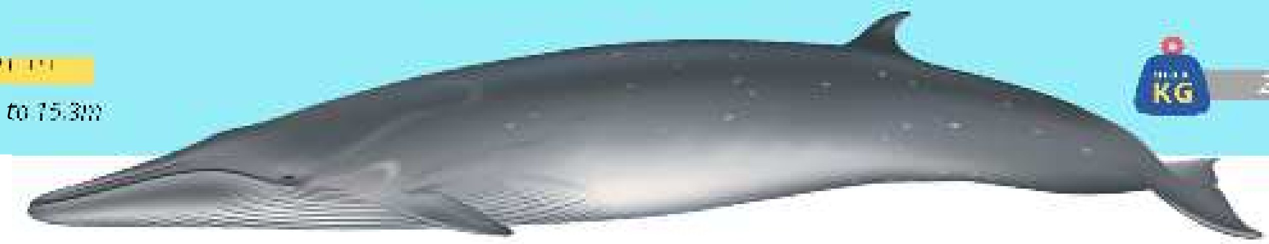


BRYDE'S WHALE

حوت برايدس [Hoot Brydes]

Balaenoptera edeni

length : *up to 15.3m*



25 000 KG

GLOBAL | *Least Concern* **REGIONAL** | *Not Evaluated*

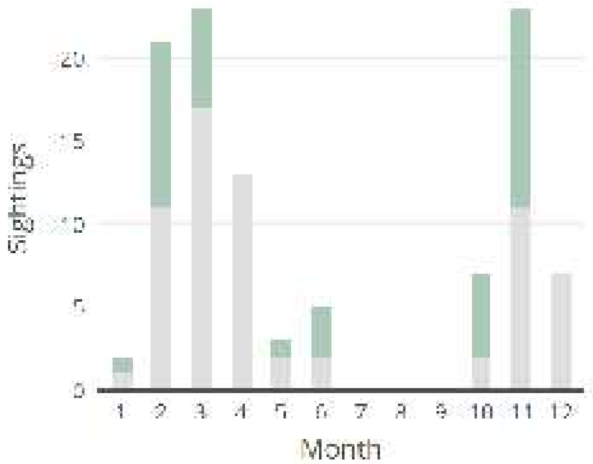
GROUP SIZE | *Minimum* 1 *Maximum* 4 *Best Estimate: Average* 1.75 *Standard Deviation* 0.80

THE BRYDE'S WHALE (*Balaenoptera edeni*), of the family Balaenopteridae, represents a species complex, the phylogeny for which is unresolved [32]. Based on genetic analysis, two subspecies of *B. edeni* are provisionally recognized globally: a larger pelagic form, *Balaenoptera edeni brydei* and a smaller nearshore form, *B. edeni edeni* [2,33,34,35,36]. In Oman, evidence from phylogenetic analyses, and corroborating morphological and behavioural studies, supports the presence of a potentially discrete population of the more offshore *B. e. brydei*, as well as an apparently more commonly occurring and widely distributed population of *B. e. edeni* in coastal areas which exhibits unusually low levels of genetic diversity [37].

It is recommended that the two subspecies should be treated as separate conservation units, and a priority for management [37].

The Bryde's Whale inhabits tropical and subtropical coastal and oceanic waters around the world [38,39] and is distributed throughout Oman, from Musandam in the north of the country to the far south of Dhofar [12]. It is most often sighted in coastal and shelf habitats, where the nearshore form is known to feed [40]. Whaling records reveal the prey in Oman to include almost exclusively small shoaling fishes, such as lanternfish, mackerel and sardines, although larger fishes, euphausiid crustaceans and mantis shrimps are also consumed [11,12,36]. The Bryde's Whale is a year-round, breeding resident of Oman [11,12,41].

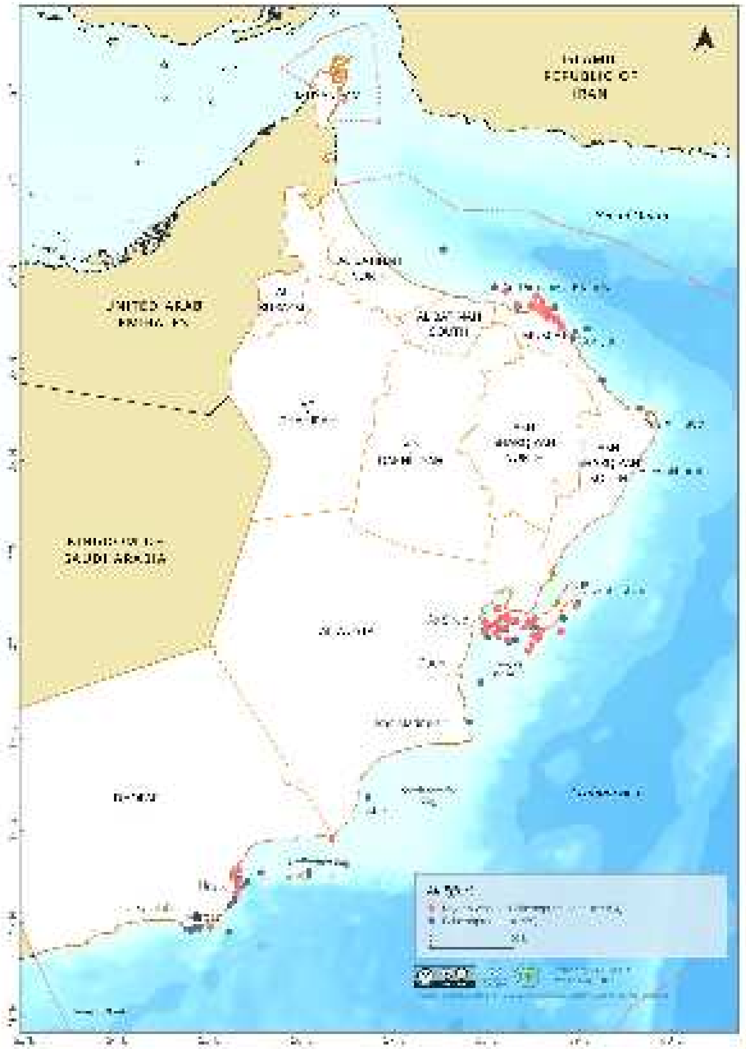
Despite researchers encountering Bryde's Whales on numerous occasions, they are notoriously difficult to photograph, and obtain biopsy samples from. Moreover, their song has not yet been characterised. They remain a species of interest for future research.



TOTAL | 38 66

Figure 3) Bryde's Whale (Balaenoptera edeni) sightings from 1961 to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations).

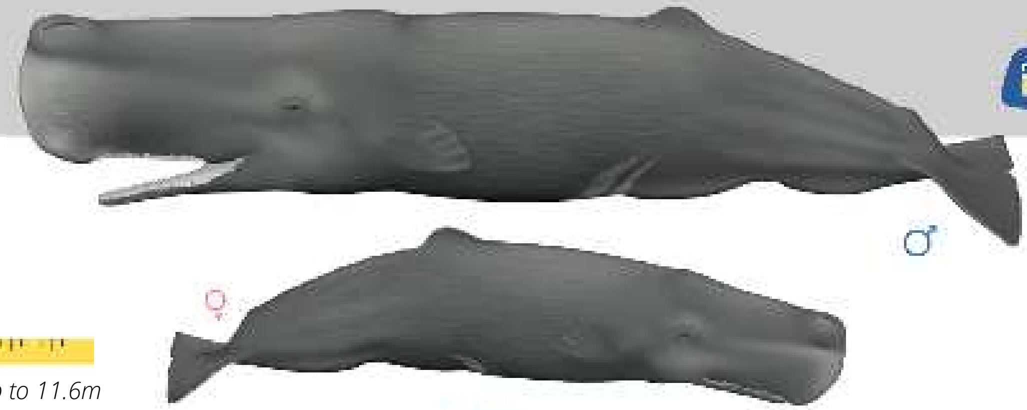
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of Bryde's Whale in Oman are reported between October and June with a peak in February, March, and November (Figure 3). Most sightings are frequently observed in the Muscat and North Al Wusta regions, as well as Dhofar. Pairings include calves and their mothers, paired adults and adults with juveniles. Out of a total of 104 sightings records between the years 2004-2017, 37% are categorized as on-effort sightings. Effort-corrected density sightings reveal the Gulf of Masirah to be a hot spot for the Bryde's Whale. There is currently no estimate of the population abundance of Bryde's Whales in Oman.



SPERM WHALE

حوت العنبر [Hoot Al Anbur]

Physeter macrocephalus



length : *up to 15.8m*

length : *up to 11.6m*

max KG 45 000

GLOBAL | *Vulnerable* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 55 *Best Estimate: Average* 7.96 *Standard Deviation* 12.25

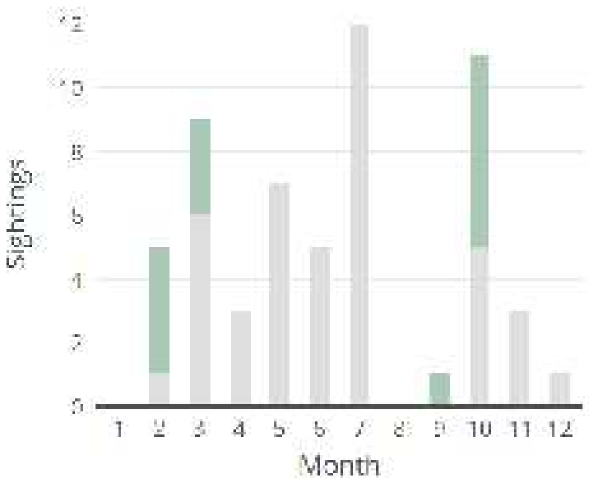
THE SPERM WHALE is the largest of the toothed whales and is classified in a family of its own, the Physeteridae. Its closest relative in Oman is, ironically, the smallest of the whales, the Dwarf Sperm Whale (*Kogia sima*). Sperm Whales exhibit considerable sexual dimorphism: Soviet whaling records reveal female whales in Oman may reach lengths of up to 11.6m whereas males may be up to 15.8m [11]. This represents a smaller than average size when compared to other areas in the Indian Ocean [42]. This, together with a lack of Cookie Cutter Shark scarring often observed on whales in more southerly locations, suggest that Sperm Whales in the Arabian Sea may represent an isolated population [11,43].

The Sperm Whale has a cosmopolitan distribution that includes most deep-water marine regions of the world and is among the most widespread of the cetaceans in Oman's offshore waters [44]. The preferred habitat is at the edge of the continental shelf [45], especially where there are subsea canyons, in depths of up to 3,450m in Oman. They may be found closer to shore where the continental shelf is narrow and drops off steeply, as occurs in several areas, such as off the coasts of Dhofar, Sharqiyah and Muscat [12].

Sperm Whales feed mostly on large, deep-water squid [46] and stomach contents of Sperm Whales washed ashore in Oman have been noted to include squid beaks [47]. Examination of stomach contents of Sperm Whales caught by Soviet whaling fleets between 1964 and 1966 in Oman revealed that ambergris (a secreted waxy deposit found in the intestines of Sperm Whales) occurred in greater abundance and in larger deposits than in Sperm Whales examined in the southern Indian Ocean [11].

Whaling records from the 19th century (n=61) show catches focused off Dhofar, with the aforementioned Soviet catches in the mid-1960s (n=714) also centred in this part of the Arabian Sea (mostly between the Gulf of Aden and Dhofar). Foetal sizes from the Soviet whaling data suggest that breeding may occur through much of the year, although whales examined in November showed a higher occurrence of recent conception and near-term pregnancies [11,43].

Non-whaling data records (n=109) of Sperm Whales in Oman reveal that sightings are mostly of single animals (n=33) or small groups of 2-4 individuals (n=29). However, infrequent larger groups are recorded including pods of 50 or more individuals [45] reported from Muscat, Ras al Hadd and Hallaniyat Bay. Group sightings frequently involve calves or juveniles alongside adults [48].

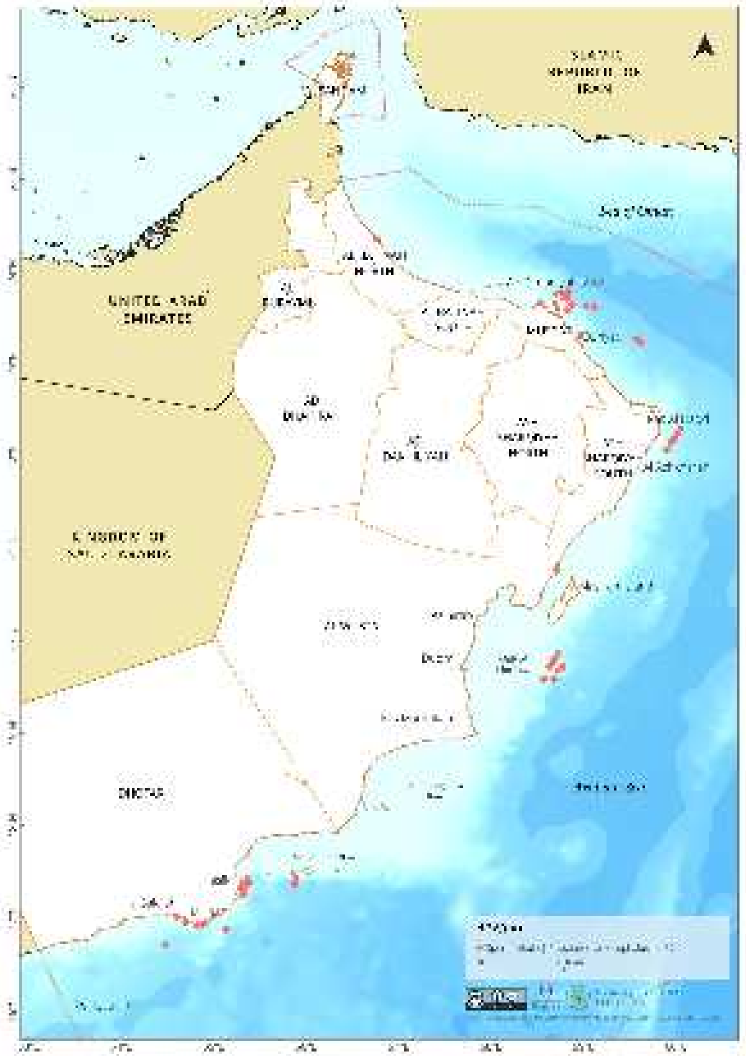


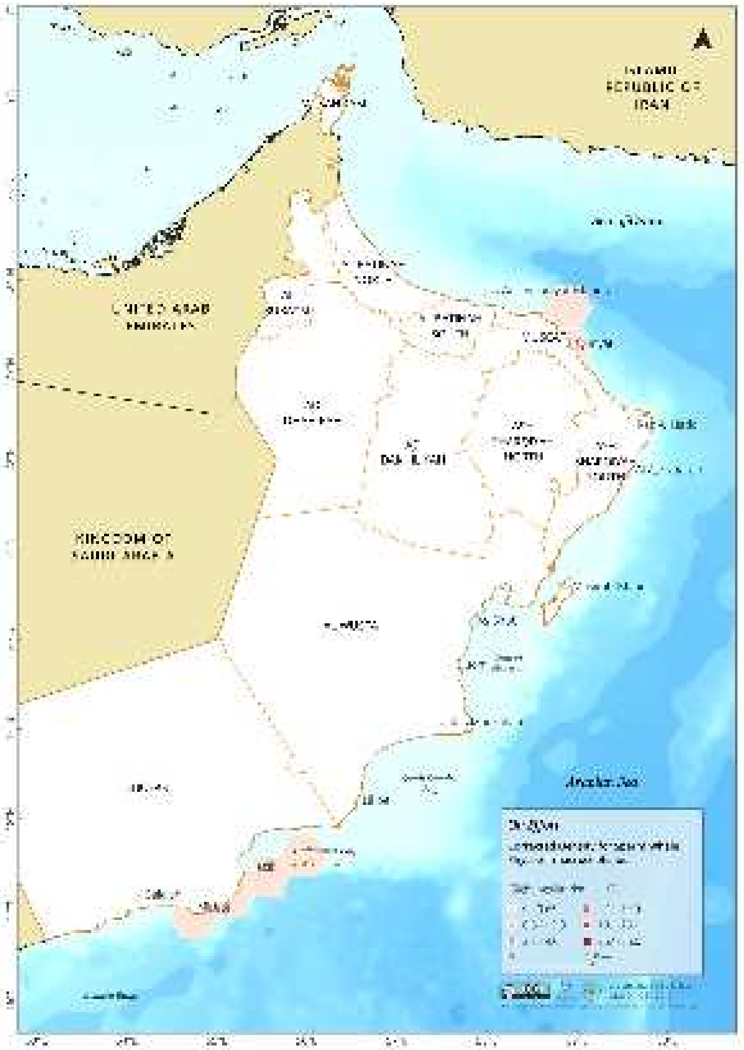
TOTAL | 14 43

*Figure 4) Sperm Whale (*Physeter macrocephalus*) sightings from 1961 to 2017 by month.* Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sighting records indicate year-round presence, though to date no sighting have been recorded in January or August (Figure 4). Out of a total of 57 sighting records, only 25% are on-effort sightings. On-effort corrected sightings density suggest that this species is most likely to be encountered in the Muscat region and in Dhofar, especially off Mirbat.

Although heavily exploited by whaling in the 19th and 20th centuries, the global population of Sperm Whales has since recovered in most areas of its range and the current global population size is estimated to be in the order of 100,000s [49]. No population estimates have been attempted in Oman, although a comprehensive review of records is provided by Gray et al. [45].





DWARF SPERM WHALE

حوت العنبر القزم [Hoot Al Ambur Al Qazam]

Kogia sima

length : *up to 2.7m*

275

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 8 *Best Estimate: Average* 2.57 *Standard Deviation* 1.99

DWARF SPERM WHALES, which as their name suggest, are among the world's smallest whales, are usually classified in the family Kogiidae, which they share with just one other species, the Pygmy Sperm Whale (*K. breviceps*) that has yet to be recorded in Oman. Dwarf Sperm Whales themselves are only rarely encountered and their distribution is poorly understood. Despite the limited evidence, however, and due to their cryptic habits, it is thought they are distributed widely in offshore tropical and warm temperate waters [50], including throughout Oman [12].

Dwarf Sperm Whales prefer deep, offshore waters where they are thought to feed mostly on cephalopods [51]. Sightings in Oman are spread throughout the year, suggesting residency, potentially within relatively small home ranges based on repeat sightings in specific locations, namely deep shelf and canyon habitats off Muscat and the western side of the Hallaniyat Bay. Nothing is known about their breeding status, or indeed about any aspects of their life history.

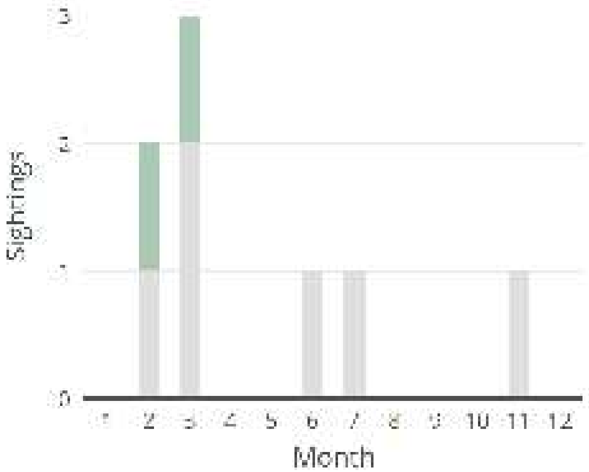
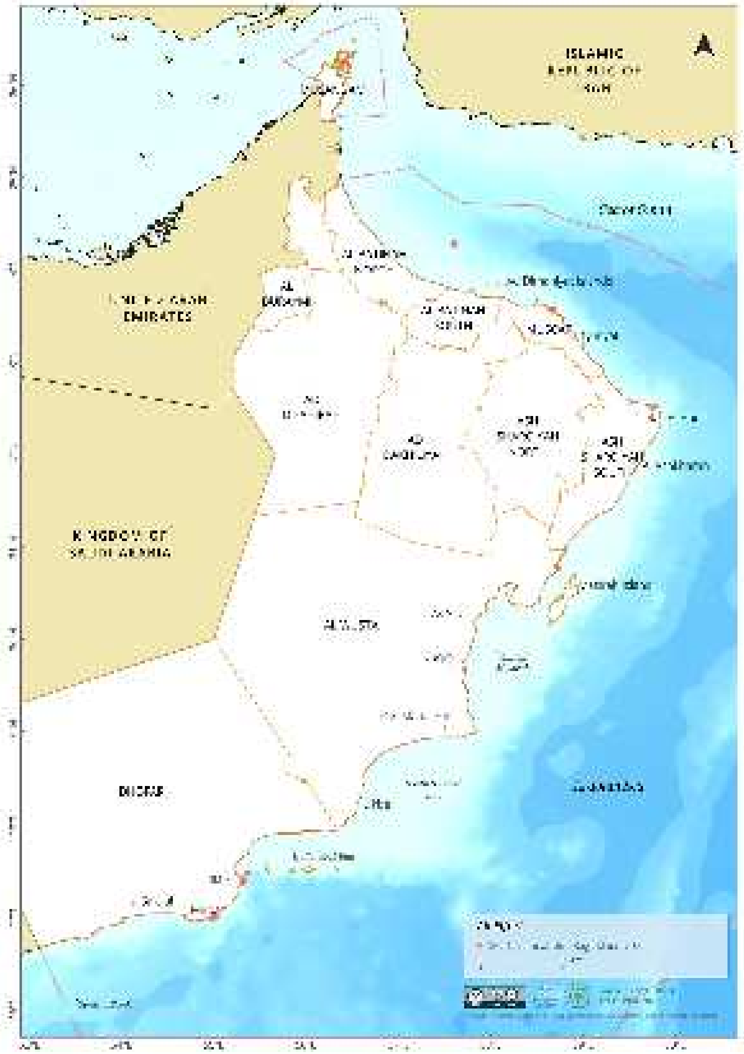
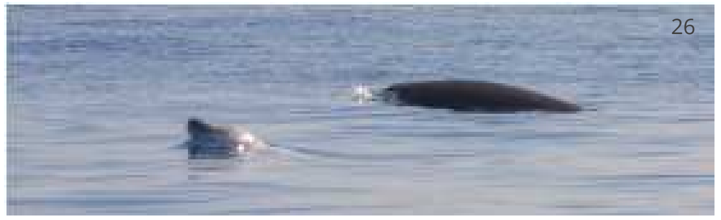


Figure 5) Dwarf Sperm Whale (Kogia sima) sightings from 1961 to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, Dwarf Sperm Whales are recorded either singly or in small groups. There have been just 8 sightings recorded in total in Oman, only 25% of which are classified as on-effort sightings (Figure 5). On-effort-corrected density sightings analysis highlights an area off Mirbat in Dhofar as potentially important habitat.

Population size and trends are not known anywhere in the world, due to lack of study and the difficulties inherent in estimating numbers of this elusive, inconspicuous species.





CUVIER'S BEAKED WHALE

حوت كوفير المعقوف اللأنف [Hoot Coffier al Maakof al Anif]

Ziphius cavirostris

length : *up to 6.9m*

3000

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 1 *Best Estimate: Average* 2.50 *Standard Deviation* 2.12

THE CUVIER'S BEAKED WHALE is one of the most widely distributed and commonly sighted of the beaked whales, globally [52], and the only one known to occur in Oman. It is one of 22 known species of beaked whales in the family Ziphiidae, all of which are medium-sized, deep water whales. The Cuvier's Beaked Whale inhabits tropical, subtropical, temperate, and polar waters around the world and is absent only in very shallow areas and the highest latitudes of polar regions [53]. In Oman it has only been seen well offshore in the Arabian Sea [12], with the exception of one record of an apparently disoriented individual that stranded live off the coast of Muscat (near Qurm) and was successfully returned to the sea following several hours of rescue efforts by concerned marine biologists.

Cuvier's Beaked Whales in Oman, as is the case globally, have been recorded in waters >1,000 m deep, where they are thought to feed mainly on squid as well as fishes and crustaceans [53]. There is no information on the breeding status of this species in Oman.

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, there are only five sightings records in Oman, involving single animals, pairs, or in one case, a small group of 3-4 individuals. These occurred in January, March, September and October (Figure 6). Two of the sightings occurred near Ras Al Hadd off the Ash Sharqiyah South region, and the others were all reported off Dhofar, between Mirbat and Al Hallaniyah. Both areas are characterized by steeply shelving, deep water bathymetry. Despite the lack of reported sightings, the on-effort corrected density analysis reveals waters north of Ras Al Hadd to be potentially important.

There are no data on the global population trend of this species, though they are regarded as the most numerous of the beaked whales, with an estimated global population size of at least 100, 000 [53]. Lack of data prevents population estimates in Oman.

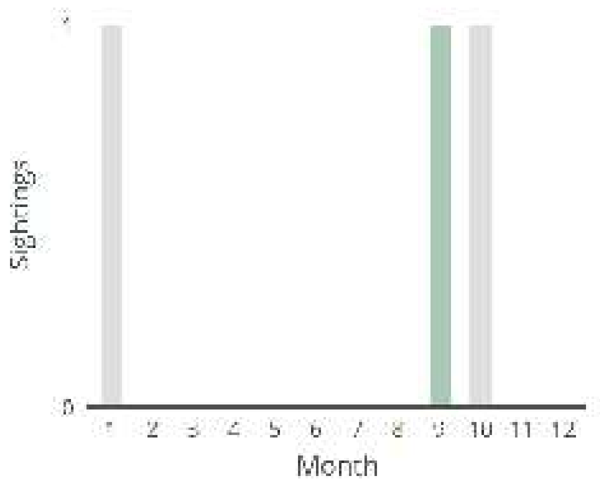
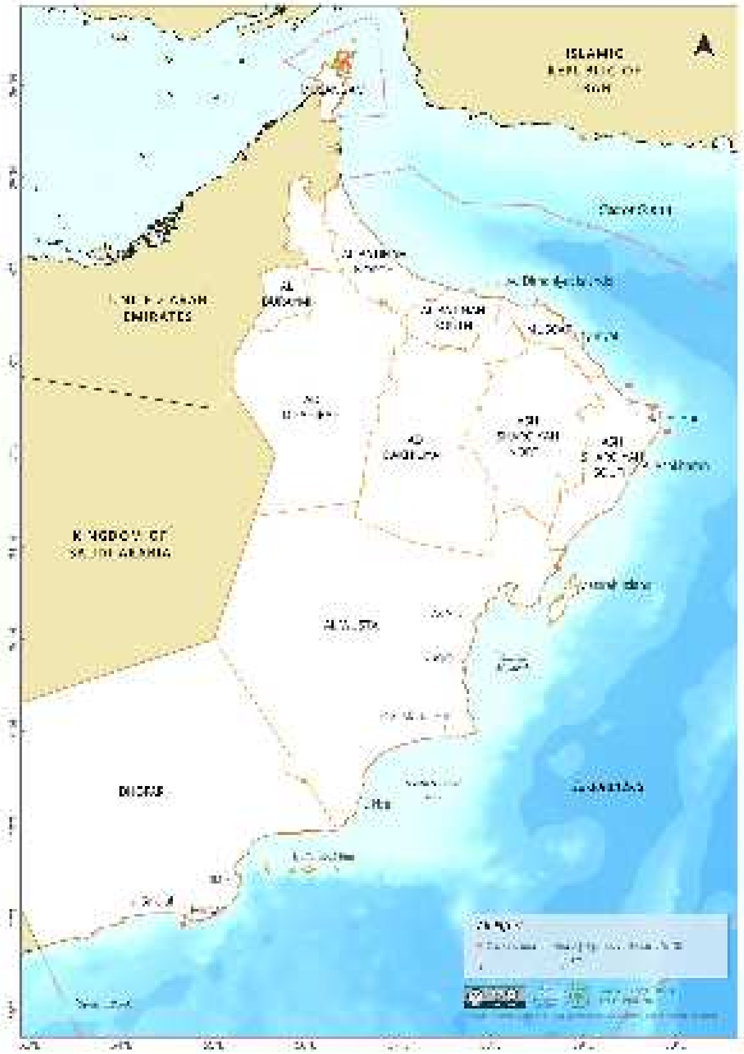
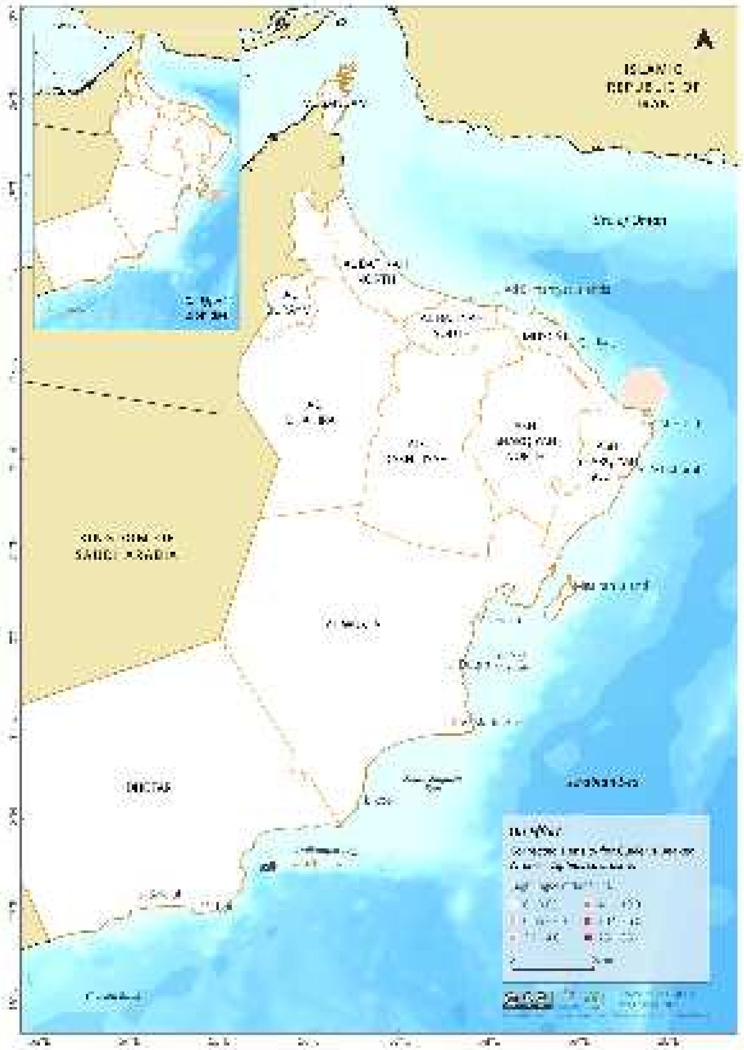


*Figure 6) Cuvier's Beaked Whale (*Ziphius cavirostris*) sightings from 1961 to 2017 by month.* Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)





KILLER WHALE

الحوت الضاري

Orcinus orca

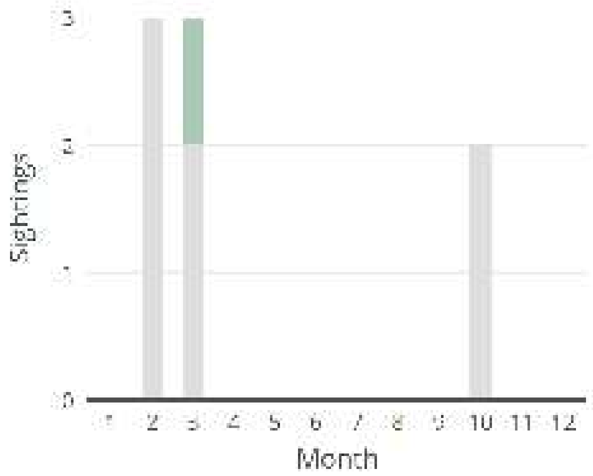
GROUP SIZE | *Minimum* 2 *Maximum* 10 *Best Estimate: Average* 5.13 *Standard Deviation* 2.85

THE KILLER WHALE is the largest member of the dolphin family (Delphinidae), and a top marine predator that is distributed throughout the world's oceans [54]. It is the sole member of its genus, and although currently considered as a single species, there is evidence for sub-species status in some parts of the world [55]. The species has, however, been classified according to ecological and morphological differences (ecotypes and morphotypes). In the eastern North Pacific these include; 'residents', 'transients' and 'offshores' [56,57], whilst in the Antarctic, five ecotypes have been suggested [58]. Different ecotypes have been found to maintain social isolation [55]. Killer Whales are more common in cold waters at high latitudes in areas of high productivity and are found in close association with continental margins [55]. In the warm waters of Oman, they are relatively rarely recorded [12].

The population identity, ecotype and/or morphotype of Killer Whales in the Northern Indian Ocean, including Oman, are not yet described. However, a better understanding of killer whale distribution and population parameters in the region is facilitated by the Northern Indian Ocean Killer Whale Alliance. This initiative maintains a sightings and photo-database that documents animals ranging from the Arabian Gulf and the Red Sea in the west, to Raja Ampat in Indonesia, and in the far east of the Indian Ocean. Among regional outcomes of this work is a record of a long-distance migration of a Killer Whale between Abu Dhabi and Sri Lanka [59]. Of 20 positively identified pods in the Alliance catalogue, three have resulted from sightings records collected in Oman.

Globally, Killer Whales feed on a wide range of prey, including marine mammals, birds, large fishes, sea turtles, and cephalopods and exhibit a variety of coordinated hunting techniques [55]. In Oman, there are records of Killer Whales pursuing Bottlenose and Rough-Toothed Dolphins [12] and attacking Sperm Whales [12,45]. Similar observations have been made in the wider Arabian Sea region, for example off Sri Lanka, where Blue Whales have also been attacked and a pod of Killer Whales was observed feeding on the remains of a beaked whale [60].

Nothing is known about the breeding status of Killer Whales in Oman, although calves have been sighted on occasion.

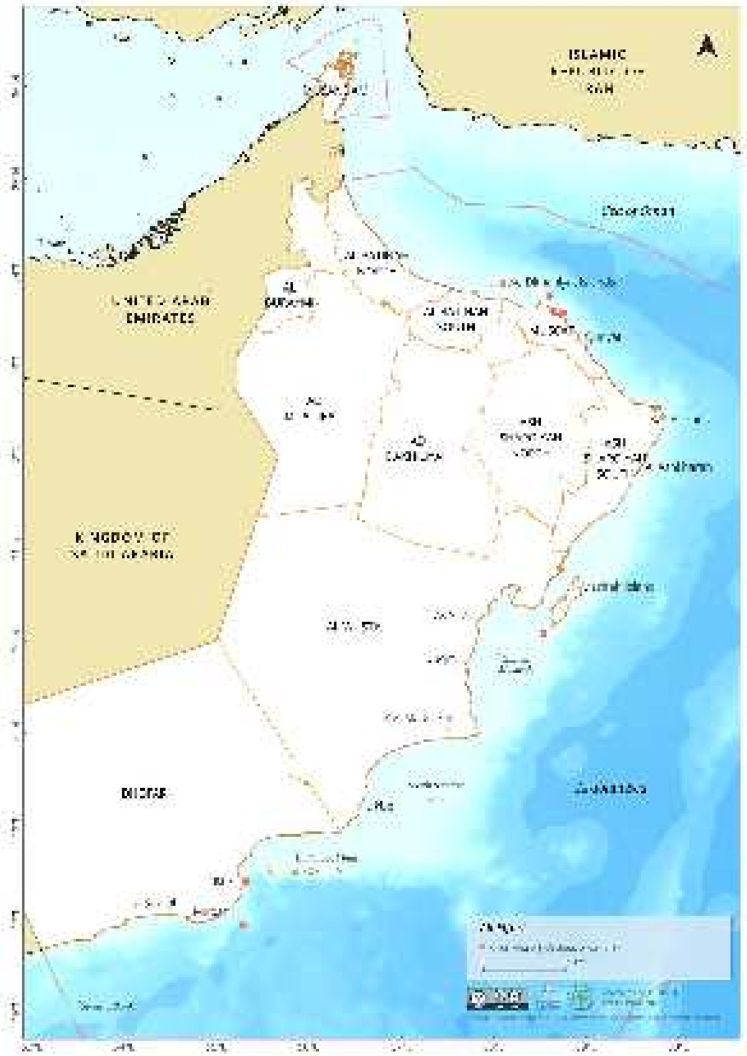


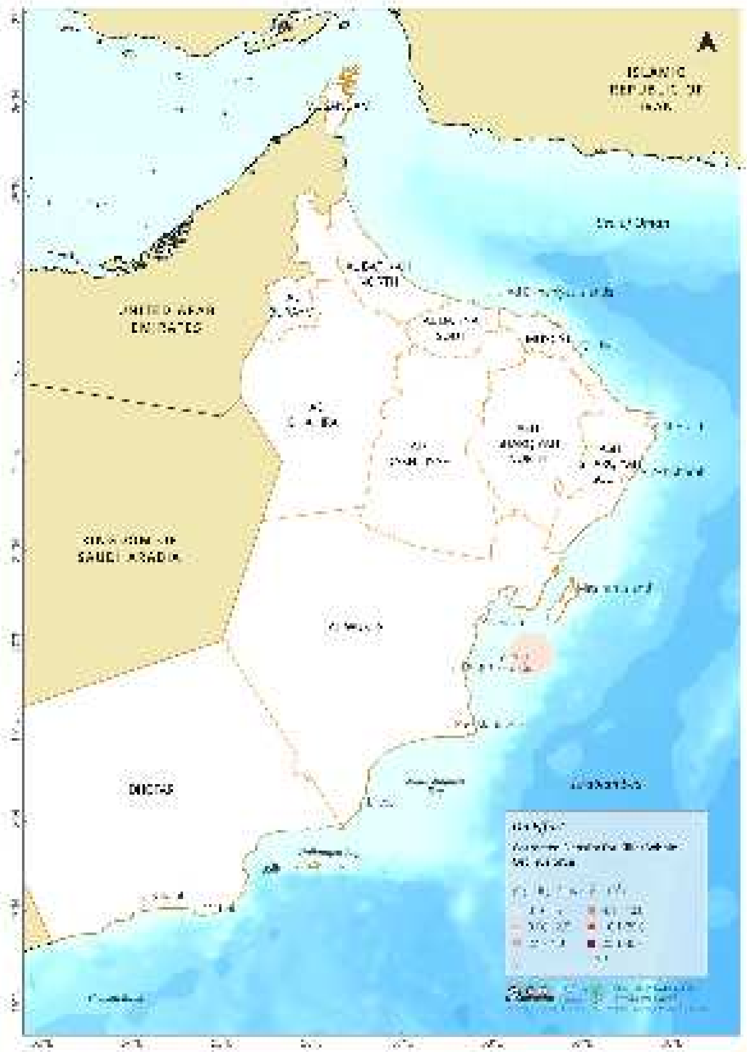
TOTAL | 1 7

Figure 7) Killer Whale (Orcinus orca) sightings from 1961to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sighting records are limited to the months of October, February and March (Figure 7). Group sightings, including lone animals and small groups of up to 10 individuals (mostly adults) are clustered off the Muscat region, but are also documented in the Hallaniyat Bay in Dhofar and at Masirah Island. Of the 8 sightings, only one was reported during an on-effort-survey which points to an area south of Masirah Island as potentially important habitat.

Killer whale population parameters are well-studied in only a few parts of the world (such as those in the North Pacific), and data are lacking in other areas, including Oman. Estimates at the global level suggest a minimum population size of ~50,000 individuals [61].





ROUGH-TOOTHED DOLPHIN

الدولفين ذو الأسنان الخشنة [Al Dolpheen tho Al Asnan Al Khashinah]

Steno bredanensis

length : *up to 2.*

160

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

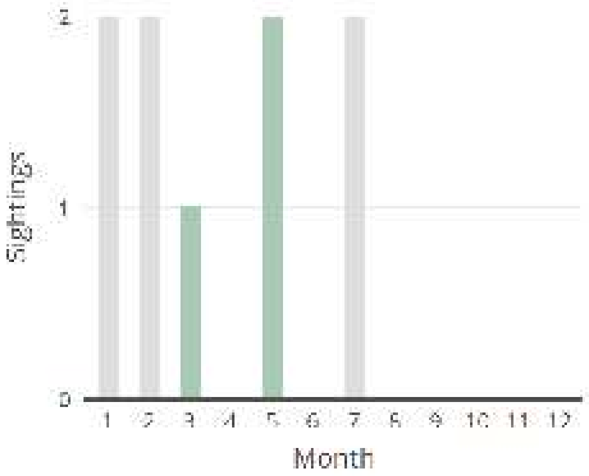
GROUP SIZE | *Minimum* 2 *Maximum* 100 *Best Estimate: Average* 16.56 *Standard Deviation* 21.11

THE ROUGH-TOOTHED DOLPHIN is a member of the large Delphinidae family. This species, placed in a genus of its own, is named for the peculiar roughened surface to the teeth formed by many narrow, irregular ridges. It inhabits tropical, subtropical, and warm temperate waters around the world [62,63] and although no subspecies are currently described, there is evidence for subpopulations in various regions [64]. The Rough-toothed Dolphin is rarely seen in Oman, but it may be more common offshore than records suggest and may also have been overlooked occasionally due to its habit of mixing with Bottlenose Dolphins with which it can be confused from a distance.

Rough-toothed Dolphins are almost exclusively found in deeper waters, though they occasionally enter shallow areas. In Oman this species usually occurs in pods of up to 20 individuals [12], but pods can exceptionally include over 100 individuals. The diet consists mostly of fishes and cephalopods [64,65]. Nothing is known of the breeding status of the Rough-toothed Dolphin in Oman.

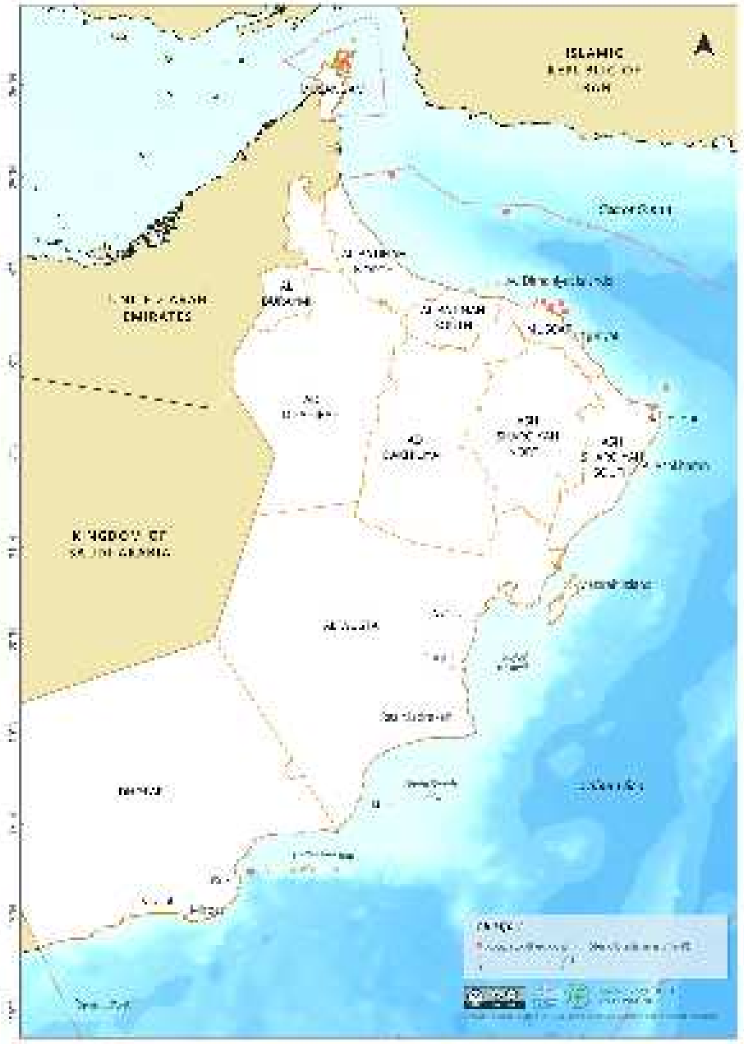
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of Rough-toothed Dolphins in Oman have occurred mostly in May, though sightings both earlier and later in the year have also been reported (Figure 8). Sightings involving large groups (n= >100) have only been reported in the Muscat region. Of the 9 sightings recorded, 33% were reported during on-effort-surveys, with the majority off Muscat. However, when considering on-effort corrected sightings density, an area in the Dhofar region on the eastern side of the Hallaniyat Bay is highlighted as significant.

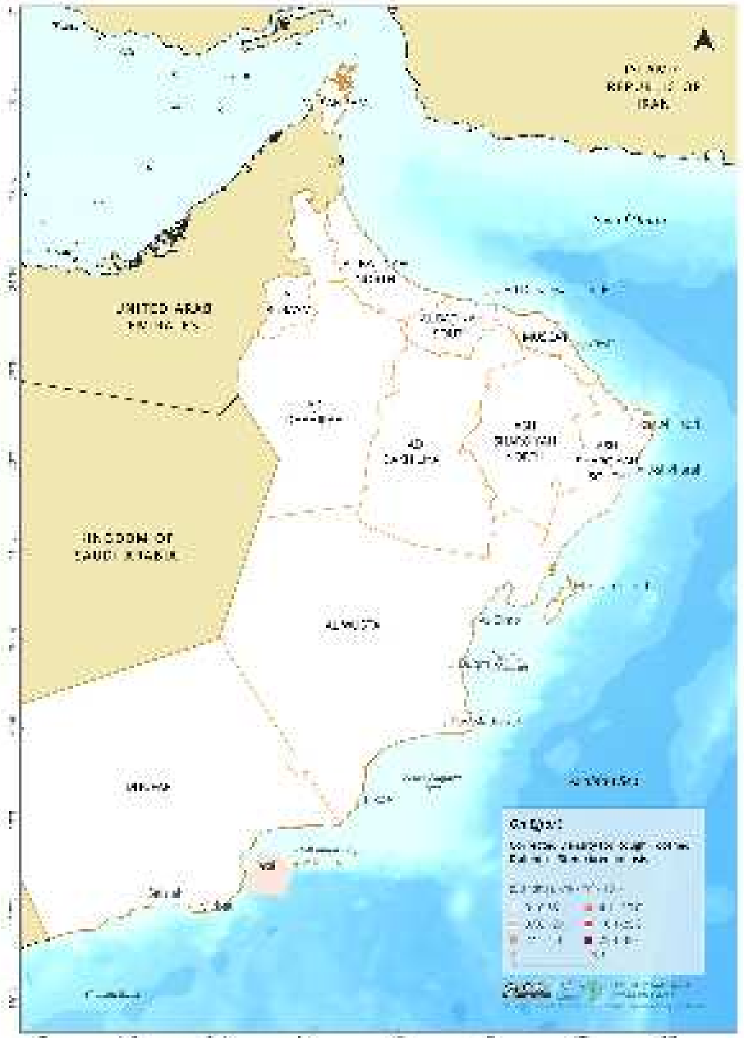
Global population trends are unavailable for this species and abundance records are also limited. Where well studied, abundance can be high, such as in the Eastern Tropical Pacific (145,900 individuals) and Hawaii (~72,500 individuals), or relatively low, such as in the Gulf of Mexico (624 individuals) [64]. No population data are available for Oman.



TOTAL | 3 6

Figure 8) Rough-toothed Dolphin (Steno bredanensis) sightings from 1961 to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)





RISSO'S DOLPHIN

دولفين ريسوس [Dolpheen Rissos]

Grampus griseus

length *: up to 4m*

500

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 600 *Best Estimate: Average* 74.00 *Standard Deviation* 137.46

THE RISSO'S DOLPHIN belongs to the family Delphinidae and is the sole member of its genus. Morphological differences between regions suggest several populations exist, but no subspecies are currently recognized [2,66]. It has a wide, cosmopolitan distribution across the Atlantic, Pacific, and Indian Oceans, and is found in tropical, subtropical, and temperate waters [67,68]. As is the case in Oman, it mainly inhabits steep banks off the continental shelf in water depths of between 400 and 1,000+ metres, but is rarely also found in semi-enclosed water bodies in some parts of the world [12,68].

Seamounts and subsea escarpments offer rich feeding grounds for the Risso's Dolphin, where it targets vertically migrating cephalopods [68]. Globally, records suggest group sizes of mostly up to 30 individuals, though this species may also be recorded alone, or in pairs [69]. Much larger groups can also occur. In Oman, groups of up to 800 individuals have been recorded [12]. Calves are sometimes sighted which, coupled with year round sightings, suggests breeding residency in Oman [12].

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, Risso's Dolphins have been sighted in every month with the exception of August and September (Figure 9). Sightings of large groups are most common in the Muscat region, followed by the North Al Wusta and North Batinah regions. Of the 81 sighting records, only 28% were reported during on-effort surveying. Although mostly sighted in northern Oman, the on-effort corrected density sightings suggest that the Dhofar region of the eastern Hallaniyat Bay is potentially significant, as well as offshore waters of the Ad Dimaniyat Islands near Muscat.

There are no established population estimates or trends for the Risso's Dolphin, either in Oman or globally, but this species is not considered rare and is potentially abundant in Omani waters.

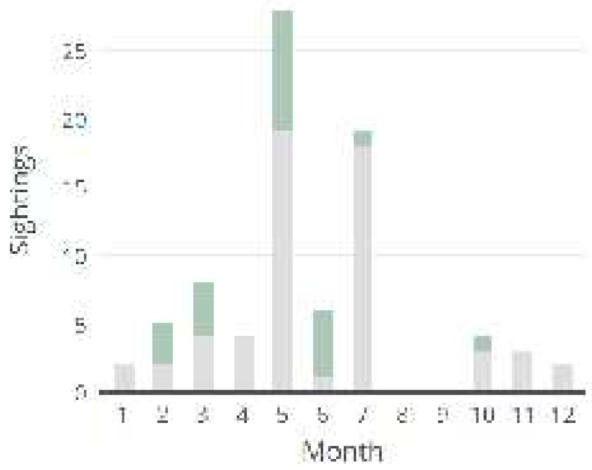
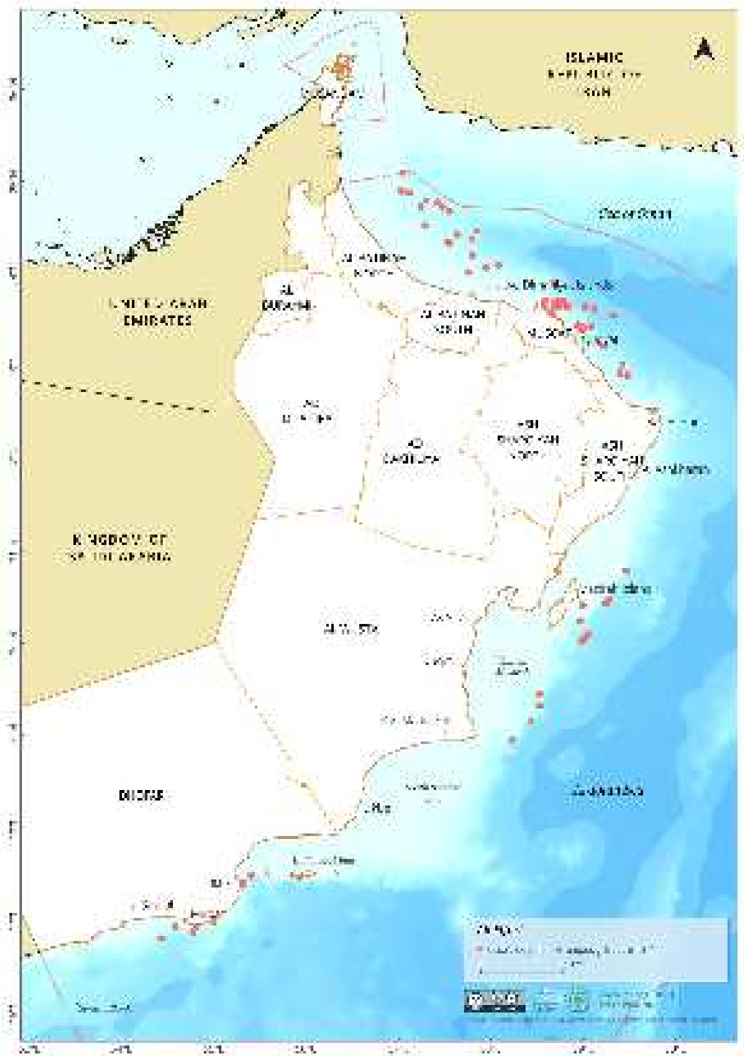
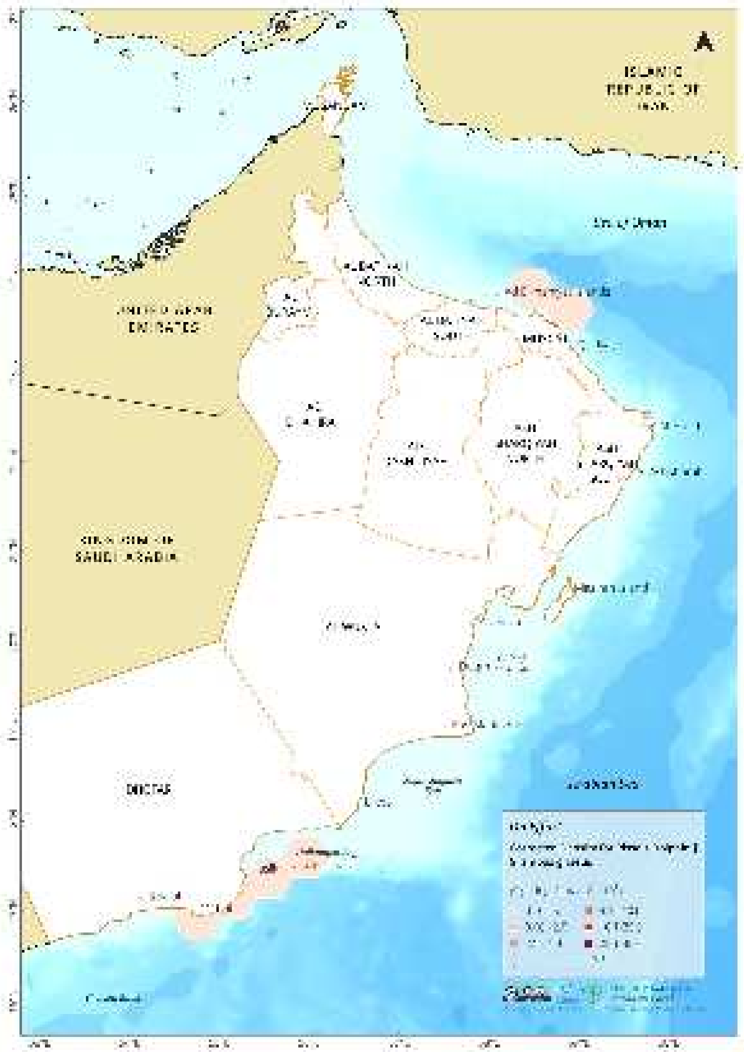


Figure 9) *Risso's Dolphin (*Grampus griseus*) sightings from 1961 to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*






46


47


48


49


50

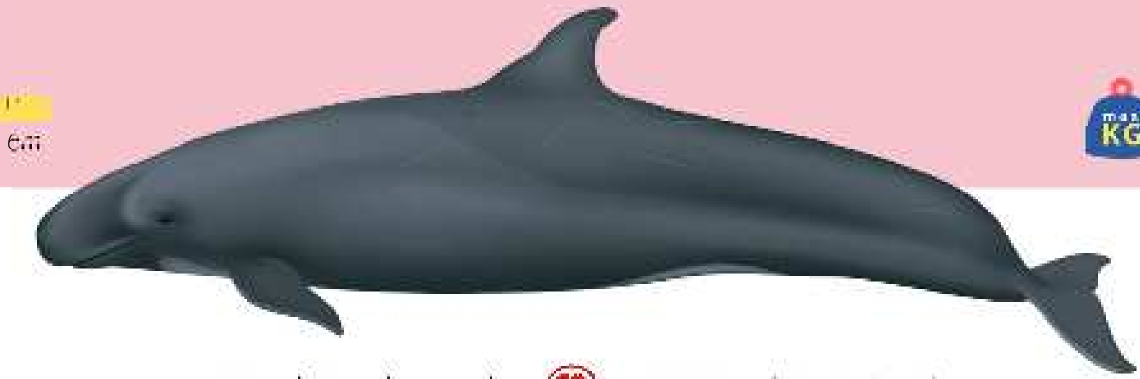
FALSE KILLER WHALE

الحوت الضاري الزائف [Al Hoot Al Darre Al Zaif]

Pseudorca crassidens

length : *up to 6m*

max KG 2200



GLOBAL | *Near Threatened* ***REGIONAL*** | *Not Evaluated*

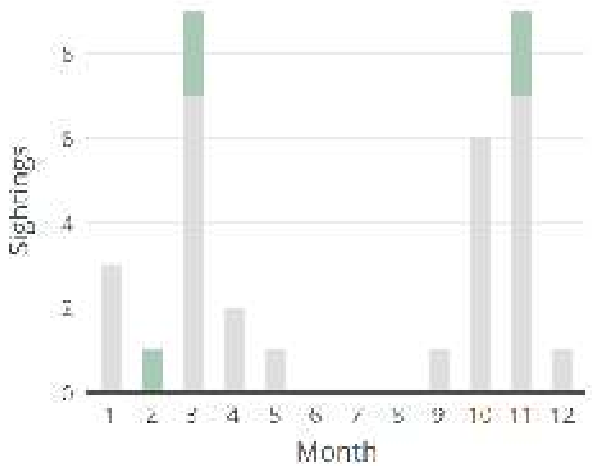
GROUP SIZE | *Minimum* 5 *Maximum* 200 *Best Estimate: Average* 64.59 *Standard Deviation* 59.27

THE FALSE KILLER WHALE is a member of the dolphin family, the Delphinidae. Its genus and common name refer to a similarity in the skull morphology between it and the Killer Whale. However, it is more closely related to the Risso's Dolphin, the Melon-headed Whale (*Peponocephala electra*), the Pygmy Killer Whale (*Feresa attenuata*) and the pilot whales (*Globicephala* spp.) and is placed with all these species within the subfamily Globicephalinae [70]. No subspecies of False Killer Whales are currently described [2,71], but there is evidence of regional variation [72,73] and regional subpopulations are recognised in Hawaii [70] and New Zealand [74], with the likelihood of further subpopulation structure elsewhere in the world being very high.

The False Killer Whale is most commonly found in tropical and subtropical waters with densities peaking in tropical regions [75,76,77]. It is usually found in deep, offshore waters, although in higher latitudes, such as in Oman, this species may sometimes enter shallower waters closer to shore [74,78]. This species' diet is primarily made up of cephalopods and large fish, such as tuna, although opportunistic feeding on dolphins released from tuna purse seine nets has been documented [71,79]. An apparent attack by this species on an Arabian Sea Humpback Whale in Dhofar suggests that they may sometimes attempt to hunt even larger prey [25]. Frequent sightings of calves off both Muscat and Dhofar, and an apparent birth witnessed off Muscat [12], reveal this species to be a breeding resident in Oman. Group sizes of >100 may occur when two or more pods meet [12].

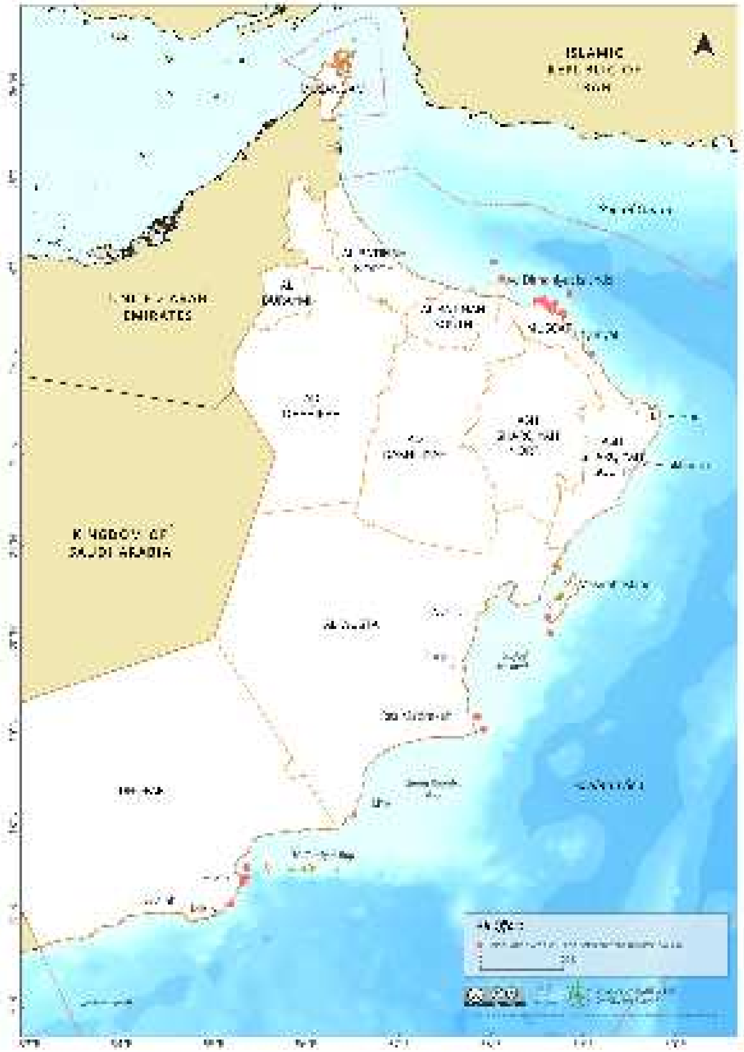
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of False Killer Whales in Oman are recorded for all but the summer months of June, July and August and are most common in the Dhofar and Muscat regions (Figure 10). Only 15% of sightings have been recorded during on-effort surveys. The distribution of False Killer Whales appears, from sightings records, to be largely concentrated off the northern Muscat coastline. However, on-effort corrected density sightings highlight two key areas of potential importance; the waters south of Masirah Island, and the western Hallaniyat Bay area in Dhofar.

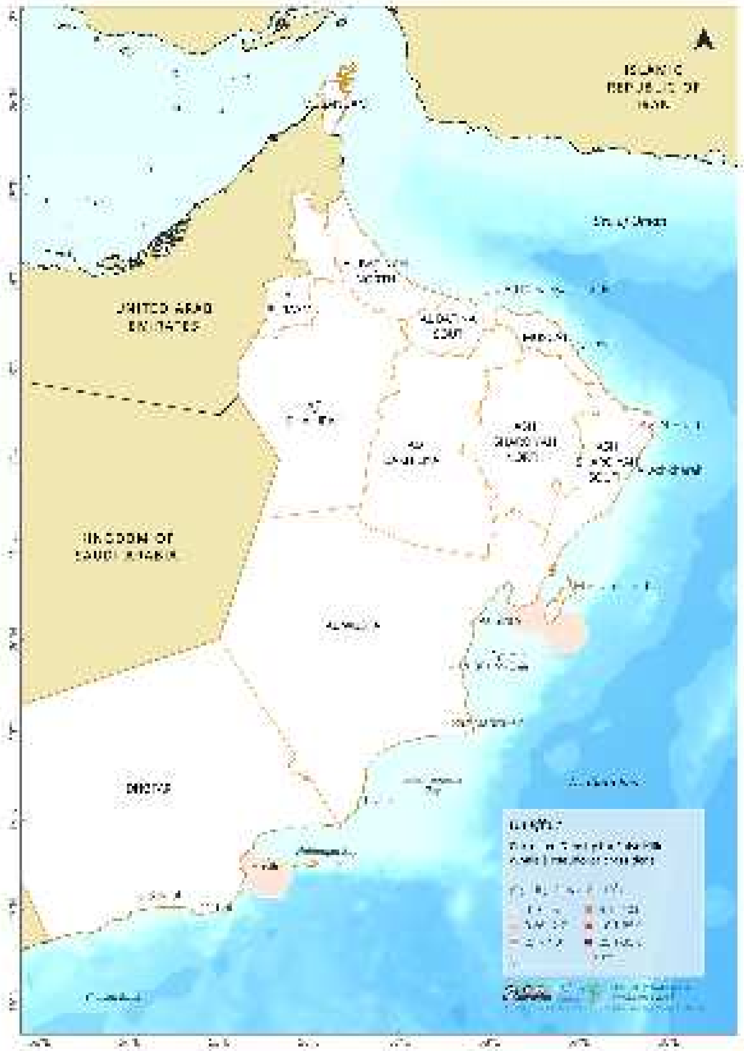
False Killer Whales are one of the less abundant delphinids even in areas where they appear in their highest densities [80]. Current population trends for this species are not known anywhere in the world, except for one Hawaiian Island insular population, for which a greater than 50% decline has been witnessed in less than two generations [81] thought to be linked to fisheries-related threats. No population estimates have been attempted in Oman.



TOTAL | 5 28 On Effort Off Effort

Figure 10) *False Killer Whale (Pseudorca crassidens) sightings from 1961 to 2017 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*





No locally taken photos

MELON-HEADED WHALE

الحوت ذو الرأس الشبيه بالبطيخة [Al Hoot Thou Al Ra'as Al Shabih Bil Bateekhah]

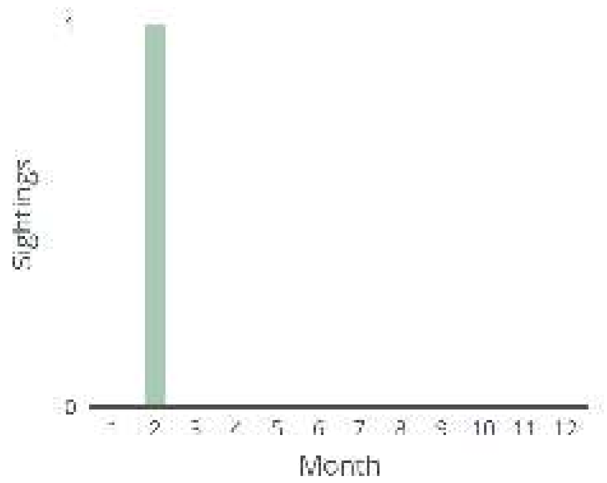
Peponocephala electra

length : *up to 2.7m*

275 KG

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 2 *Maximum* 3 *Best Estimate: Average* 2.00 *Standard Deviation* -



TOTAL | 1 0 On Effort Off Effort

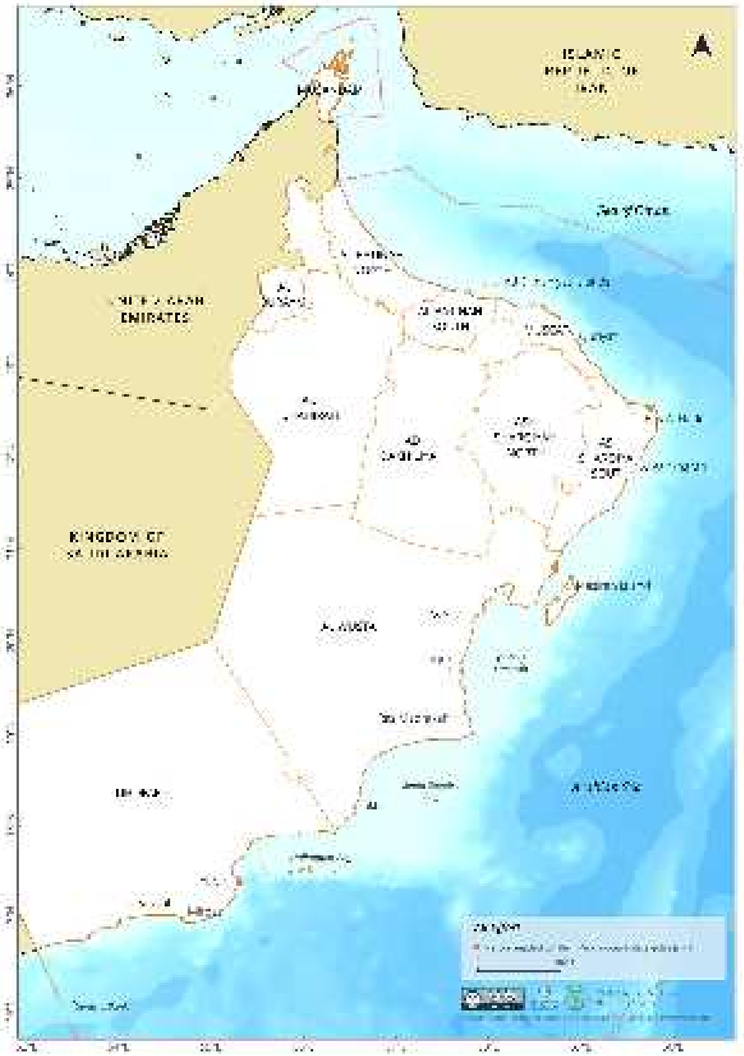
Figure 11) *Melon-headed Whale (Peponocephala electra) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*

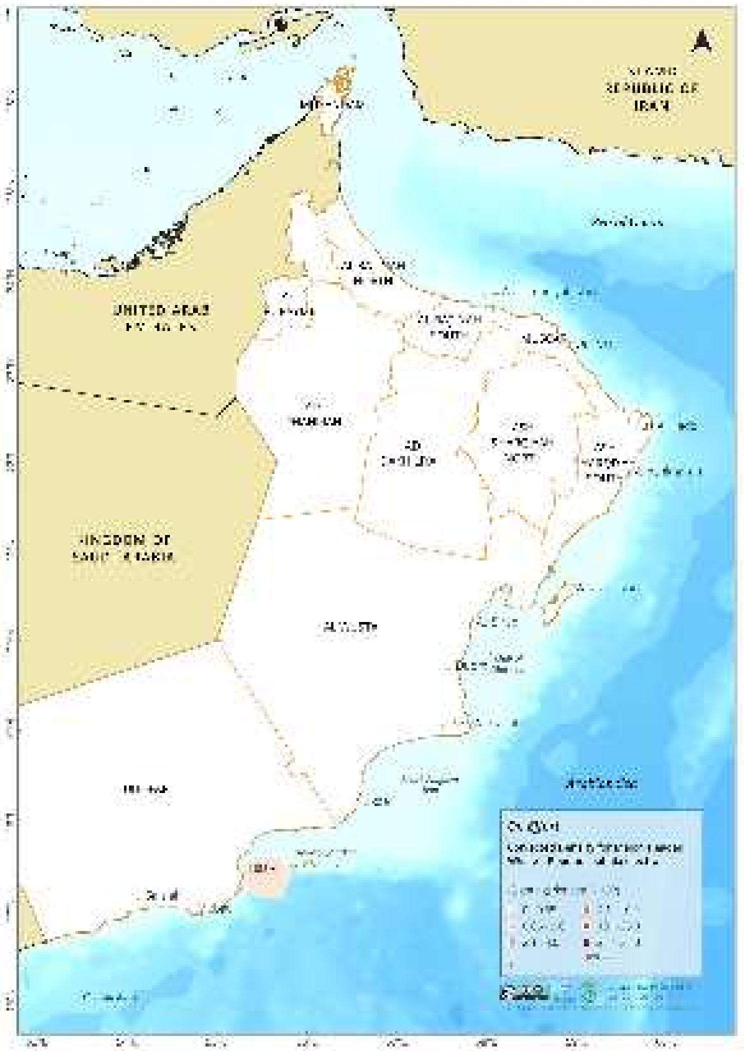
THE MELON-HEADED WHALE is a member of the dolphin family, the Delphinidae, and belongs to the subfamily Globicephalinae. Its external morphology is very similar to that of the Pygmy Killer Whale [82,83]. No subspecies of Melon-headed Whale are currently recognised [2] and this species shows only low levels of genetic differentiation both within and between ocean basins, suggesting high levels of population connectivity [84].

The Melon-headed Whale is found in deep tropical and subtropical waters globally [86] and is primarily oceanic [82], although resident populations are evident around islands and archipelagos [83]. This species occurs in large pods of several hundred individuals and feeds nocturnally on squid, fishes, and shrimps [82,86].

The current population trend is unknown, except in some areas where they are commonly sighted, such as the Hawaiian Islands [87], Gulf of Mexico [88], the eastern tropical Pacific [89], the western Pacific Ocean [90] and the southwestern Indian Ocean [91,92]. Based on local population estimates, the global population of these whales is expected to be over 180,000 individuals [83].

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, a damaged skull collected from a beach in Oman at Al Hallaniyah in February 1982 [85], and a single sighting in February 2015 [40] are the only records of this species (Figure 11). Consequently, the majority that is known about it, is inferred from records elsewhere in the world.





No locally taken photos

PYGMY KILLER WHALE

الحوت الضاري القزم [Al Hoot Al Dharri Al Qazam]

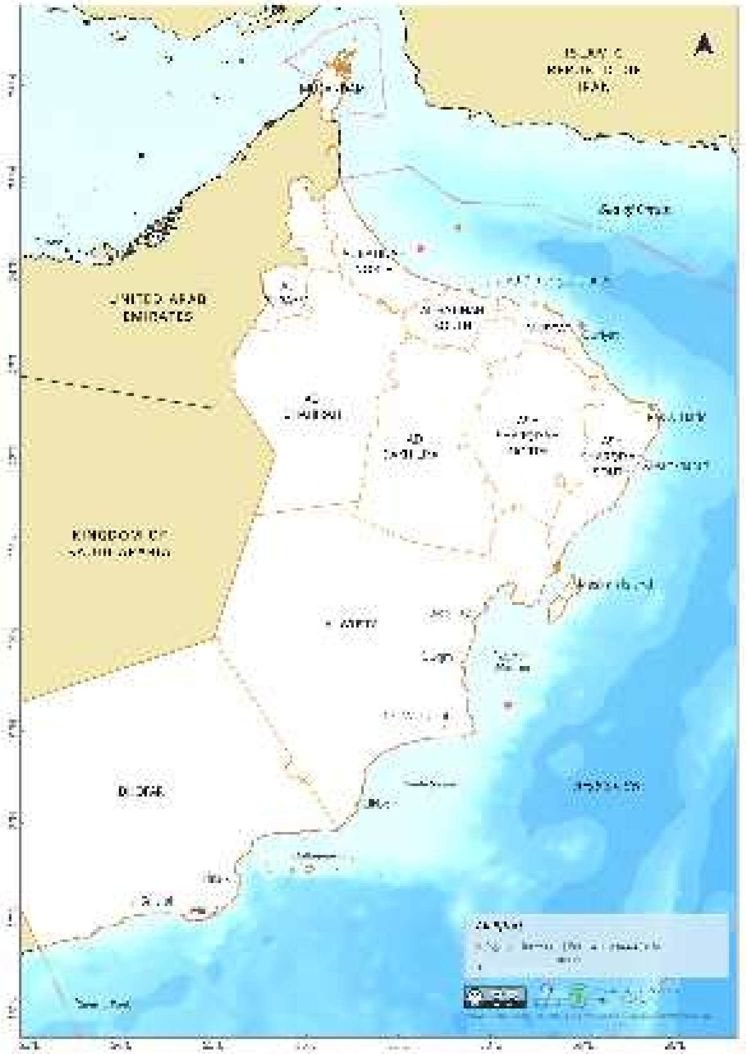
Feresa attenuata

length : *up to 2.6m*

225

GLOBAL | *Least Concern* *REGIONAL* | *Not Evaluated*

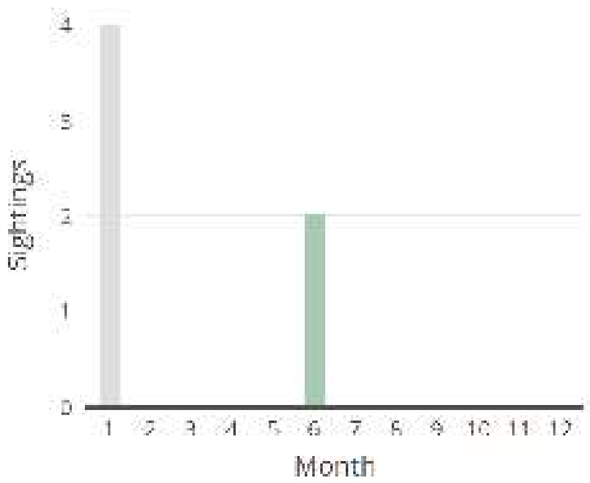
GROUP SIZE | *Minimum* 12 *Maximum* 50 *Best Estimate: Average* 16.00 *Standard Deviation* 20.08



THE PYGMY KILLER WHALE belongs to the dolphin family, the Delphinidae, and is placed in the subfamily Globicephalinae. It closely resembles the Melon-headed Whale and the two species are frequently confused in the field [93,94]. There are currently no recognized subspecies [2], however there has been little assessment of variability between different geographical regions [94]. The Pygmy Killer Whale is found in deep tropical and subtropical waters between 40° N and 35° S, rarely close to shore except where waters are deep and clear [95]. In Oman, all sightings have been recorded in deep offshore waters in both the Sea of Oman and the Arabian Sea.

Prey includes squid, octopus and fish [12,95,96] and there is at least one record of this species attacking dolphins associated with tuna in the eastern tropical Pacific [97]. In Oman, Pygmy Killer Whales often occur as single sightings, or in groups of between 12 and 50 individuals, but elsewhere in the world they are more commonly recorded in small groups that range from pairs of individuals to groups of around 30-40 [94,95].

No on effort sightings were reported within the areas of measured vessel effort.



TOTAL | 2 4

Figure 12) *Pygmy Killer Whale (Feresa attenuata) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, six sightings of Pygmy Killer Whale have been reported in Oman, four in the month of January and two in June (Figure 12). Of the 6 sightings, only 33% (n=2) were reported during on-effort surveys.

No population estimates for this species have been made in Oman and population status is generally poorly understood globally. However, this species appears to be naturally rare throughout its range [12,95].

SHORT-FINNED PILOT WHALE

الحوت المرشد القصير ذو الزعانف [Al Hoot Al Morched Al Qaseer tho Al Za'anif]

Globicephala macrorhynchus

length : *up to 6m*

max KG 3600

GLOBAL | *Least Concern* **REGIONAL** | *Not Evaluated*

GROUP SIZE | *Minimum* 15 *Maximum* 25 *Best Estimate: Average* 20.00 *Standard Deviation* -

THE SHORT-FINNED PILOT WHALE is a member of the dolphin family, the Delphinidae, and is placed within the subfamily Globicephalinae. It shares its genus with just one other species, the long-finned pilot whale (*G. melas edwardii* and *G. melas melas*) [2], which inhabit cooler, temperate waters and are not found in Oman. The Short-finned Pilot Whale is distributed in tropical, subtropical, and warm temperate waters, rarely venturing further than 50° N or 40° S [98], in both coastal and pelagic waters [98,99]. Though no subspecies are currently recognised [2], there is growing evidence of genetic differentiation between northern and southern Japanese populations [99], with the suggestion of two distinct subspecies [100].

A high degree of sexual dimorphism in size is recorded with Short-finned Pilot Whales, with adult males approximately 1m longer than the smaller females [98]. Almost nothing is known about this species in Oman as only one record has been made to date [12].

The Short-finned Pilot Whale prefers deeper waters of the continental shelf and slope [101], and are primarily adapted to feeding on squid, with reduced tooth counts associated with ram-and-suction feeding methods [98,102], consistent with other squid-adapted predators such as Risso's Dolphins and Sperm Whales [98]. Some populations demonstrate deep, fast dives in pursuit of large, high calorie squid species [98,103]. Nothing is known about feeding or prey in Oman.

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, Oman's only record of this species was of a group sighting reported in October 2012 off Dhofar (Figure 13). This consisted of between 15-25 individuals which is typical of this highly sociable species that is often recorded elsewhere in pods of 10-20 individuals, with school sizes of 20-90 individuals [12,98,101].

There are no global population estimates for this species, in spite of a number of regional abundance records around the world [98,101]. However, Short-finned Pilot Whales have been described as 'relatively abundant' around the Maldives and in the northern Indian Ocean more generally [44,104].

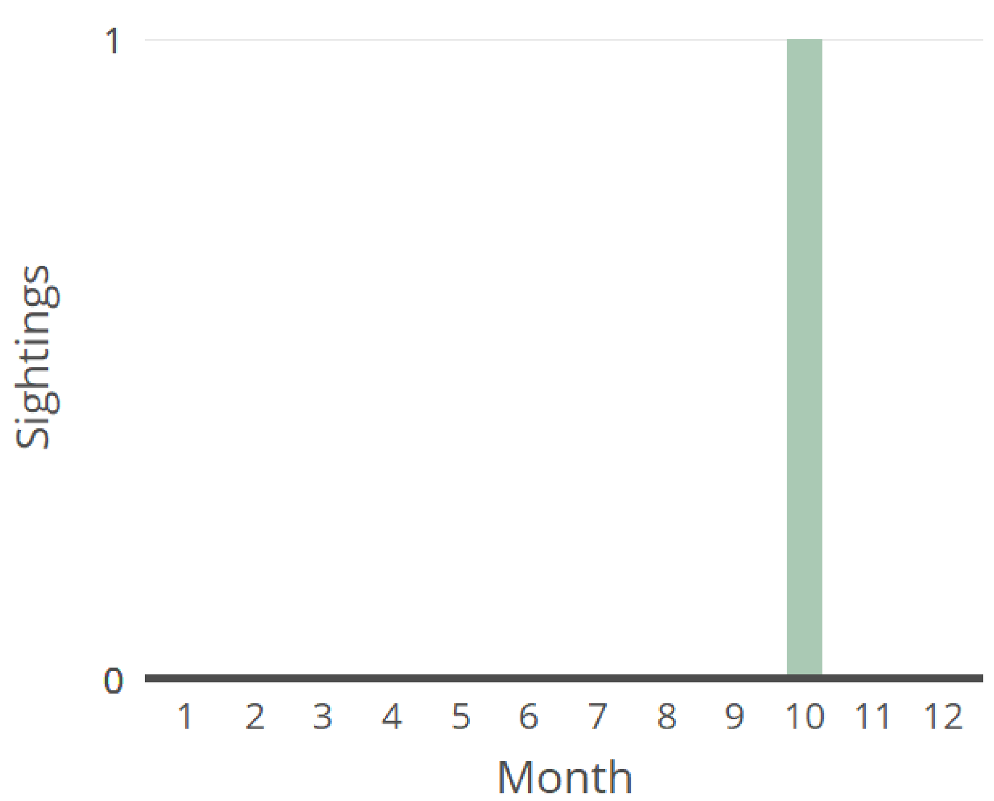
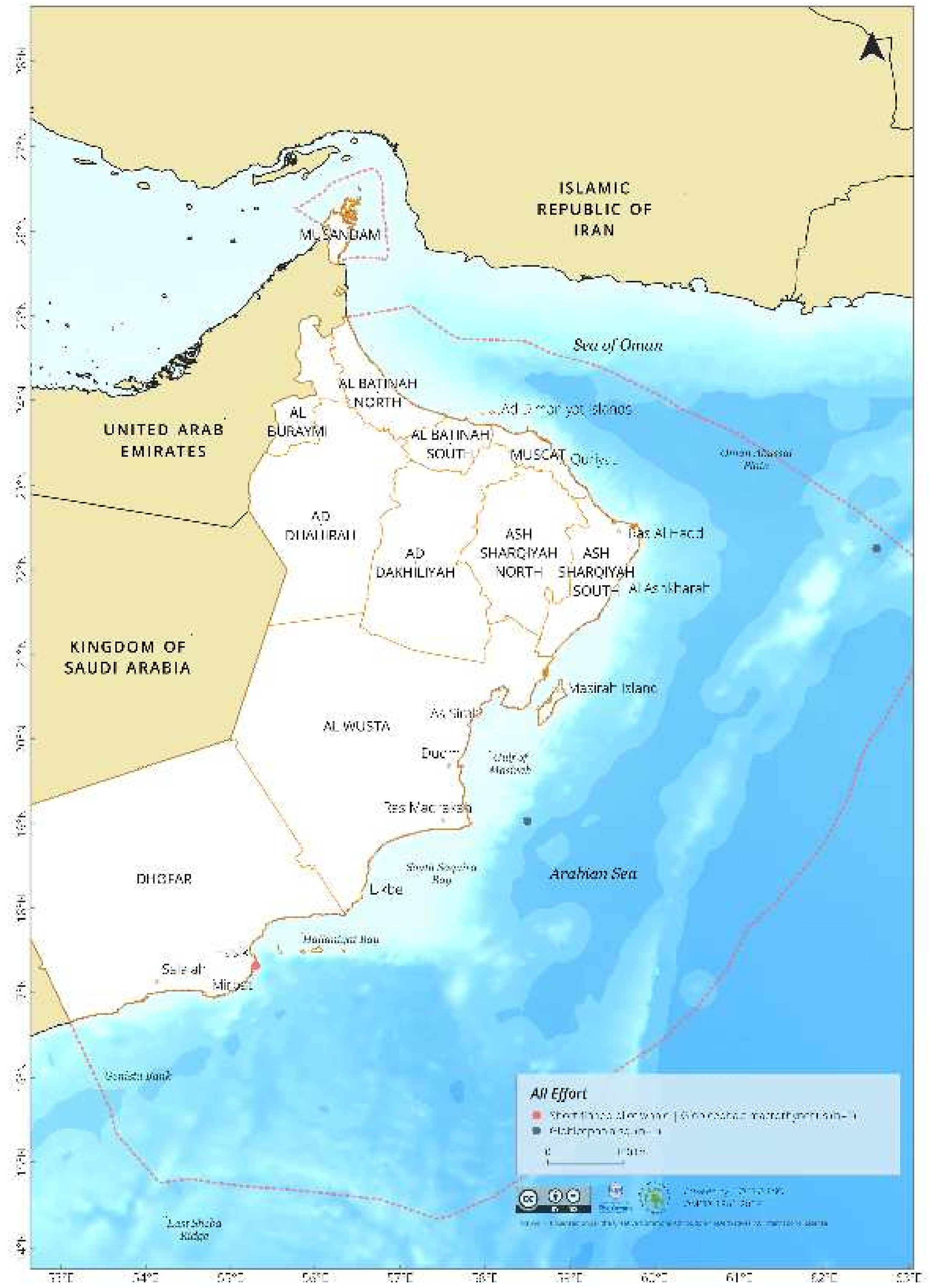
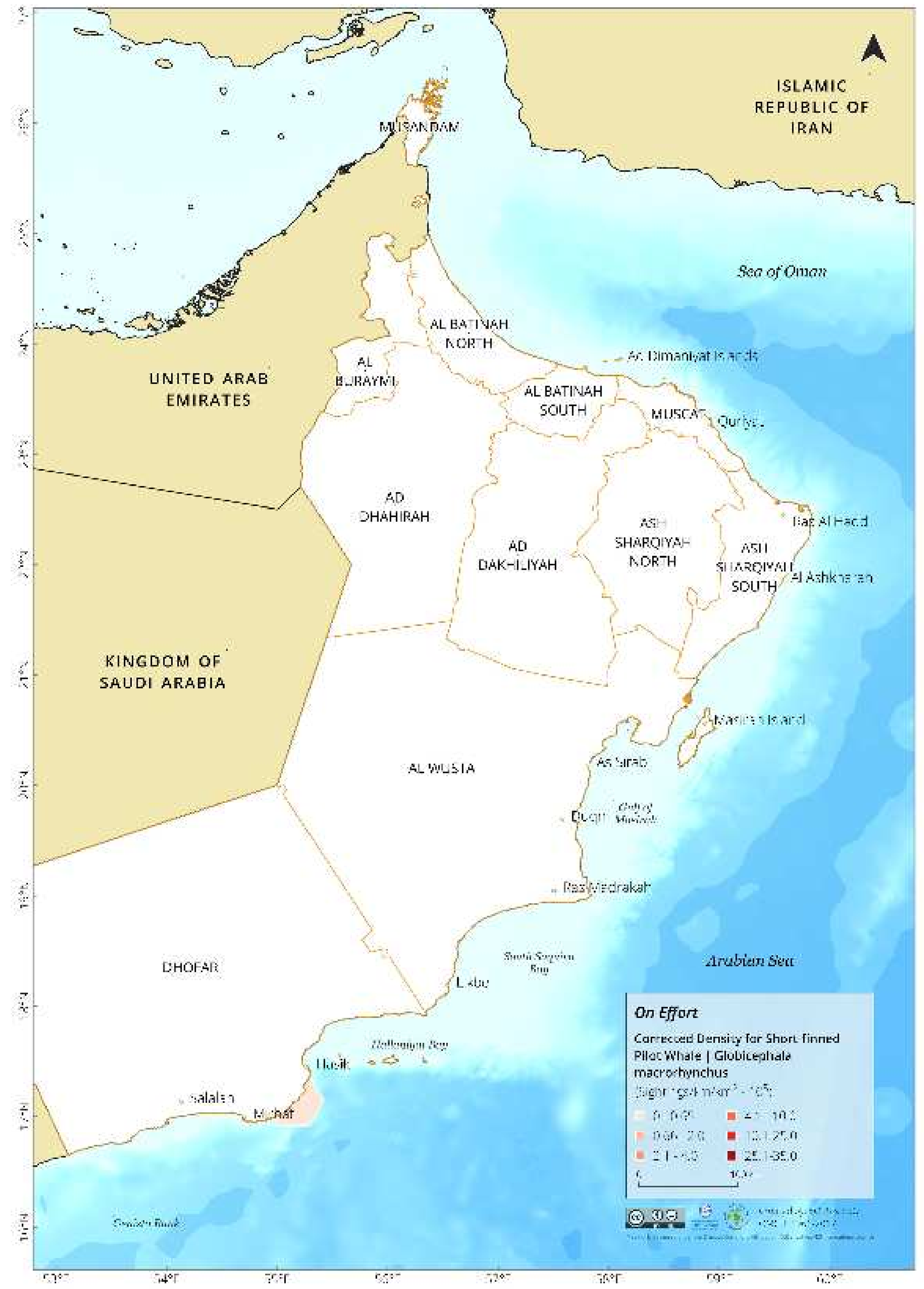


Figure 13) Short-finned Pilot Whale (Globicephala macrorhynchus) in 2012 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)





INDIAN OCEAN HUMPBACK DOLPHIN

الدولفين الأحدب [Al Dolpheen Al Ahdab]

Sousa plumbea

length : up to 3.14m

280 KG

GLOBAL | *Endangered* **REGIONAL** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 50 *Best Estimate: Average* 10.68 *Standard Deviation* 13.35

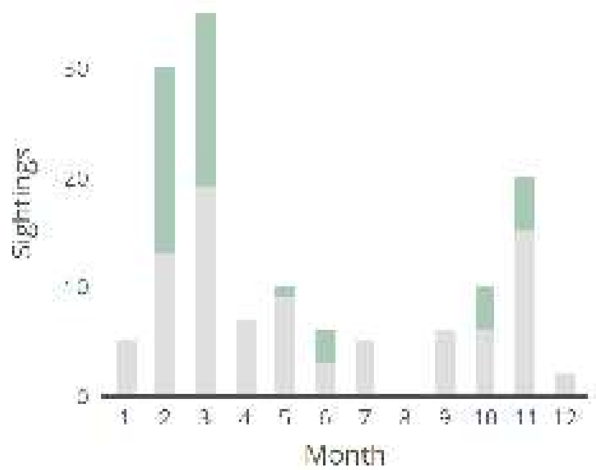
THE INDIAN OCEAN HUMPBACK DOLPHIN, was previously referred to as the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) until, in 2014, results of genetic studies, as well as characteristics of external and skeletal morphology, and colour, led to the identification of *Sousa plumbea* as a distinct species [105,106]. Of the humpback dolphins sampled throughout the western Indian Ocean (n=94), samples from Oman (n=58) showed the highest genetic diversity, longest divergence times and also the greatest number of haplotypes unique to the area [107], suggesting the potential for colonisation of new habitats in East Africa by animals from Arabia.

The geographic range of the Indian Ocean Humpback Dolphin extends from South Africa to at least the southern tip of India, and in Oman specifically includes coastal waters of the Arabian Sea, a small part of the Sea of Oman and the Arabian Gulf [108,109]. There is an unexplained break in distribution in Oman between Musandam and Ras al Hadd, suggesting the presence of discrete regional populations [12, 110]. This species has a very narrow habitat niche, preferring depths of less than 25m in coastal habitats within 3km of shore [111], with many sightings in Oman recorded very close to shore [108]. Largely because of this, as well as a naturally low reproductive rate, Indian Ocean Humpback Dolphins are very susceptible to environmental change and anthropogenic threats and are in danger of extinction [108,110,111].

Analysis of the stomach contents of stranded animals retrieved from the Gulf of Masirah revealed a narrow prey focus consisting of inshore fish species, such as catfish (*Arius* sp.) and croakers (*Otolithes ruber* and *Johnius* sp.) that inhabit murky waters with a muddy substratum [112]. These data, combined with direct observations, imply that the Gulf of Masirah may provide important feeding grounds for the Indian Ocean Humpback Dolphin [110,112].

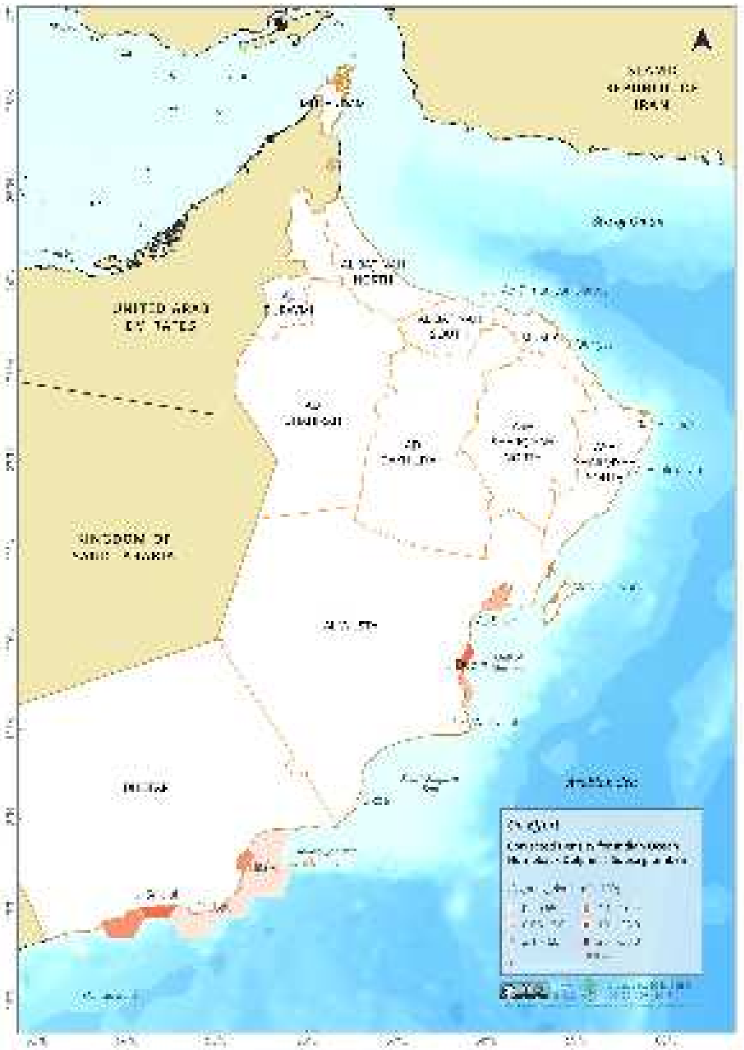
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of Indian Ocean Humpback Dolphins in Oman are documented for all but the month of August (Figure 14). They are seldom sighted in solitude; large group sightings with pairings of calves, juveniles and adults have been reported in the Dhofar, Musandam and North Al Wusta regions, and this species is known to be a breeding resident of Oman [12,110]. Out of a total of 136 sighting records, approximately 34% were identified during on-effort surveying. The distribution of Indian Ocean Humpback Dolphins appears to be largely concentrated off Al Wusta, Dhofar and parts of Musandam. On-effort corrected density sightings particularly highlight the Gulf of Masirah and the Dhofar coastline to be potential areas of importance.

In southern Oman (off Al Wusta and Dhofar) in the early 2000s, this species was one of the most commonly recorded coastal cetaceans, with large group sizes of greater than 40 individuals frequently recorded, ranging up to ‘superpods’ of a hundred or more [110]. Whilst no population estimates are available for Oman, numbers of *S. plumbea* are thought to have dropped over the past two decades due to anthropogenic impacts and associated high mortality rates [113,114]. Globally, the total population of Indian Ocean Humpback Dolphins is estimated to be as low as a few tens of thousands across habitats that are restricted and discontinuously distributed [106,108].



TOTAL | 46 90 On Effort Off Effort

Figure 14) Indian Ocean Humpback Dolphin (Sousa plumbea) sightings from 1986 to 2015 by month. Sightings are categorized as on-effort (during active watch on surveys), or off-effort (during survey but off watch or during another sighting, third party reports, shore-based observations)



COMMON BOTTLENOSE DOLPHIN

الدولفين العام القاروري الأنف [Dolpheen Al Aam Al Qarorie Al Anf]

Tursiops truncatus

length : *up to 4m*

650

GLOBAL | *Least Concern*   ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 10 *Maximum* 125 *Best Estimate: Average* 38.68 *Standard Deviation* 82.53

THE COMMON BOTTLENOSE DOLPHIN belongs to the family Delphinidae. Its scientific name, *Tursiops truncatus*, was previously the name given to all bottlenose dolphins around the world [115]. However, in 1999 molecular data supported the separate classification of *T. aduncus*, the Indo-Pacific Bottlenose Dolphin [116,117]. The Common Bottlenose Dolphin itself is divided into three subspecies: the Black Sea Bottlenose Dolphin (*T. t. ponticus*), Lahille's Bottlenose Dolphin (*T. t. gephyreus*) of the western South Atlantic Ocean, and the nominate subspecies that includes the remaining Common Bottlenose Dolphins worldwide (*T. t. truncatus*) [2]. Those in Oman are currently assigned to this third nominate subspecies.

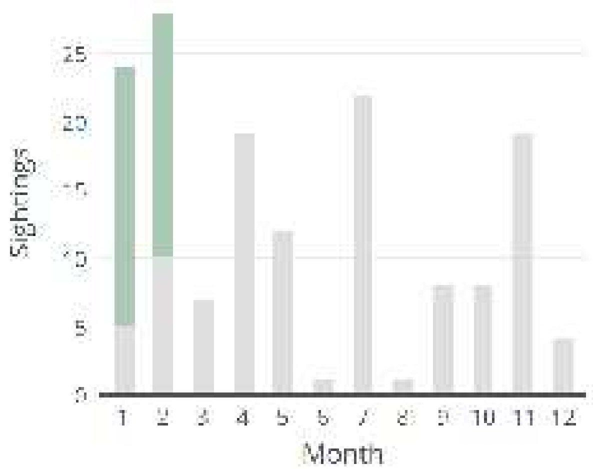
The Common Bottlenose Dolphin has a cosmopolitan, circumglobal distribution [118], including tropical and temperate inshore, coastal, shelf and oceanic waters [115] extending from the Faroe Islands in northern Europe to southern New Zealand, with records extending as far as 53-55° S off South America [119,120,121]. In Oman, they are widely distributed from waters off Salalah, Dhofar in the south to the north of Musandam [10,12]. This species inhabits an extensive range of habitats from deep pelagic to shallow coastal waters [118,122], but is most often seen offshore in Oman [12].

The diet is primarily made up of squid and fish, though they may also prey upon crustaceans such as shrimp [123,124,125,126]. A stranded Common Bottlenose Dolphin examined in Muscat was found to contain mainly pelagic prey species, including tuna, in its digestive tract [112].

In Oman, this species is thought to be a breeding resident based on year round sightings and presence of calves. It may occur in groups of several hundred and has been observed to mix with other species, including Indo-Pacific Bottlenose Dolphins, Risso's Dolphins, Rough-toothed Dolphins, Indian Ocean Humpback Dolphins and Humpback Whales [12,41], as well as more recently (2018), False Killer Whales.

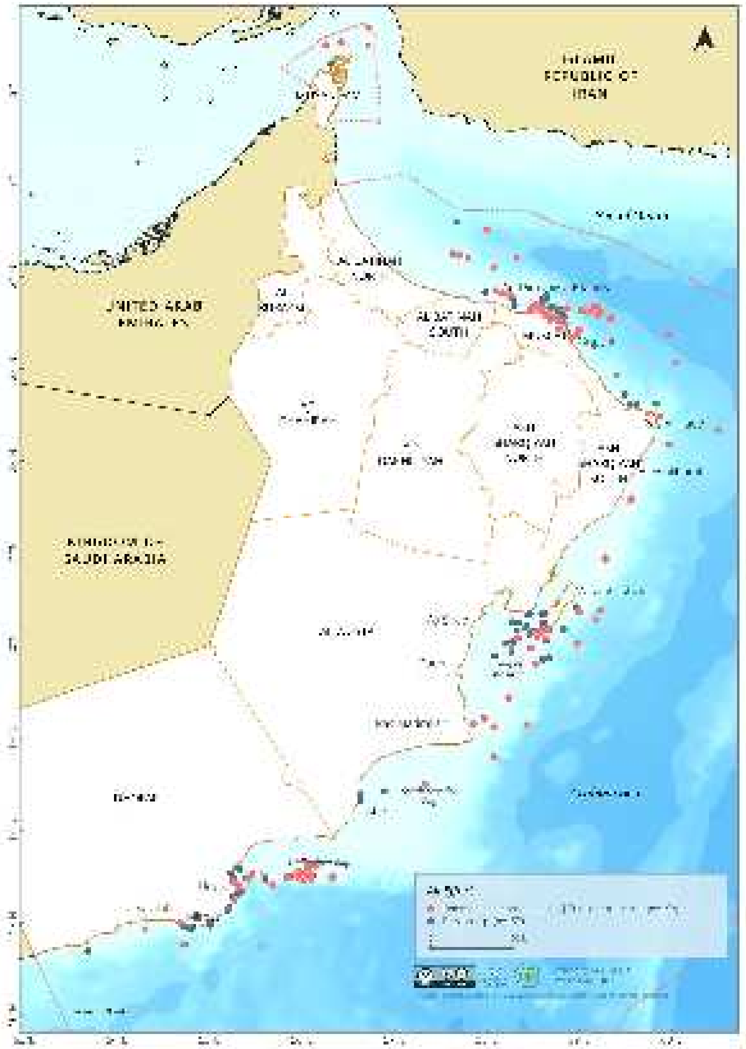
COMMON BOTTLENOSE DOLPHINS have been reported year-round in Oman (Figure 15). Based on data collected between 1961 and 2017, of the 153 sightings, 24% were reported during on-effort surveying. Although very widely distributed, on-effort corrected density analysis highlights waters off Al Hallaniyah as a key area of potential importance.

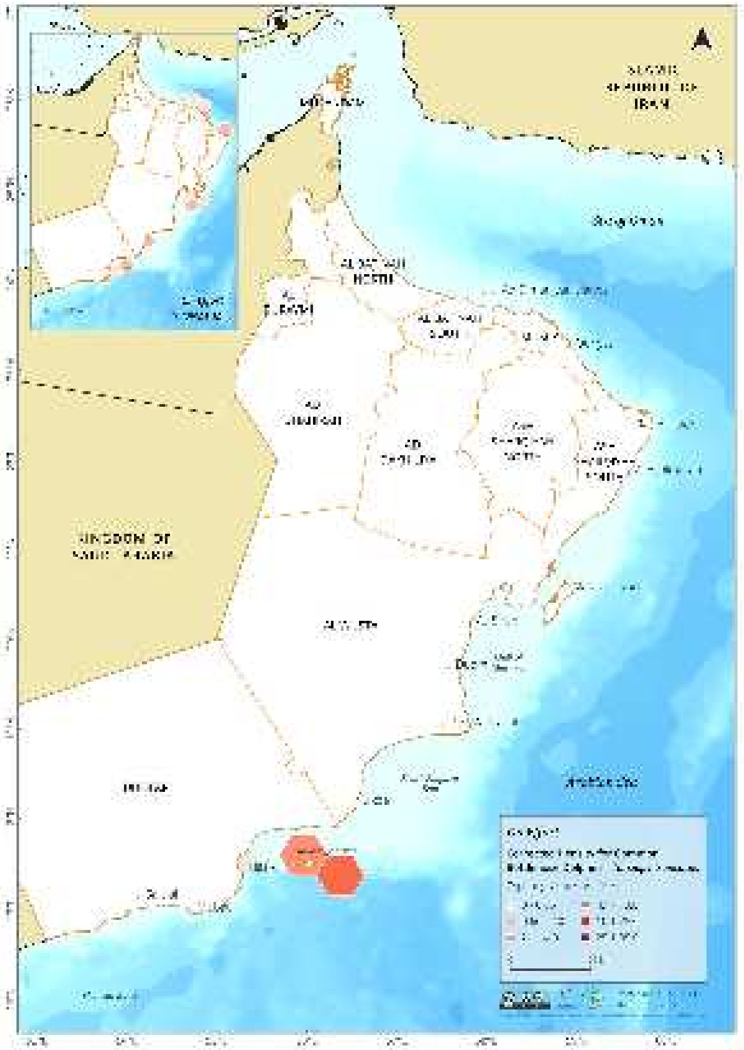
Population abundance estimates for this species off Oman have not been attempted, but it is thought to be relatively common. Worldwide abundance is estimated at ~750,000 individuals [115].



TOTAL | 37 116

Figure 15) *Common Bottlenose Dolphin (*Tursiops truncatus*) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*





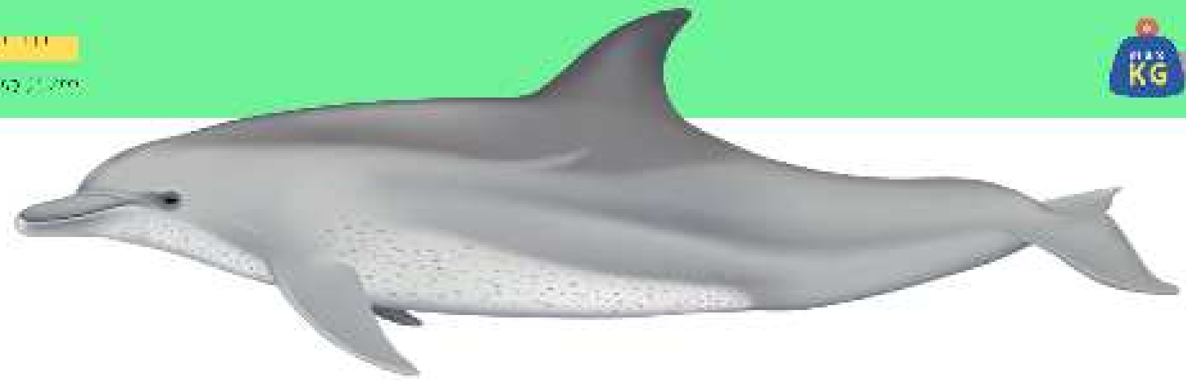
INDO-PACIFIC BOTTLENOSE DOLPHIN

دولفين المحيط الهندي – الباسيفيكي القاروري الأنف [Dolpheen Al Mohit Al Hindi – Al Pacifici Qarrori Al Anf]

Tursiops aduncus

length : *up* [illegible]

MAX KG 230



GLOBAL | *Near Threatened* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 500 *Best Estimate: Average* 51.37 *Standard Deviation* 76.01

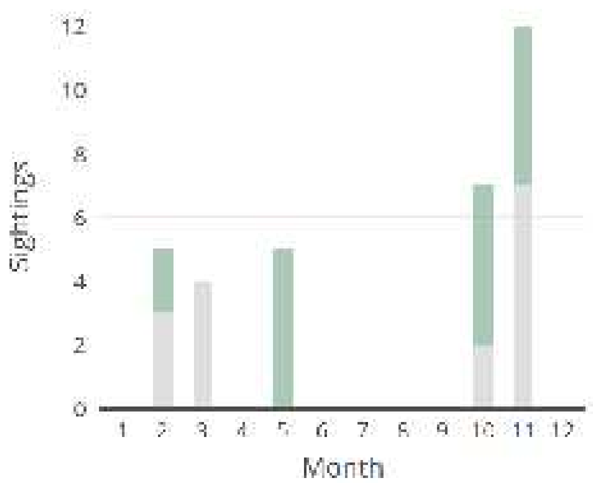
THE INDO-PACIFIC BOTTLENOSE DOLPHIN, *Tursiops aduncus*, is a member of the family Delphinidae and is closely related to the Common Bottlenose Dolphin (*T. truncatus*). However, it is smaller, slimmer and has a comparatively longer beak than the Common Bottlenose Dolphin, as well as often-spotted undersides [12,117]. It was formally recognized as a separate species of *Tursiops* in 1999 [116,117,127]. Prior to this date all Bottlenose Dolphins in Oman were identified as *T. truncatus* and *T. aduncus* was unrecorded [12]. The pre-1999 data used in analysis for the two *Tursiops* species in this Atlas have been separated, wherever possible, based on relevant metadata associated with records. Genetic analyses conducted on tissue samples collected in the Arabian Sea revealed evidence for a new *'aduncus'* type lineage that diverged from the holotype Australasian lineage approximately 261 thousand years ago [128]. This new lineage co-occurs with the Australasian lineage in Oman, with the new lineage thought to be centred in the Gulf of Masirah. This lineage, as well as four or five other different lineages (such as those from Africa, Pakistan, Bay of Bengal, China and Australia) [129] may eventually be recognized as a distinct subspecies of *T. aduncus*.

The distribution of the Indo-Pacific Bottlenose Dolphin is discontinuous, but spans tropical and warm-temperate waters of the Indo-Pacific region, and commonly occurs in estuarine and shallow coastal waters surrounding oceanic islands or on the continental shelf [93,129,130,131]. In Oman, Indo-Pacific Bottlenose Dolphin distribution is predominantly coastal, extending from the very south of Oman, off Dhofar, to the north of Musandam [12,41], and is frequently associated with shallow coral and mixed benthic communities. Habitat overlap and associations with other species has been observed in the Hallaniyat Bay area [41] and probably occurs more widely (for example with the Indian Ocean Humpback Dolphin). The relatively intensive anthropogenic use of coastal habitat in Oman, makes the Indo-Pacific Bottlenose Dolphin very susceptible to potential population decline [12]. Anecdotal evidence for this has been noted in the Gulf of Masirah and Muscat region where local sightings of this species were once common but have declined to almost zero over the past three decades.

This species' diet consists mostly of cephalopods and an extensive range of reef, demersal and schooling fish [132,133,134]. The stomach contents of stranded specimens from the Gulf of Masirah (n=10) included shallow water cephalopods and reef associated species such as the cuttlefish, *Sepia pharaonis* and demersal fishes such as the croaker, *Otolithes ruber* [112].

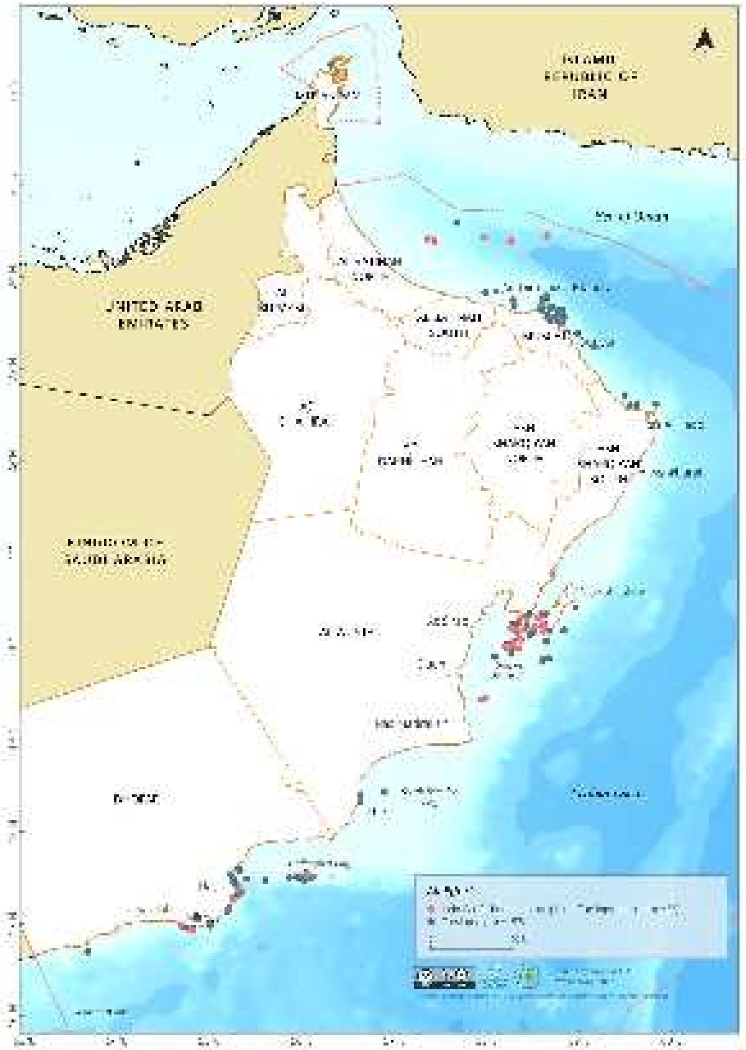
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sighting of Indo-Pacific Bottlenose Dolphins in Oman are reported in five months of the year, but anecdotal reports from specific areas (such as Al Hallaniyah) indicate active breeding and year-round residency (Figure 16). Group size varies from 5-20 individuals, which is typical of this species [93], up to several hundred, with largest groups recorded in the North Al Wusta region. Of the 33 confirmed sightings, 52% were reported during on-effort-surveys. Records are mostly clustered around Muscat, Masirah Island and Dhofar, whilst effort-corrected density analyses highlight the Gulf of Masirah as potentially important habitat for the Indo-Pacific Bottlenose Dolphin.

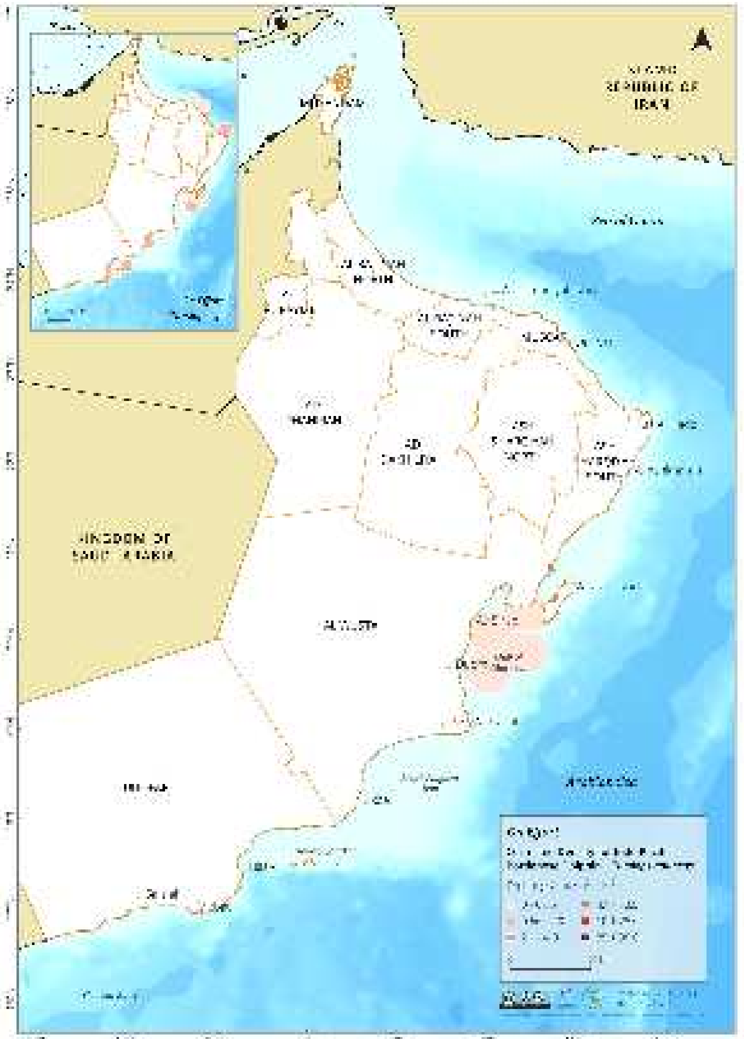
Population abundance estimates are not available for this species in Oman, but anecdotal evidence suggests it may be in decline. Globally, 40,000 or more individuals are estimated [129].



TOTAL | 17 16

Figure 16) *Total number of Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*) sightings from 1961 to 2017 by month. Sightings are categorized by on effort (optimal observation conditions), or off effort (sub-optimal conditions, third party reports, during acoustic watch, shore-based surveys, or during another sighting).*





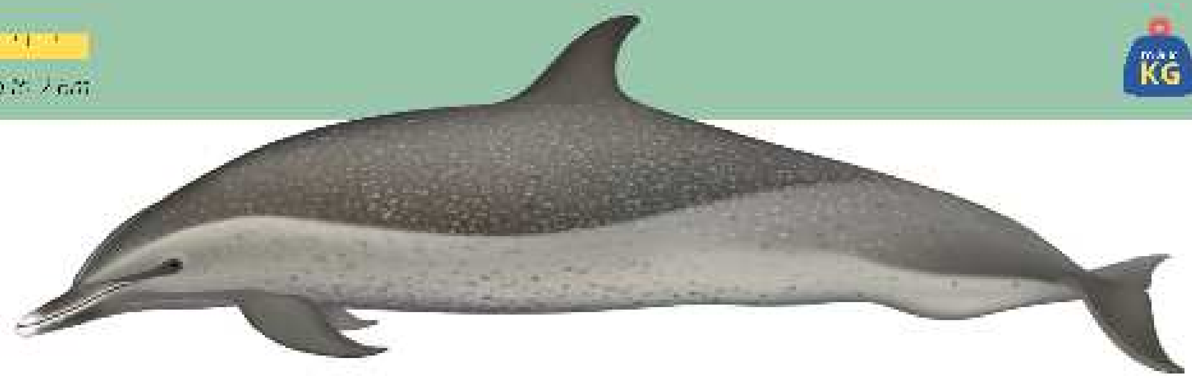
PANTROPICAL SPOTTED DOLPHIN

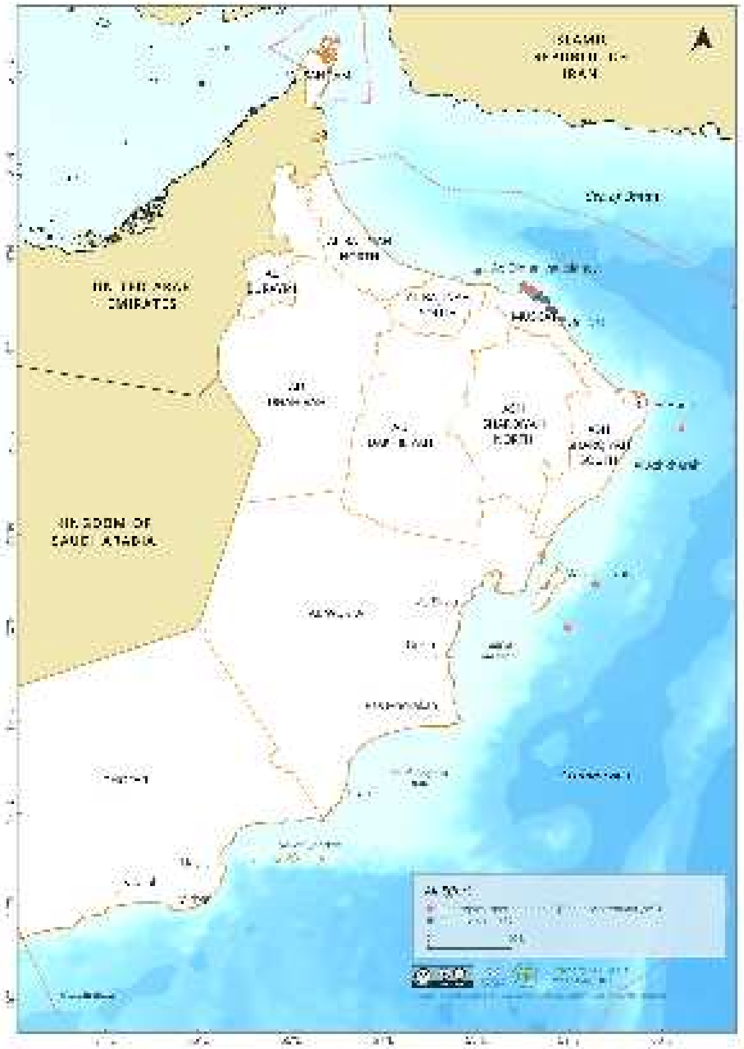
الدولفين المداري المبقع [Al Dolphine Al Madare Al Mobaqaa]

Stenella attenuata

length : *up [illegible]*

119





No locally taken photos

GLOBAL | *Least Concern* ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* - *Maximum* - *Best Estimate: Average* 208.00 *Standard Deviation* 284.13

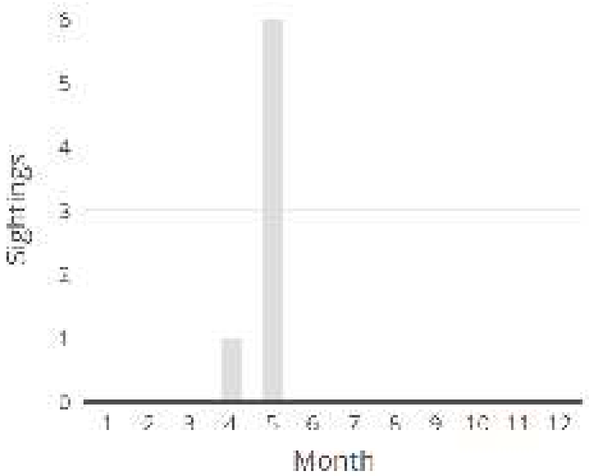
THE PANTROPICAL SPOTTED DOLPHIN is a member of the family Delphinidae and was separated from the Atlantic Spotted Dolphin (*S. frontalis*) following revision by Perrin et al. [135]. Currently, two subspecies of Pantropical Spotted Dolphin are recognised: *S. a. attenuata* in oceanic waters and *S. a. graffmani* in coastal waters of the eastern tropical Pacific [2,136]. Oman's dolphins are thought belong to the oceanic subspecies *S. a. attenuata*.

As its common name suggests, the Pantropical Spotted Dolphin occurs in tropical waters in the Atlantic, Pacific and Indian oceans, roughly between 40°N to 40°S [93,137]. It is mainly oceanic, occurring across a variety of oceanic habitats [92,136,138], though they are also common on reef slopes and around oceanic islands and archipelagos [90,91,92,138]. In Oman, this species has mostly been seen well offshore, but also occasionally a few kilometres from the coastline (off Muscat for example) where the bathymetry slopes steeply, in which cases it was observed in mixed pods with both Spinner and Indo-Pacific Common Dolphins [12]. Mixed-species associations with Spinner Dolphins are a common occurrence for Pantropical Spotted Dolphins [12,136,137].

Nothing is known about the diet of the Pantropical Spotted Dolphin in Oman, but elsewhere in the world it preys mostly on pelagic fishes, squid, and crustaceans [12,137], although there is variation among populations [136]. The breeding status of this species in Oman is also not known, but calves and juveniles have been observed, distinguishable not only by their size, but also a complete lack of the characteristic spotting which adults usually show in Oman.

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings of Pantropical Spotted Dolphins in Oman have occurred in the months of April and May only (Figure 17). These sightings were all reported 'off-effort' and corrected density sightings analysis is therefore not possible. Sightings involved large groups (up to 500 or more) in the northern Muscat region.

Global population trends or estimates of abundance are not yet known, although regional estimates of abundance in the eastern tropical Pacific (~1,300,000 individuals, [139]), Hawaii (~16,000 individuals, [89]), and northern Gulf of Mexico (~51,000 individuals, [140]) have been noted. There are no population abundance estimates for Oman.



TOTAL | 0 7

Figure 17) *Pantropical Spotted Dolphin (*Stenella attenuata*) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*

No on effort sightings were reported within the areas of measured vessel effort.

No locally taken photos

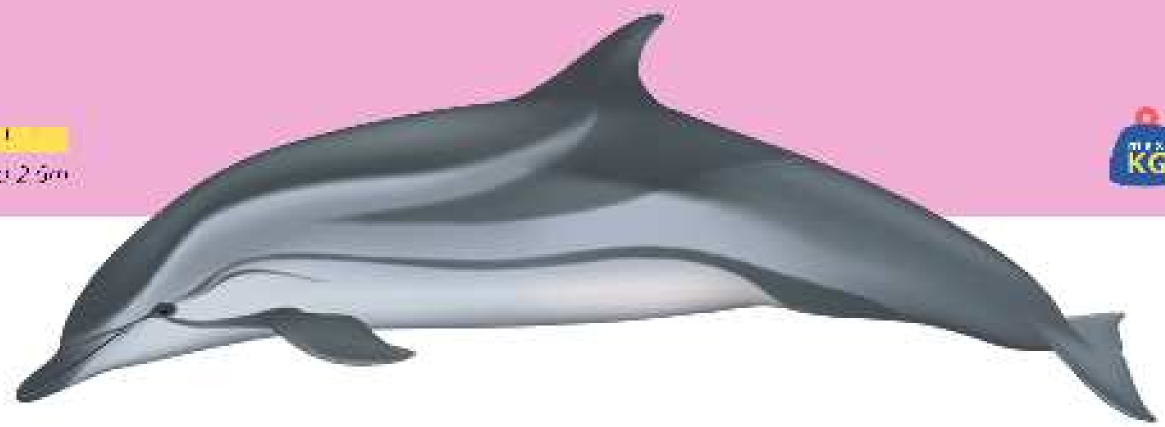
STRIPED DOLPHIN

الدولفين المخطط [Al Dolpheen Al Mukhatat]

Stenella coeruleoalba

length *: up to 2.5m*

160



GLOBAL | *Least Concern*   ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* -   *Maximum* -   *Best Estimate: Average* -   *Standard Deviation* -

THE STRIPED DOLPHIN is a member of the family Delphinidae. Although no sub-species currently exist [2], recent genetic analyses suggests isolation of some populations [141,142]. Nothing is currently known about population structure in Oman.

The Striped Dolphin is a cosmopolitan species which inhabits tropical, subtropical and temperate waters in the Atlantic, Pacific, and Indian Oceans [93,143,144]. It has only very rarely been recorded in Oman [10,12], mostly as strandings, and little is therefore known about its distribution in the Sultanate's waters. However, it is considered likely that it occurs, albeit rarely, throughout the country and/or is restricted to deep, seldom surveyed waters far from shore [12].

*No reported Striped Dolphin (*Stenella coeruleoalba*) sightings from 1961 to 2017 by month.*

THERE HAVE BEEN NO SIGHTINGS OF THE STRIPED DOLPHIN, (*Stenella coeruleoalba*) recorded during research, and only two third party-sightings have been reported. Our knowledge of this species in Oman is therefore currently very limited. It is, however, known to occur in neighbouring waters, again albeit rarely recorded, such as a 2017 record on the continental slope in approximately 300m water depth off Fujairah, United Arab Emirates, which lies between Oman's northern Batinah region and Musandam [145].

Despite the lack of global population estimates for the Striped Dolphin, high abundances have been recorded in regional areas such as the western north Pacific (570,000 individuals; [146]), nearshore Japan (~20,000 individuals; [147]), and the eastern tropical Pacific (~1,500,000 individuals; [148]). It would appear, from records to date, that this species is uncommon in the Arabian region but further survey work offshore in the future is required to assess population status.

No sightings were reported within the boundaries of the EEZ.

No on effort sightings were reported within the areas of measured vessel effort.

INDO-PACIFIC COMMON DOLPHIN

الدولفين الشائع [Al Dolpheen Al Sha'aa]

Delphinus delphis tropicalis

length

KG 235

GLOBAL | *Data Deficient* **REGIONAL** | *Not Evaluated*

GROUP SIZE | *Minimum* 1 *Maximum* 3000 *Best Estimate: Average* 317.30 *Standard Deviation* 482.50

THE INDO-PACIFIC COMMON DOLPHIN is a member of the family Delphinidae. The taxonomy of its genus, *Delphinus*, has long been under scientific discussion. Until recently, two globally distributed species of Common Dolphin were recognised: the Short-beaked Common Dolphin (*D. delphis)* and the Long-beaked Common Dolphin (*D. capensis)* as proposed by Heyning and Perrin [149]. However, it is now considered that the long-beaked condition is caused by regional ecology (to do with prey types) and in some regions, Long-beaked Common Dolphins were shown to be more closely related, genetically, to Short-beaked Common Dolphins than to Long-beaked Dolphins in other regions [2,150]. *D. capensis* is therefore no longer used and only *D. delphis* is recognised. There are, however, four recognised subspecies of *D. delphis*, including the widespread *D. delphis delphis,* as well as one in the Eastern North Pacific (*D. delphis bairdii*), one in the Black Sea (*D. delphis ponticus*) and one in the Indian Ocean (*D. delphis tropicalis*) [2]: It is the latter that occurs in Oman.

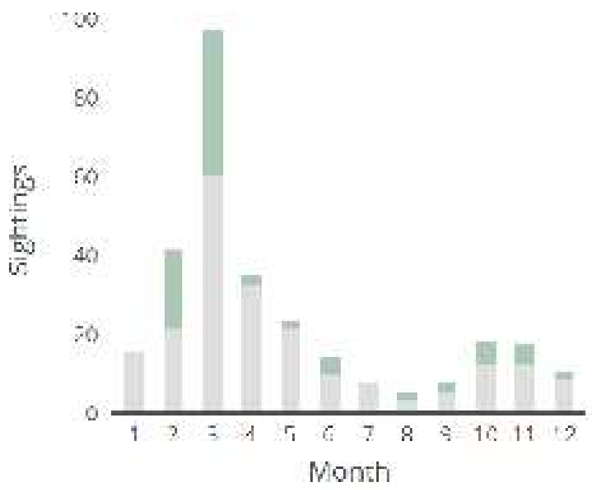
The distribution of the Indo-Pacific Common Dolphin includes, as its name suggests, a wide ranging area across the Indo-Pacific [10,151]. In Oman it inhabits waters at the edge of the continental shelf (50-200m) with group sizes of up to 3000 individuals or more [10,12,41], though it may also range further from shore.

As common dolphins occupy a wide range of habitats around the world, from nearshore areas to open ocean, their prey also varies, with those offshore concentrating on fish and squid [152] and those closer to shore targeting schooling fishes like anchovies, sardines, and mackerel, that are more common to continental shelf or coastal areas [153]. Indo-Pacific Common Dolphins in Oman have been observed feeding cooperatively on small schooling fishes, sometimes in mixed groups with Spinner Dolphins and, more rarely, Pantropical Spotted Dolphins [12]. The stomach contents of beach cast specimens have revealed a variety of fishes and cephalopods [12].

Calves have been noted often in Oman and multiple times of year, with a potential peak in spring [12], suggesting that this species is a breeding resident.

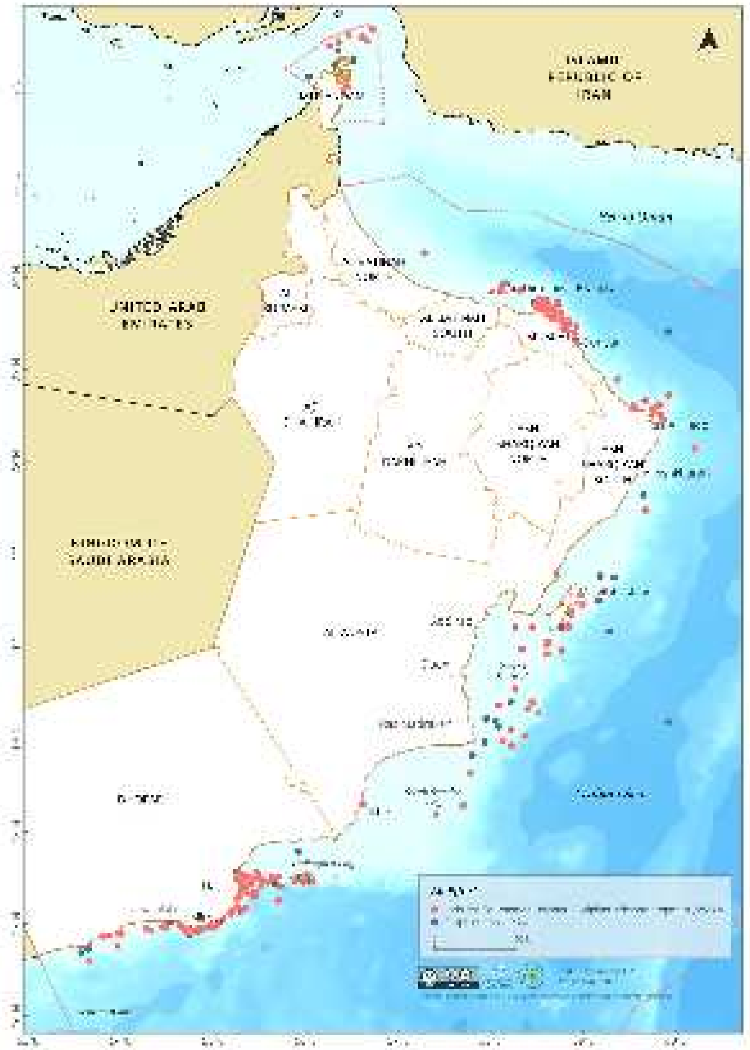
BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, sightings generally occur year round, with most records in March (Figure 18). Indo-Pacific Common Dolphins are highly social and large group sightings (n=1000+) are relatively common, including in Dhofar, Muscat, Masirah Island, Hallaniyat Bay and North Al Wusta regions. This species is known to be widely distributed throughout Oman, whilst on-effort corrected density analysis emphasizes Ras Al Hadd and the southern region of Dhofar to be hot spots.

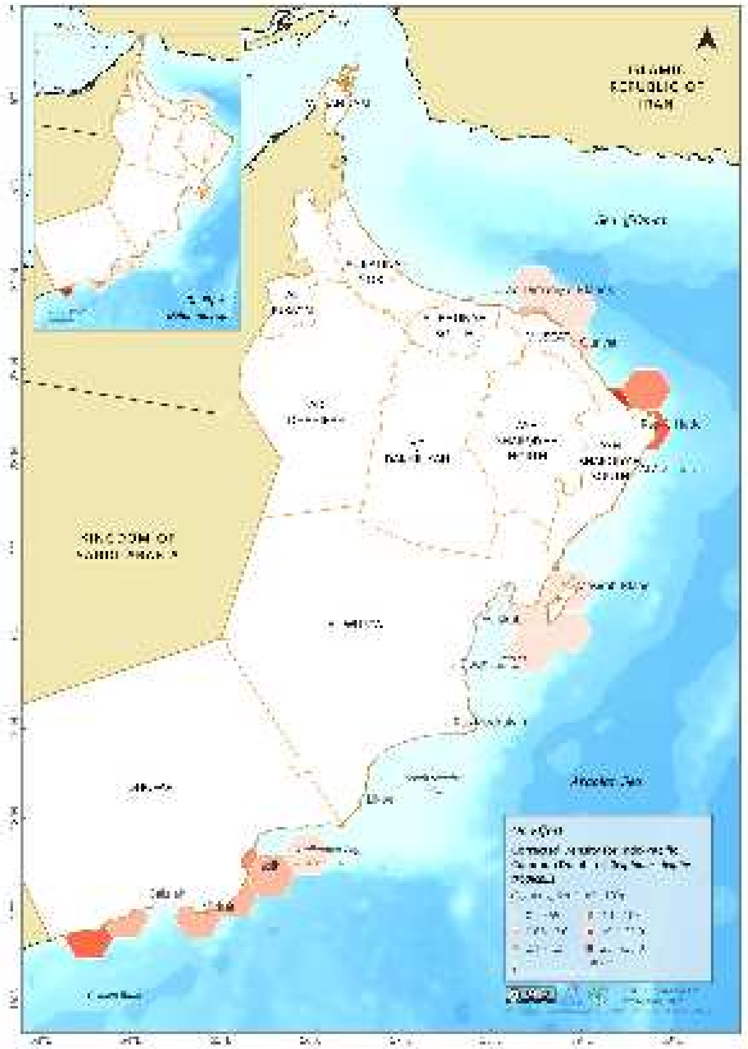
Population estimates of Indo Pacific Common Dolphins in various parts of the world show it to be a very abundant species [154]. No estimate is available for Oman, but it is considered likely to be abundant here too based on sightings records.



TOTAL | 84 205

Figure 18) *Indo-Pacific Common Dolphin (*Delphinus delphis tropicalis*) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*

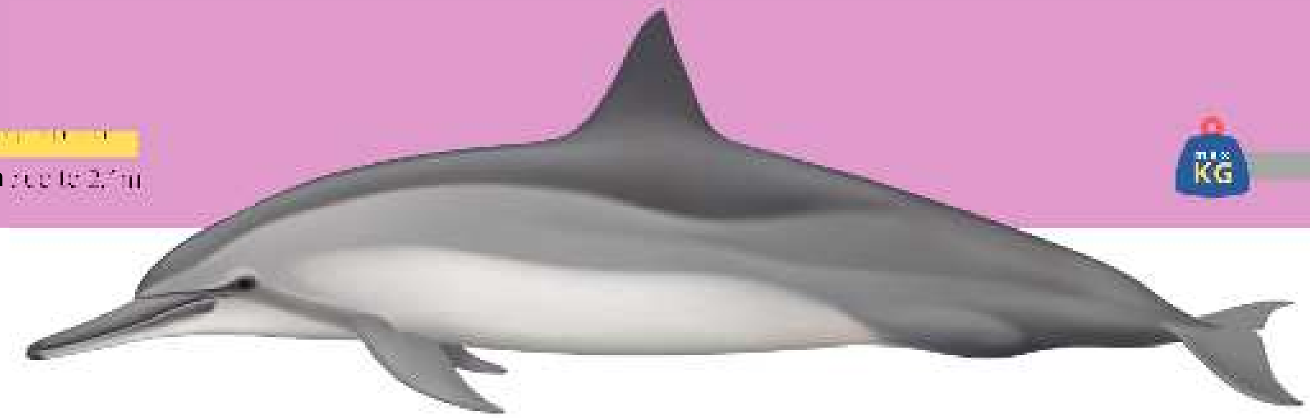




SPINNER DOLPHIN

الدولفين الدوار [Al Dolpheen Al Dowar]

Stenella longirostris



length

82

GLOBAL | *Least Concern*   ***REGIONAL*** | *Not Evaluated*

GROUP SIZE | *Minimum* 2 *Maximum* 1500 *Best Estimate: Average* 241.95 *Standard Deviation* 248.09

THE SPINNER DOLPHIN is a member of the family Delphinidae. Its common name refers to its spectacular aerial spinning displays, a behaviour unique to the species. Four subspecies are recognised [2]; *Stenella longirostris longirostris* (Gray's Spinner Dolphin), *S. l. orientalis* (Eastern Spinner Dolphin), *S. l. centroamericana* (Central American Spinner Dolphin) and *S. l. roseiventris* (Dwarf Spinner Dolphin), with Gray's Spinner Dolphin being the most commonly distributed [155,156], including in the Indian Ocean [157]. In Oman, two morphotypes of *S. l. longirostris* have been observed; a larger form with a tripartite pattern and a smaller form with less distinct pattern and elusive habits [12,41]. This smaller form may represent an as yet undescribed subspecies [85,157].

Spinner Dolphins are widely distributed in the Indian, Pacific and Atlantic Oceans, inhabiting tropical and subtropical waters in both the northern and southern hemisphere [44]. In Oman, they are most commonly encountered in the Sea of Oman where waters are subject to a distinct, shallow thermocline [12]. They appear to be less common, but still present, in the more mixed waters of the Arabian Sea. Spinner Dolphins are oceanic and in Oman are most frequently seen over the continental shelf in water depths of 50 to 400m where they mostly occupy the surface layer [12,158].

The stomach contents of Spinner Dolphins in the Muscat area revealed myctophids (lantern fish) as the primary prey items, indicating feeding in the bathypelagic and mesopelagic zones [112]. In Muscat, behavioural observations of Spinner Dolphins [158] suggests groups move offshore at night to feed (when myctophids are at the surface) and move inshore during the day-time for resting. This diurnal pattern exposes Spinner Dolphins during morning periods of rest and socialising to a high degree of disturbance from dolphin watching tour operators in the Muscat area [159].

Spinner Dolphins are known to associate with aggregations of tuna in Oman (and the wider Indian Ocean) [12]. Local fishermen in Muscat know this and follow Spinner Dolphins as a way of locating tuna which they mostly catch by hand. This behavior, however, makes the dolphins vulnerable to bycatch in larger tuna fisheries operations in the Arabian Sea [160].

BASED ON DATA COLLECTED BETWEEN 1961 AND 2017, the highest encounter rate for this species is in the Muscat area, where groups with calves are common [12]. Mating is observed year round though there appears to be a peak a calving in spring according to anecdotal sightings records (Figure 19). Group sizes generally vary from 50 to 1,800, but groups numbering approximately 300 individuals are more typical [12].

Out of a total of 213 sighting records, 32% were spotted during on-effort surveying. The remainder are third party records, mostly from privately owned recreational vessels and occasionally tourism operators. Spinner Dolphins are most frequently sighted along the northern Muscat coastline and near the Ad Dimaniyat Islands, but are also commonly seen towards Ras Al Hadd in the Ash Sharqiyah South region. On-effort corrected density sightings analysis highlights waters off the Muscat shoreline and the northern coastline of Ash Sharqiyah South, towards Ras Al Hadd, as areas of potential importance.

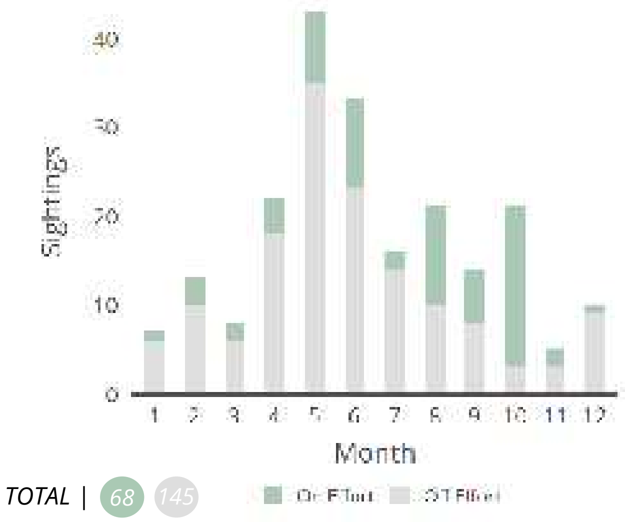


Figure 19) *Spinner Dolphin (*Stenella longirostris*) sightings from 1961 to 2017 by month. Sightings are categorized as on effort (during active watch on surveys), or off effort (during survey but off watch or during another sighting, third party reports, shore-based observations)*

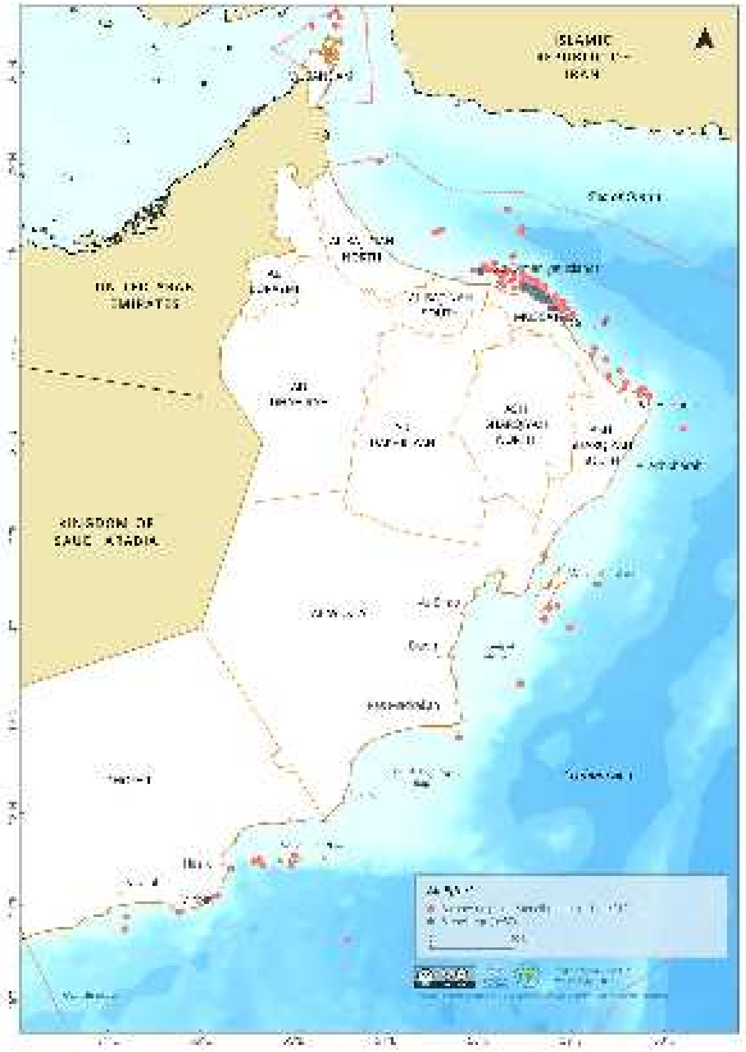


PHOTO CREDITS

1 ~ ~ ~ ~ ~ R.Baldwin
2 ~ ~ ~ ~ ~ R.Baldwin
3 ~ ~ ~ ~ ~ D.MacDonald
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5 ~ ~ ~ ~ ~ K.Findlay
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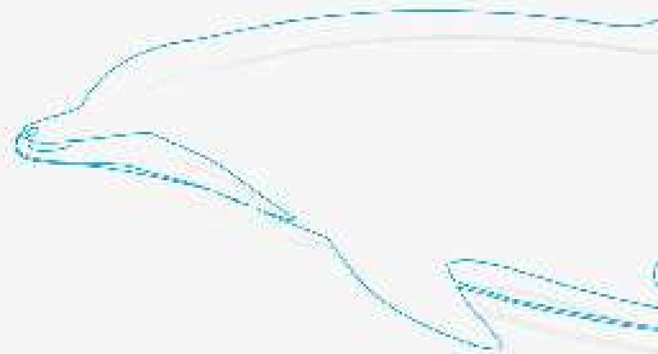

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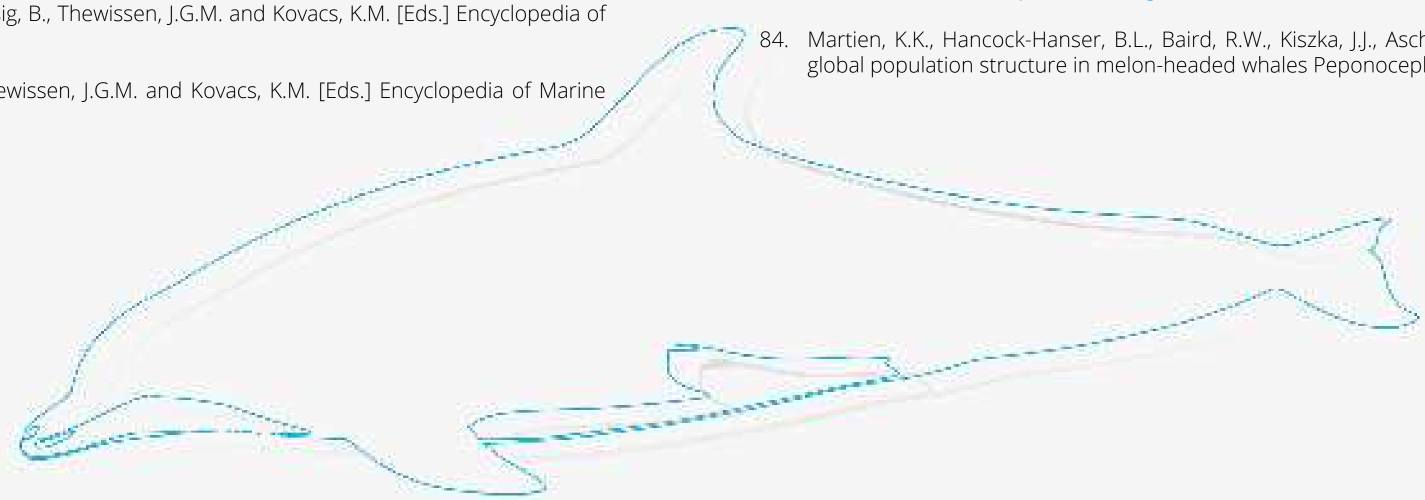

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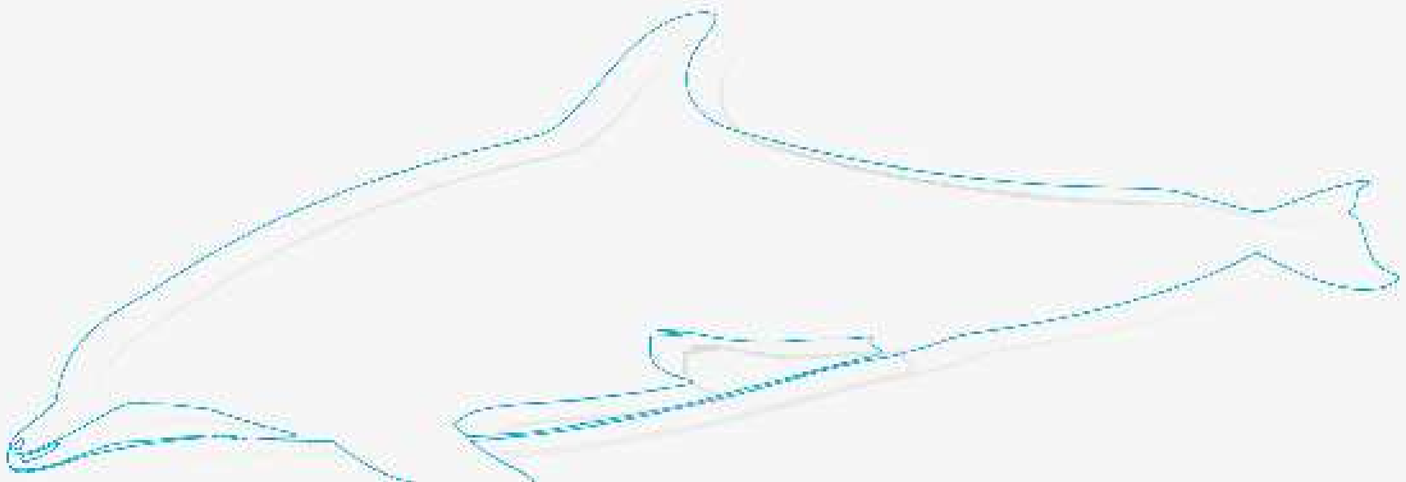

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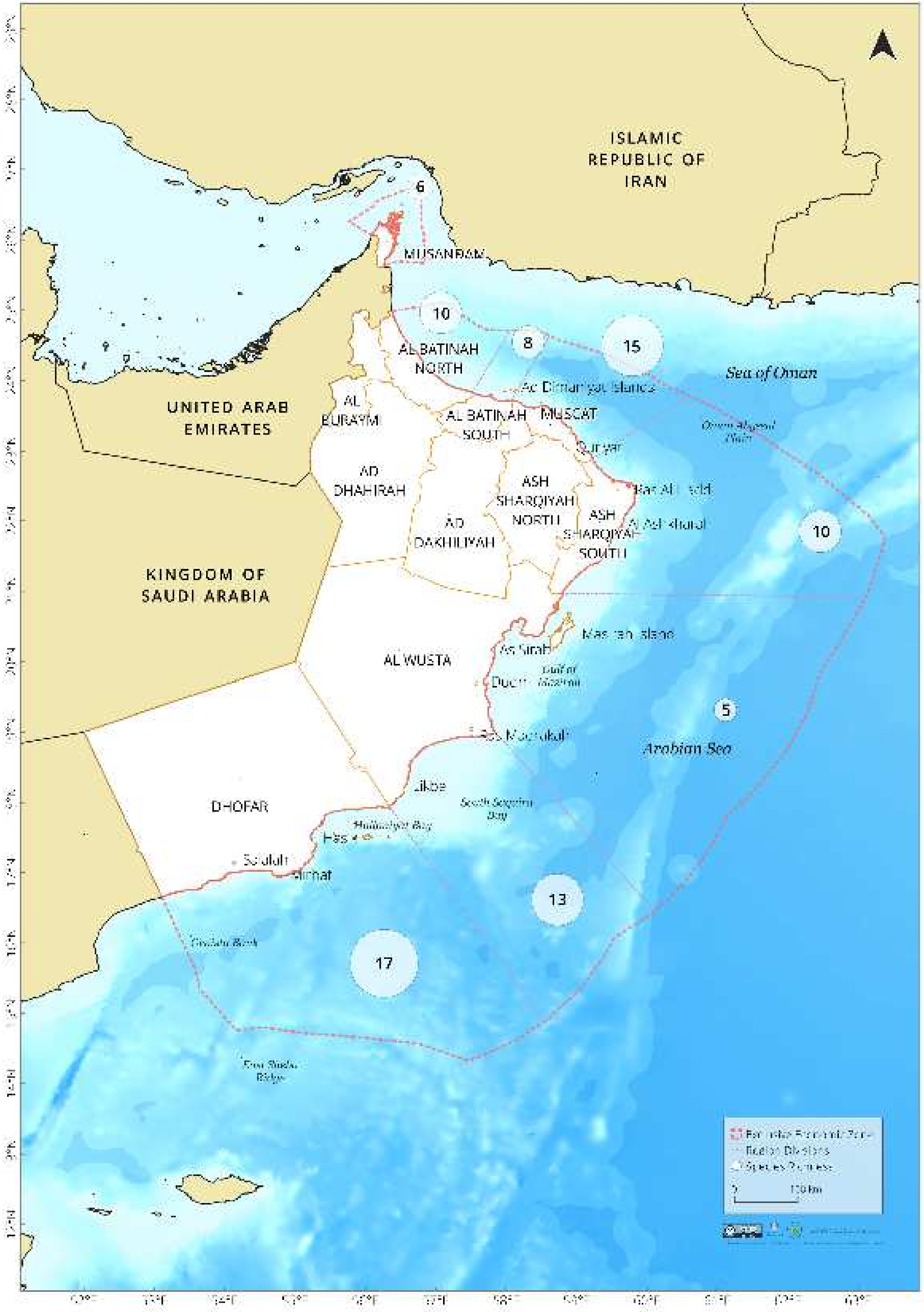
AREA ASSESSMENT

2

AREA ACCOUNTS



INTRODUCTION

THIS CHAPTER provides and overview of the cetacean species that occur in selected regions of Oman. A total of seven sea regions have been demarcated by extending the boundary line for each Oman governorate seaward as shown in the map to the right. The seven governorates of Oman are 1) Musandam, 2) Al Batinah North, 3) Al Batinah South, 4) Muscat, 5) Ash Sharqiyah South, 6) Al Wusta, and 7) Dhofar. The Al Wusta region is mostly treated as a single sea region in this section, though may sometimes be referred to elsewhere in the Atlas as Al Wusta South and Al Wusta North as these two areas have been subject to differing levels of vessel survey effort; Al Wusta North has been the subject of much greater effort. Note that the defined sea regions are arbitrary and, unlike on land, do not conform to any existing official jurisdictional mandate. The purpose of the divisions is to allow for spatial review in this Atlas at a scale that is relevant to spatial planning, policy and impact assessment at the national level. As in Chapter 1, the outer boundaries of the sea regions are aligned with the seaward extent of Oman's Exclusive Economic Zone (EEZ).

In the following pages, two maps are presented for cetacean species in Oman for each sea region: one displaying sighting locations, and the other showing species richness. Sighting distribution relative to key geomorphological features is discussed in the text accompanying the maps. Note that not all cetacean sightings correspond to a geomorphological feature and sightings may also be associated with more than one feature. The review of each region also includes a summary of observed species behaviour which provides an indication of species habitat use. It should be noted that none of the sightings data presented in this section have been corrected for survey effort and therefore include related biases.

SPECIES SIGHTINGS

* denotes reported sightings only to the family or genus level

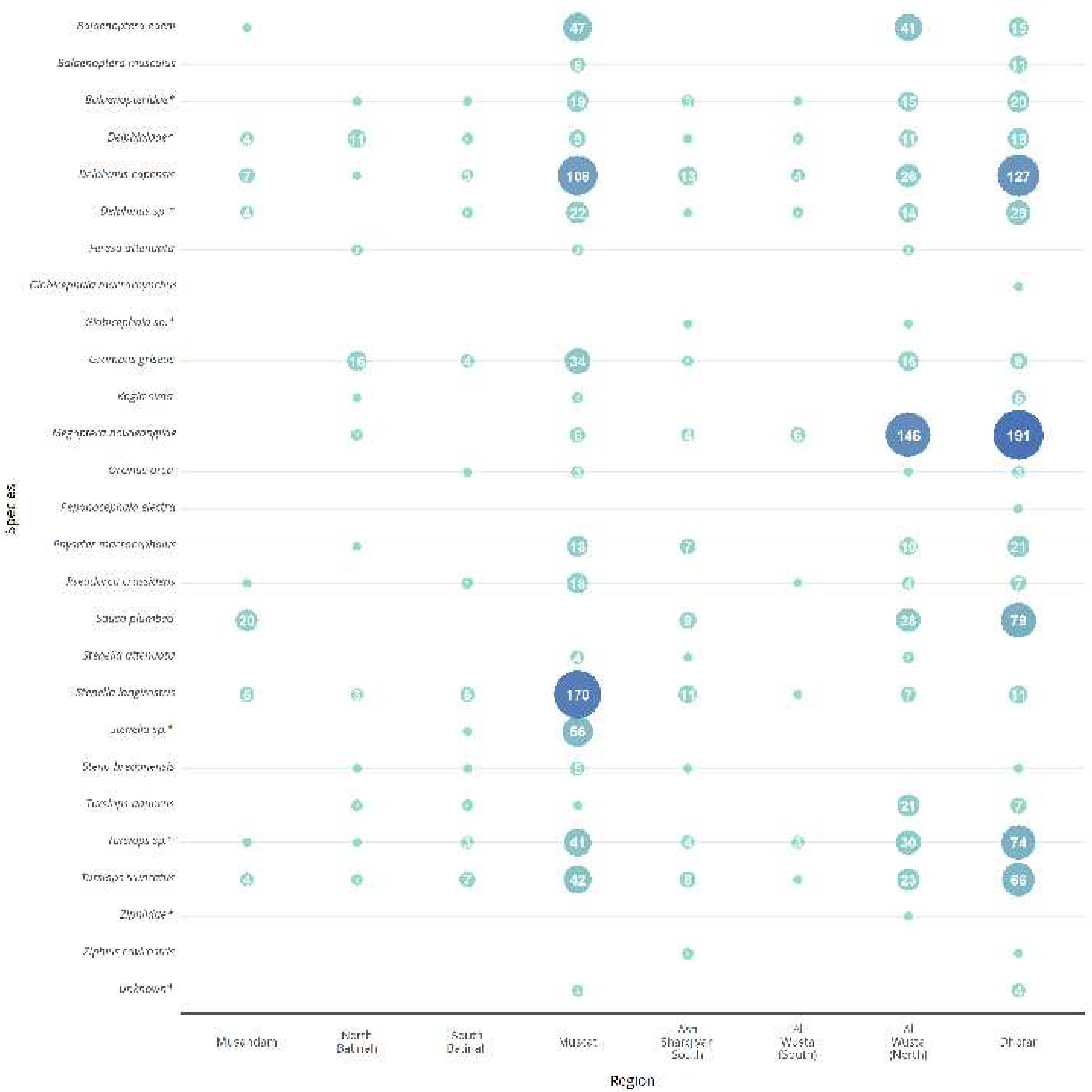


Figure 1) Summary of species sightings in the eight defined regions from the Oman Cetacean Database: 1961-2017 (Non-labelled circles indicate a record of one)

BACKGROUND

The region of Musandam is characterized by a mountainous terrestrial environment that slopes acutely to the coast. Offshore, the continental shelf is relatively narrow and the continental slope is relatively steep. The coastline is punctuated by extensive fjord like embayments, most of which are relatively flat-bottomed. In the winter months of January-March, mean monthly (night time) sea surface temperatures range from 22.2˚C to 23.0˚C compared to a range of 29.6˚C to 30.3˚C in the summer months of June-August. Mean monthly Net Primary Productivity (NPP) is at its maximum during the winter season with an average of 3,917-4,290 gC/m^2/day. During the summer months, NPP is consistently lower (839-1,063.5 gC/m^2/day). Its location and geomorphology make coastal areas of Musandam among the least exposed to wave action and ocean swells.

SPECIES SIGHTINGS (n = 47)

In the Musandam region, a total of 6 cetacean species have been recorded, predominantly in northern waters. A large proportion of records (n=43) corresponds with key geomorphological features. This includes the outer continental shelf (47%), followed by the mid continental shelf (33%), and inner continental shelf (14%). Other notable species distribution includes the shelf valley (5%), and basin (2%).

SPECIES RICHNESS

The highest species richness in the Musandam region occurs off the north west of the peninsula with up to 5 species documented in a single 15km diameter hexagon.

MUSANDAM

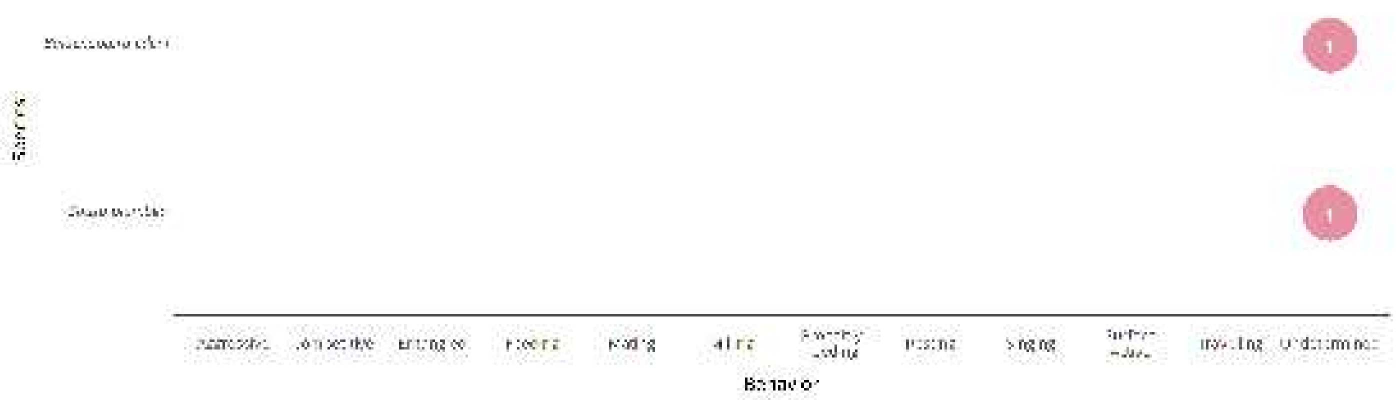
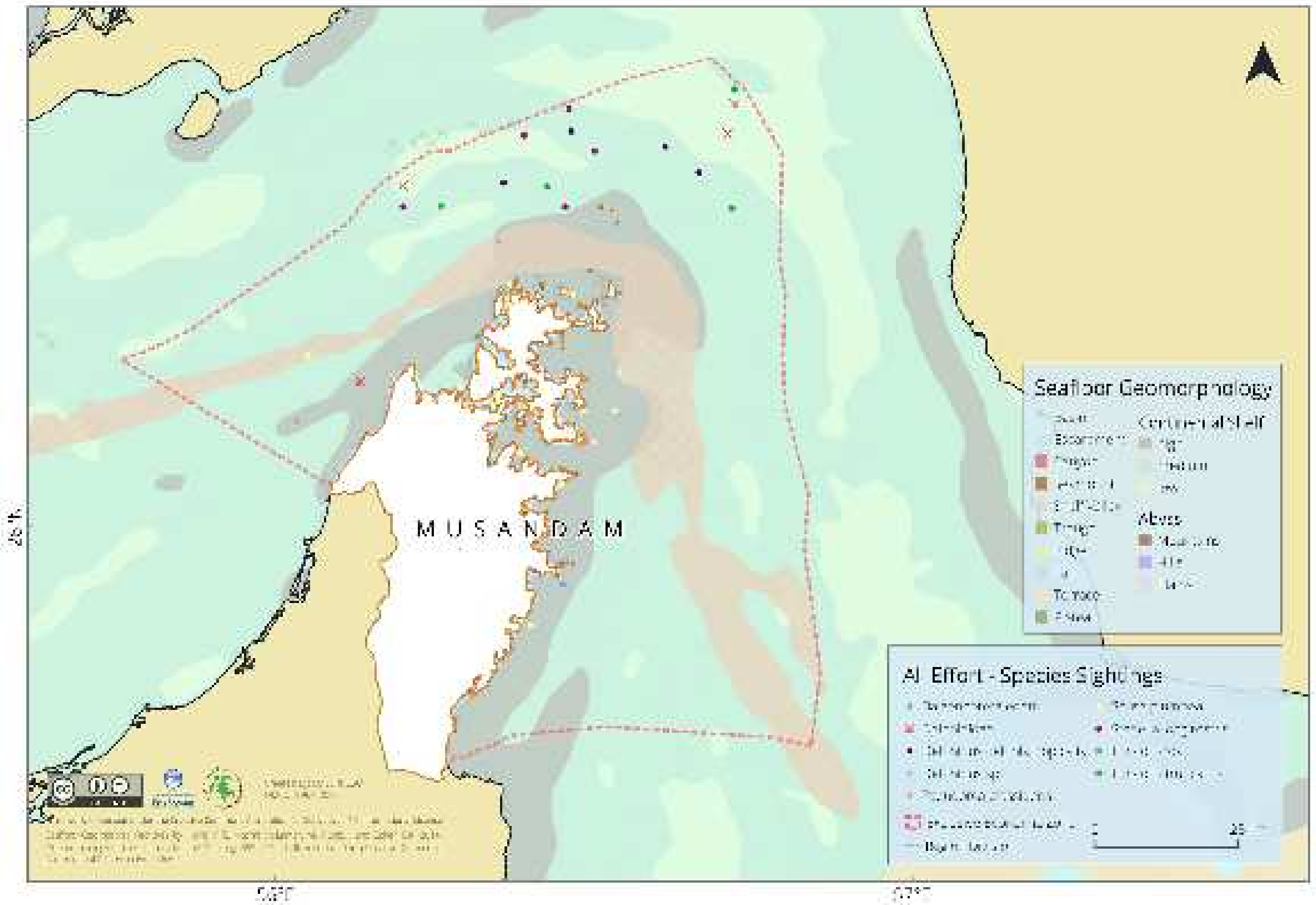
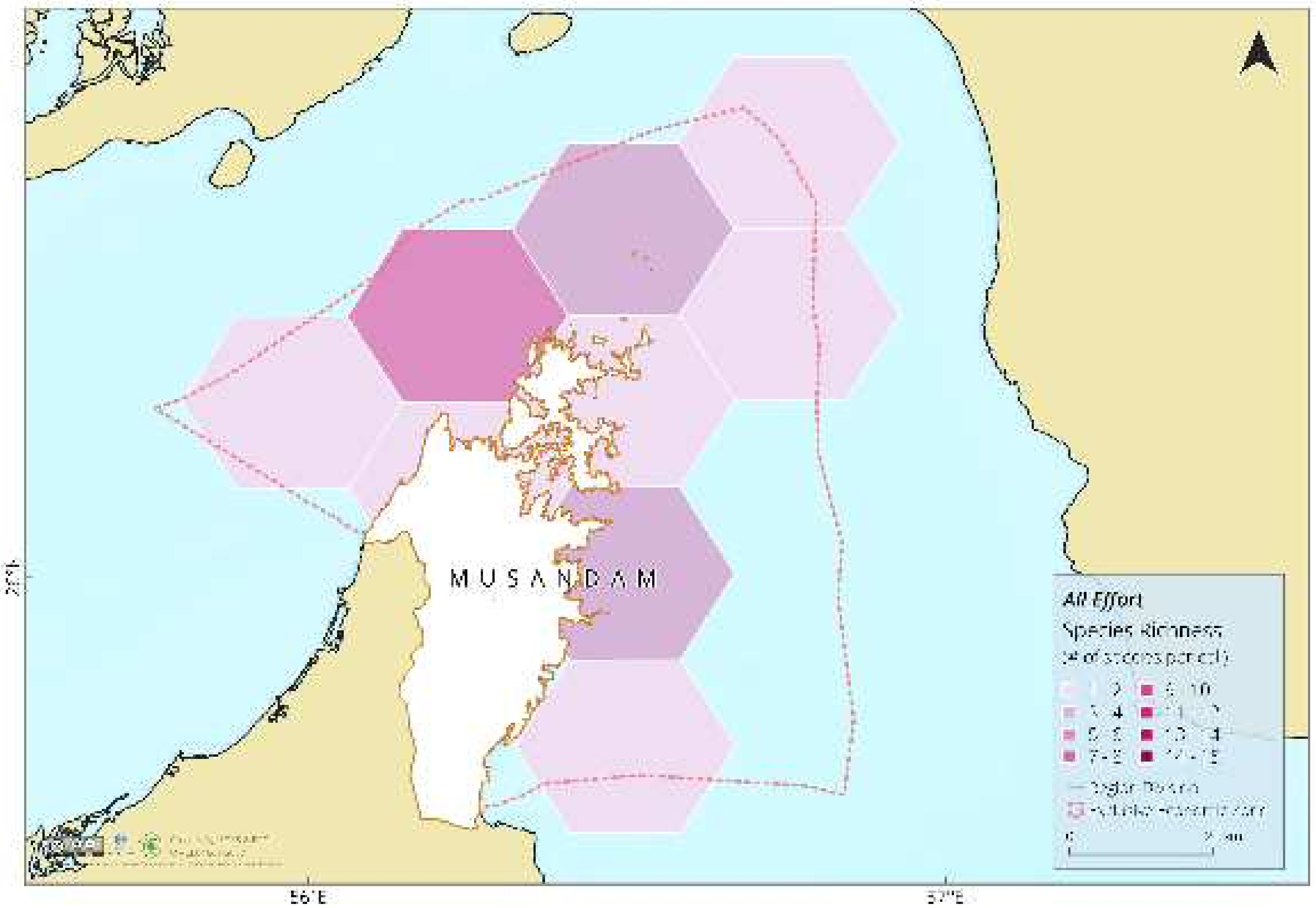


Figure 2) Summary of recorded behaviour of cetacean species sighted in the Musandam region.

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*





BACKGROUND

The North Batinah region primarily features a relatively flat, low energy shoreline and is characterized by a wide continental shelf. Mean monthly nightly sea surface temperatures in the winter months of January-March range from 22.7˚C to 23.6˚C, compared to 29.8˚C to 30.3˚C in the summer months of June-August. Apart from the winter months when average NPP ranges 3,696-4,415 gC/m2/day, the average NPP remains relatively low throughout the year (459-1,718.5 gC/m2/day).

SPECIES SIGHTINGS (n = 44)

In the North Batinah region 10 cetacean species have been recorded. Most sightings records are distributed in offshore waters (a result of observations made during deep water seismic surveys). Of the limited number of sightings records (n=6) that correspond with key geomorphological features, 50% are distributed across the continental terrace, 33% along the outer continental shelf, and 17% over basin features.

SPECIES RICHNESS

Species richness in the North Batinah region reaches peak density in the south east with up to 4 species in an individual 15km diameter hexagon.

NORTH BATINAH

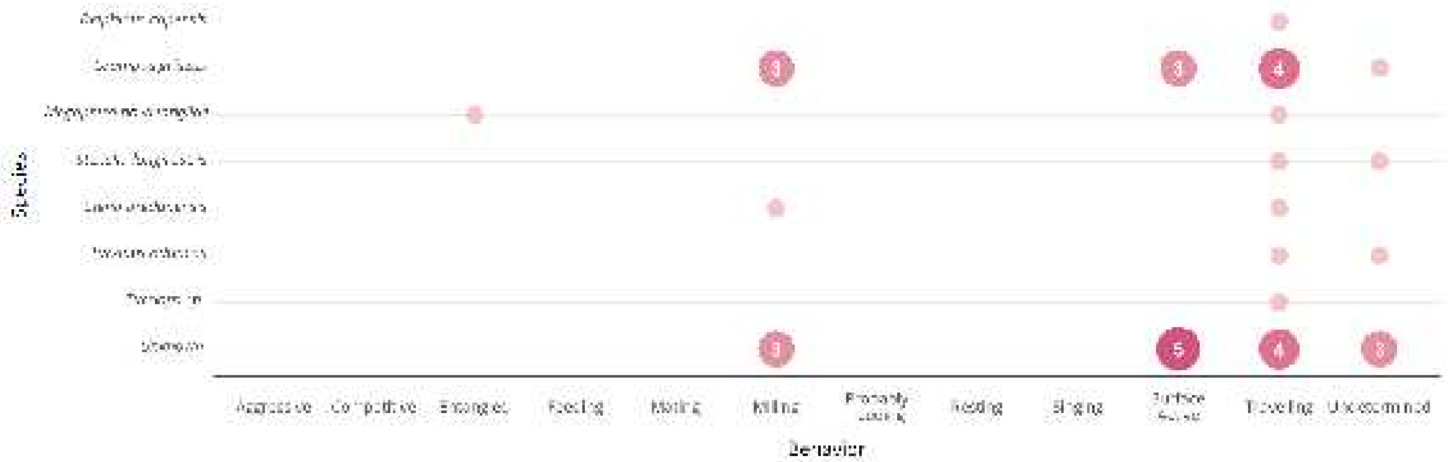
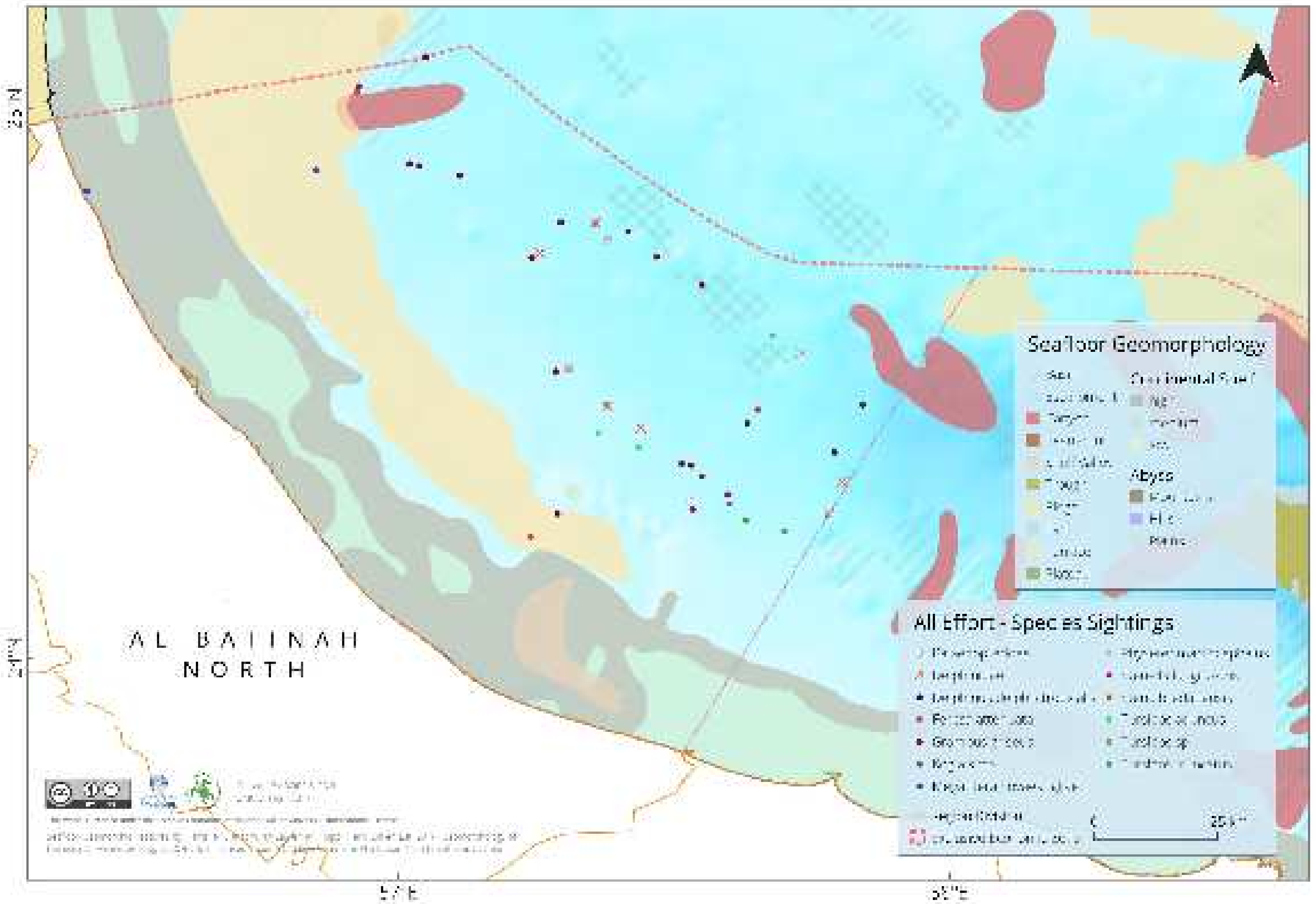
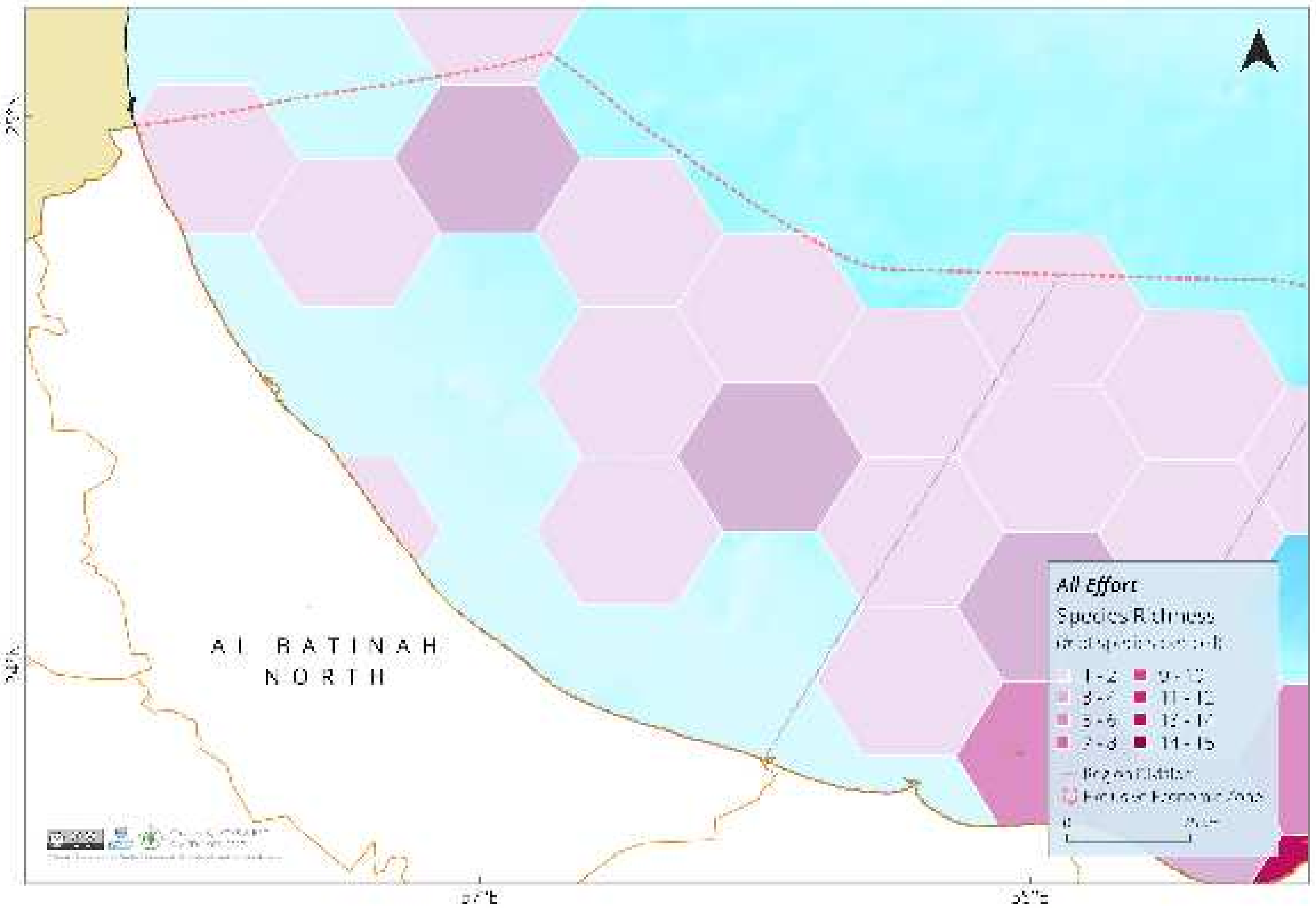


Figure 3) Summary of recorded behaviour of cetacean species sighted in the North Batinah region (Non-labelled circles indicate a record of one)

* Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.





BACKGROUND

The South Batinah region has similar characteristics to Al Batinah North with a predominantly flat, low-energy coastline and wide continental shelf (ranging approximately 22-24km from shore). Like Al Batinah North, mean monthly nightly sea surface temperatures in the winter months of January-March range from 22.8˚C to 23.7˚C compared to 29.1˚C to 29.8˚C in the summer months of June-August. Average NPP ranges 3,712-4,509.5 gc/m2/day in the winter months and 560.1-1,290.5 gc/m2/day in the summer months.

SPECIES SIGHTINGS (n = 34)

In South Batinah, a total of 7 cetacean species have been recorded. The distribution of sightings is generally relatively sparse, although there is a cluster of sightings around Ad Dimaniyat Islands. Sightings records that correspond with key seafloor geomorphological features (n=27) indicate that 48% occur over the high continental shelf, 26% in areas of escarpments, 11% over the medium continental shelf, and 7% in areas featuring canyons.

SPECIES RICHNESS

Relatively high species richness in the South Batinah region is evident around the Ad Dimaniyat Islands with up to 6 species in an individual 15km diameter hexagon.

SOUTH BATINAH

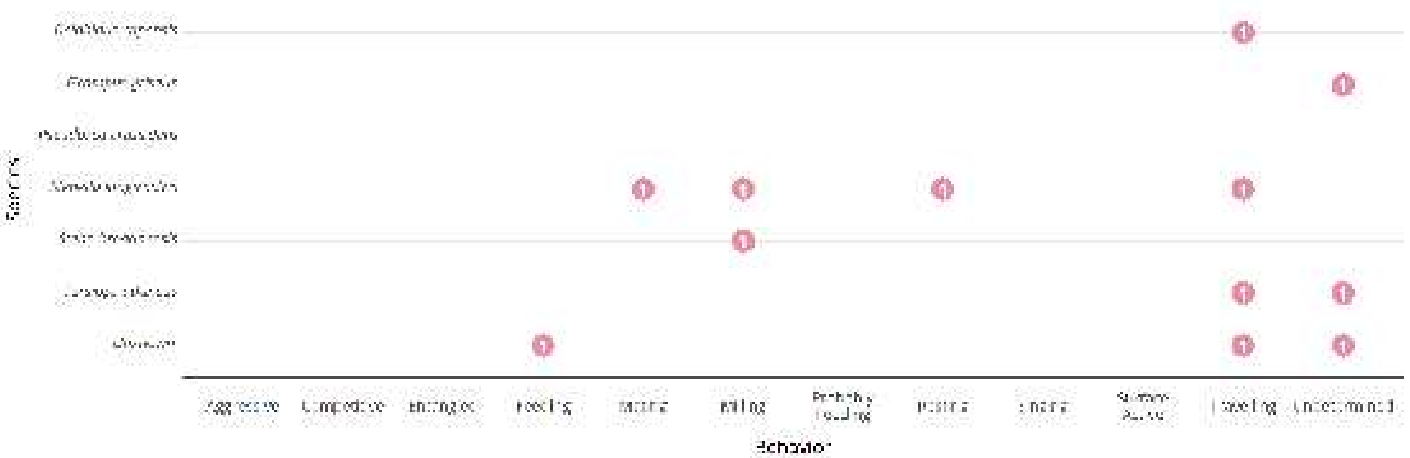
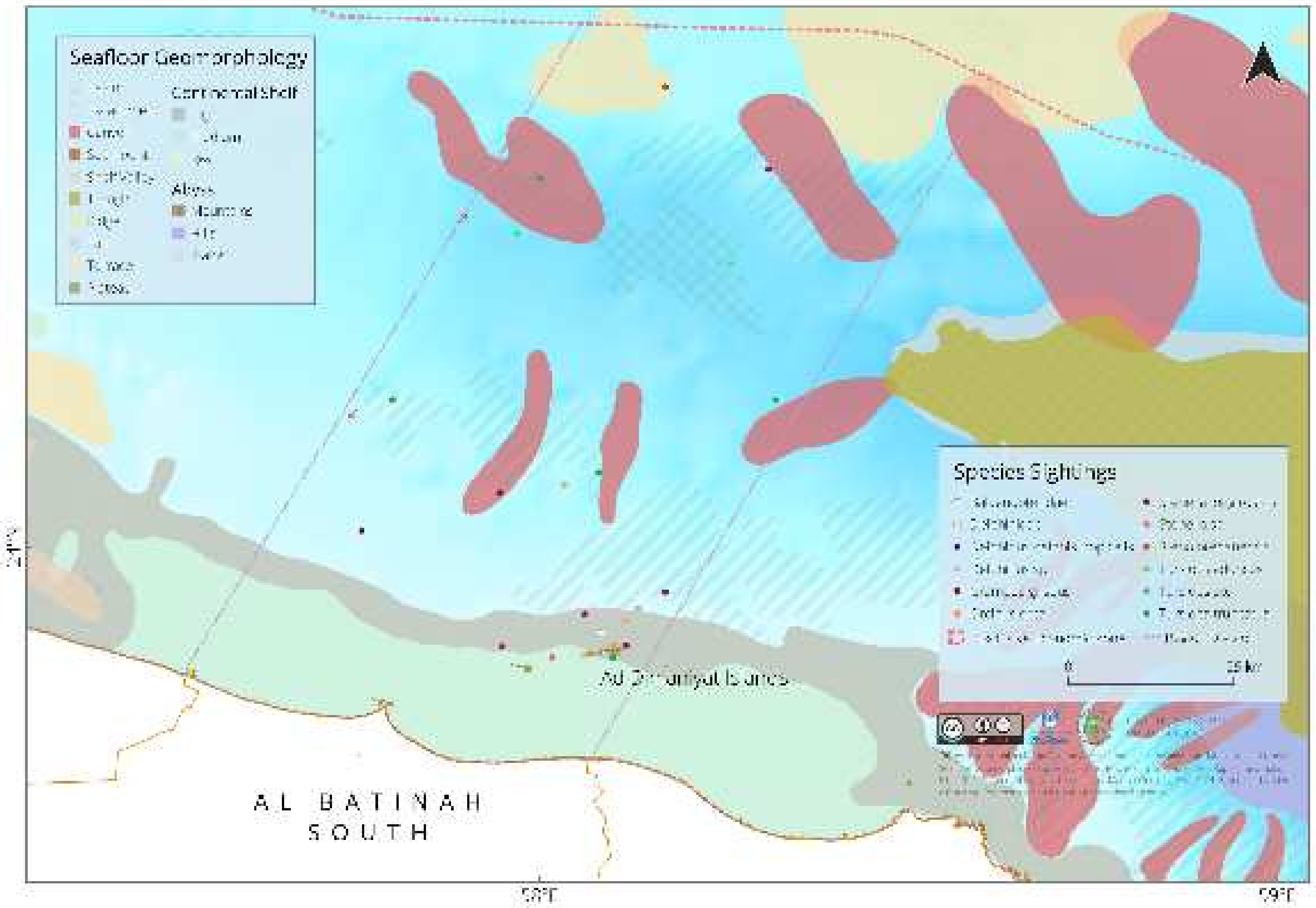
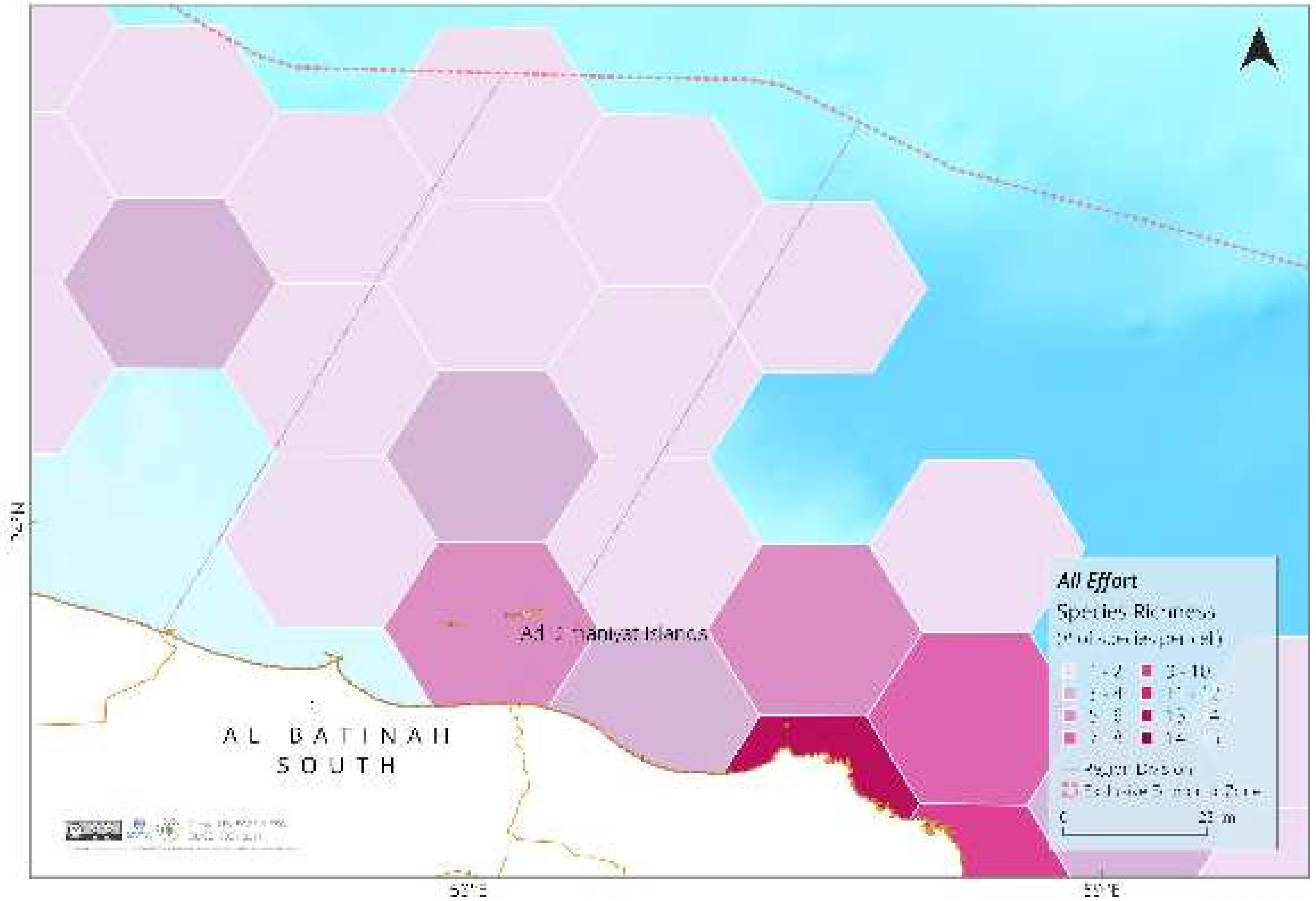


Figure 4) Summary of recorded behaviour of cetacean species sighted in the South Batinah region.

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*





MUSCAT

BACKGROUND

The rocky coast of Muscat is characterized by low cliff, pocket beaches and sheltered bays, and the offshore area features a relatively narrow continental shelf that is punctuated by deep canyon features running perpendicular to the shoreline. The continental shelf widens towards the north west. Mean monthly nightly sea surface temperatures in the winter months of January-March range from 23.0˚C to 23.8˚C compared to the range of 28.0˚C to 29.2˚C in the summer months of June-August. The average NPP during the winter months is high (3,364.8-4,486.0 gC/m2/day) compared to the summer months which record an average of 850-1,713.2 gC/m2/day. The coastline is generally sheltered but is exposed to seasonal northwesterly shamal winds and associated wave action.

SPECIES SIGHTINGS (n = 615)

In the Muscat region, 16 species of cetacean have been recorded. Spatially, sightings records cluster in the north of the region. Sightings (n=707) are associated with a number of different geomorphological features: 58% are recorded from the low continental shelf with only 2% found in the mid continental shelf. The occurrence of cetaceans over canyons (14%), escarpments (20%) and abyssal hills (2%) is also observed.

SPECIES RICHNESS

High species richness in the Muscat region is most evident in the area between Al-Qurm and Bandar Khayran, close to busy marinas and associated small vessel traffic, with up to 13 species in an individual 15km diameter hexagon. Easy access has made this area subject to regular recording of sightings, including that from dedicated cetacean surveys and third parties.

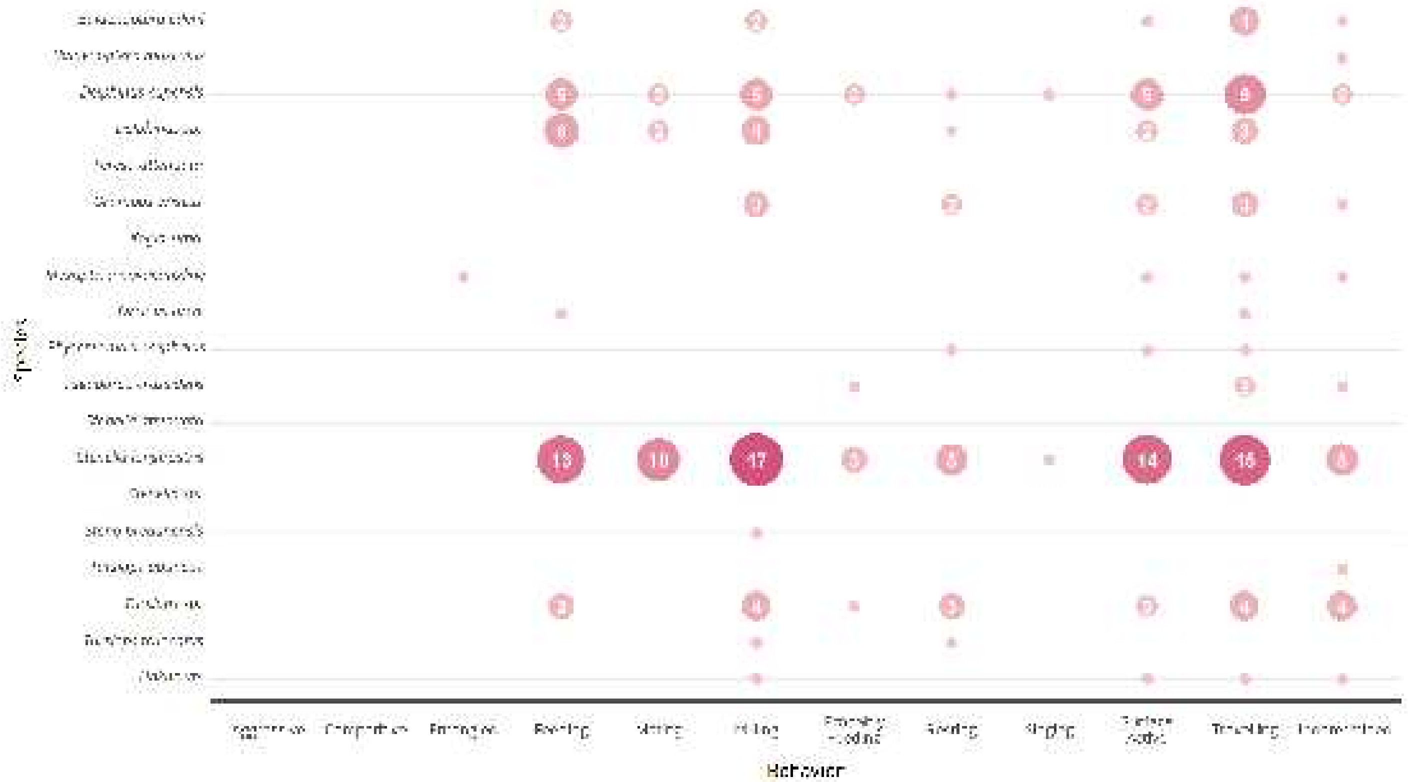
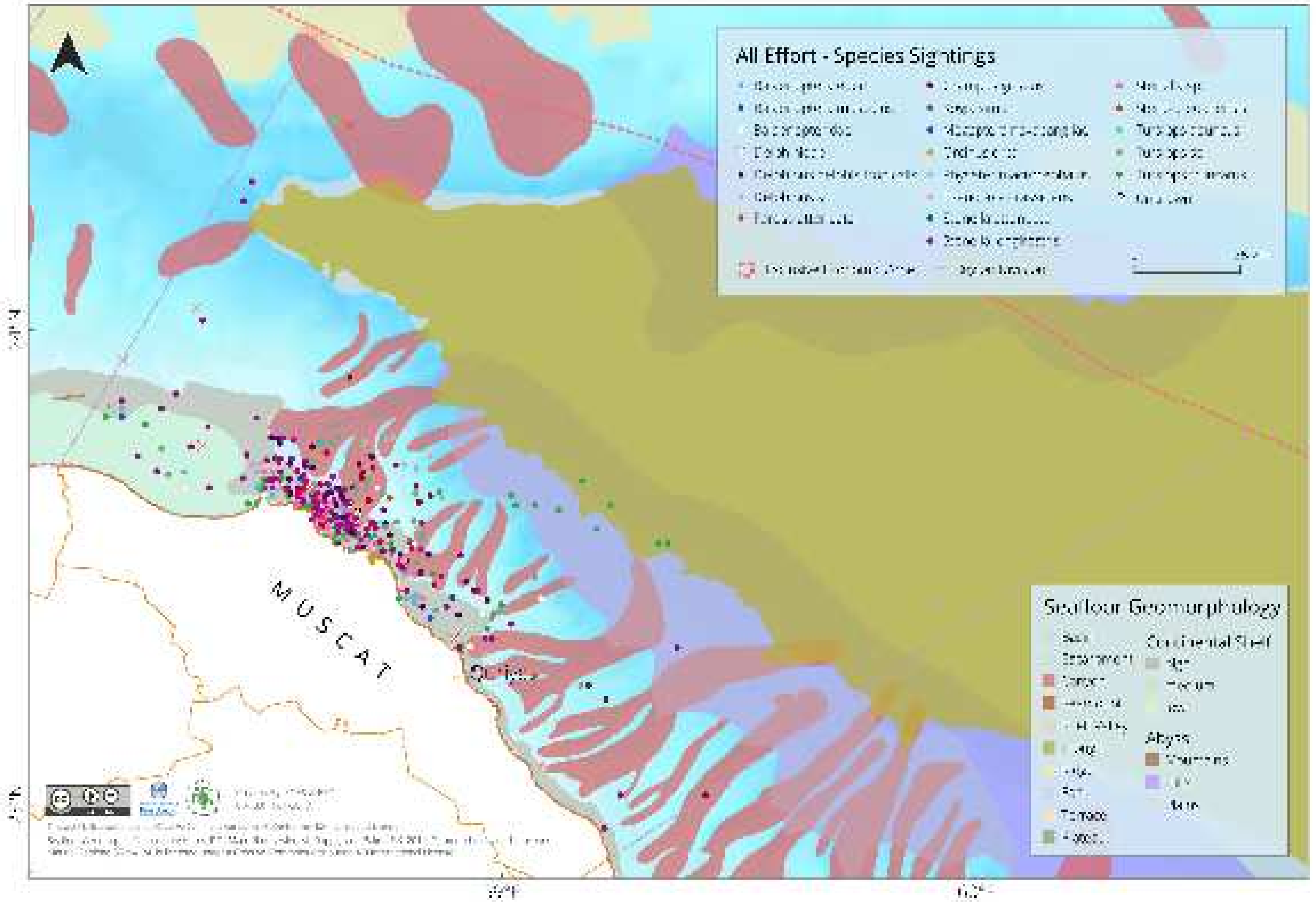
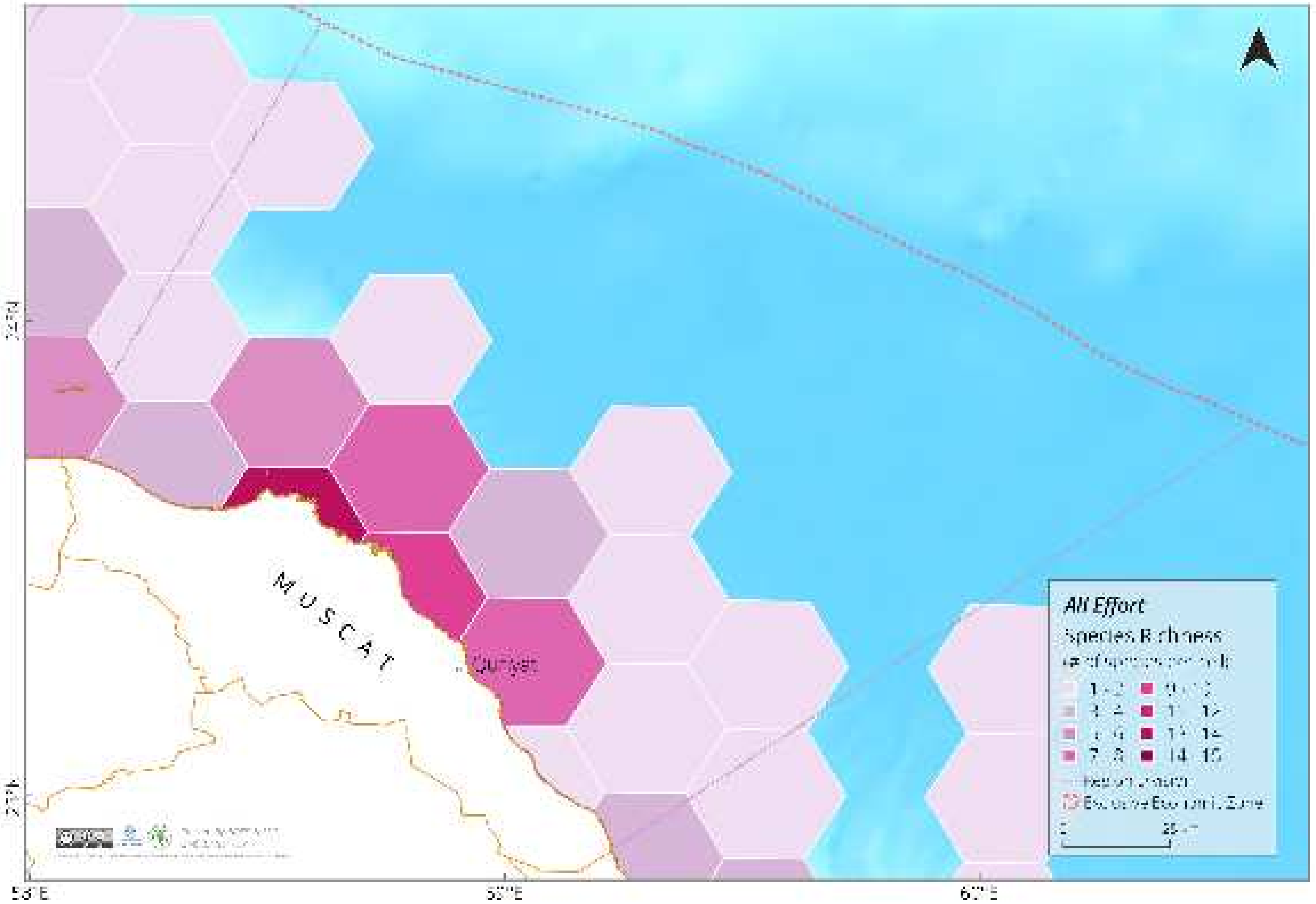


Figure 5) Summary of recorded behaviour of cetacean species sighted in the Muscat region. (Non-labelled circles indicate a record of one)

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*





BACKGROUND

The coast of South Ash Sharqiyah is a mix of sandy and rocky shoreline and the width of the continental shelf off this area varies greatly, ranging from less than 1km to approximately 74km. The continental shelf narrows considerably at Ras Al Hadd. Mean monthly nightly sea surface temperatures in the winter months of January-March range from 23.6˚C to 24.5˚C, and there is a similar range of 25.0˚C to 27.1˚C in the summer months of June-August due to strong upwelling associated with seasonal monsoon conditions. Strong upwelling events also result in high NPP during the winter months, with a range of 2,344.0-3,485.4 gC/m2/day, and also during the summer months, with a range of 1,024.5-3,064.3 gC/m2/day.

SPECIES SIGHTINGS (n = 68)

In South Ash Sharqiyah 10 cetacean species have been recorded. The distribution of sightings is clustered around the sandy headland of Ras Al Hadd. The sightings records that correspond with key seafloor geomorphological features (n=91) include 34% recorded over escarpments, 16% over the outer continental shelf, 16% over canyons, 7% over basins and 5% over abyssal hills.

SPECIES RICHNESS

Highest species richness in the South Ash Sharqiyah region is evident in the north east of the region, where up to 5 species occur in an individual 15km diameter hexagon.

SOUTH ASH SHARQIYAH

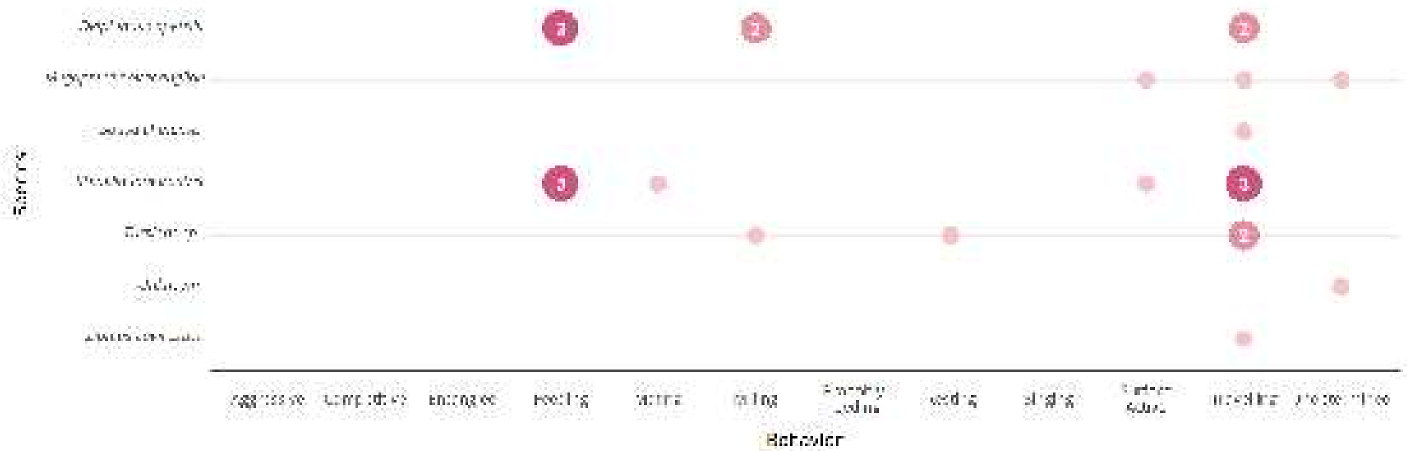
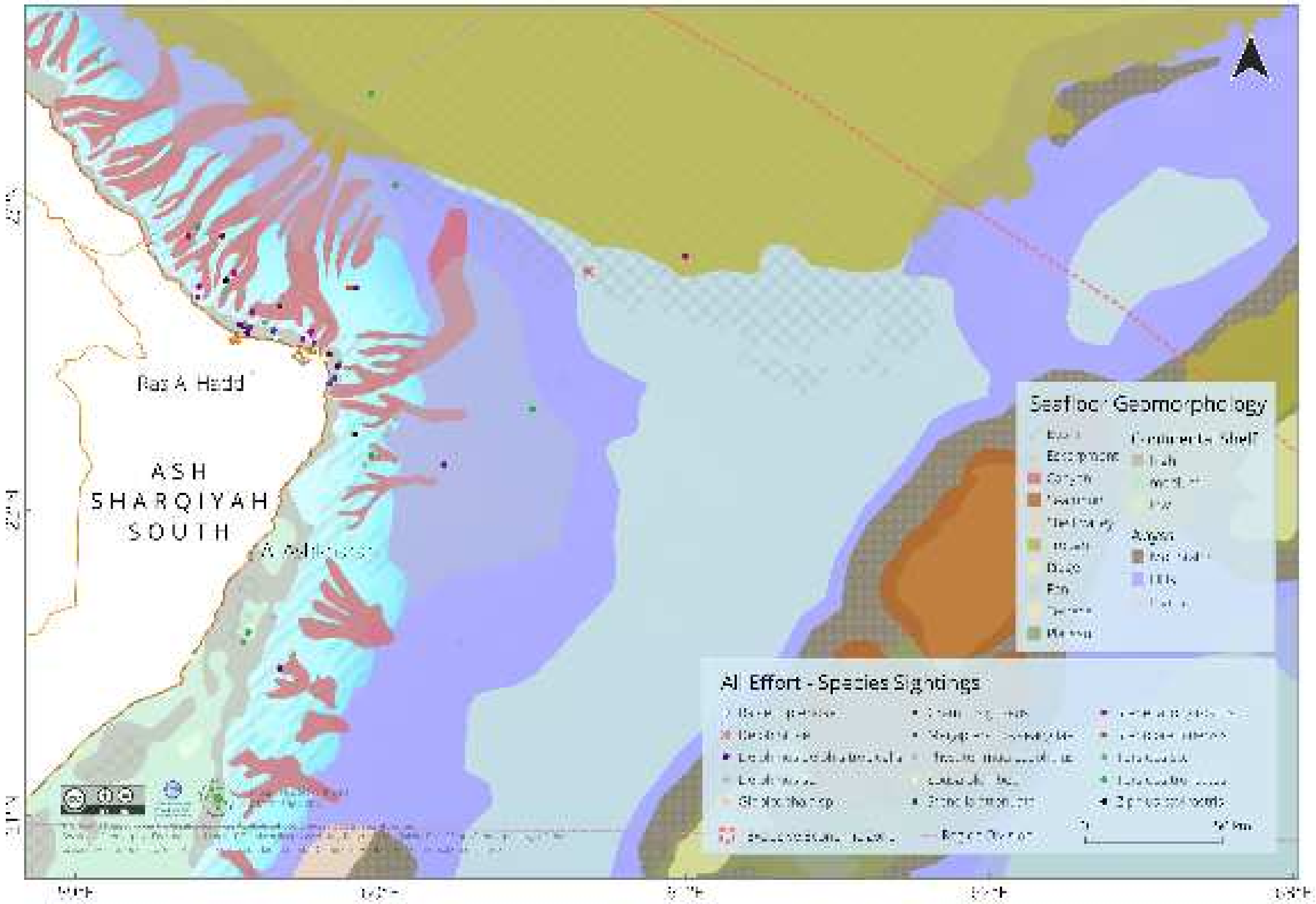
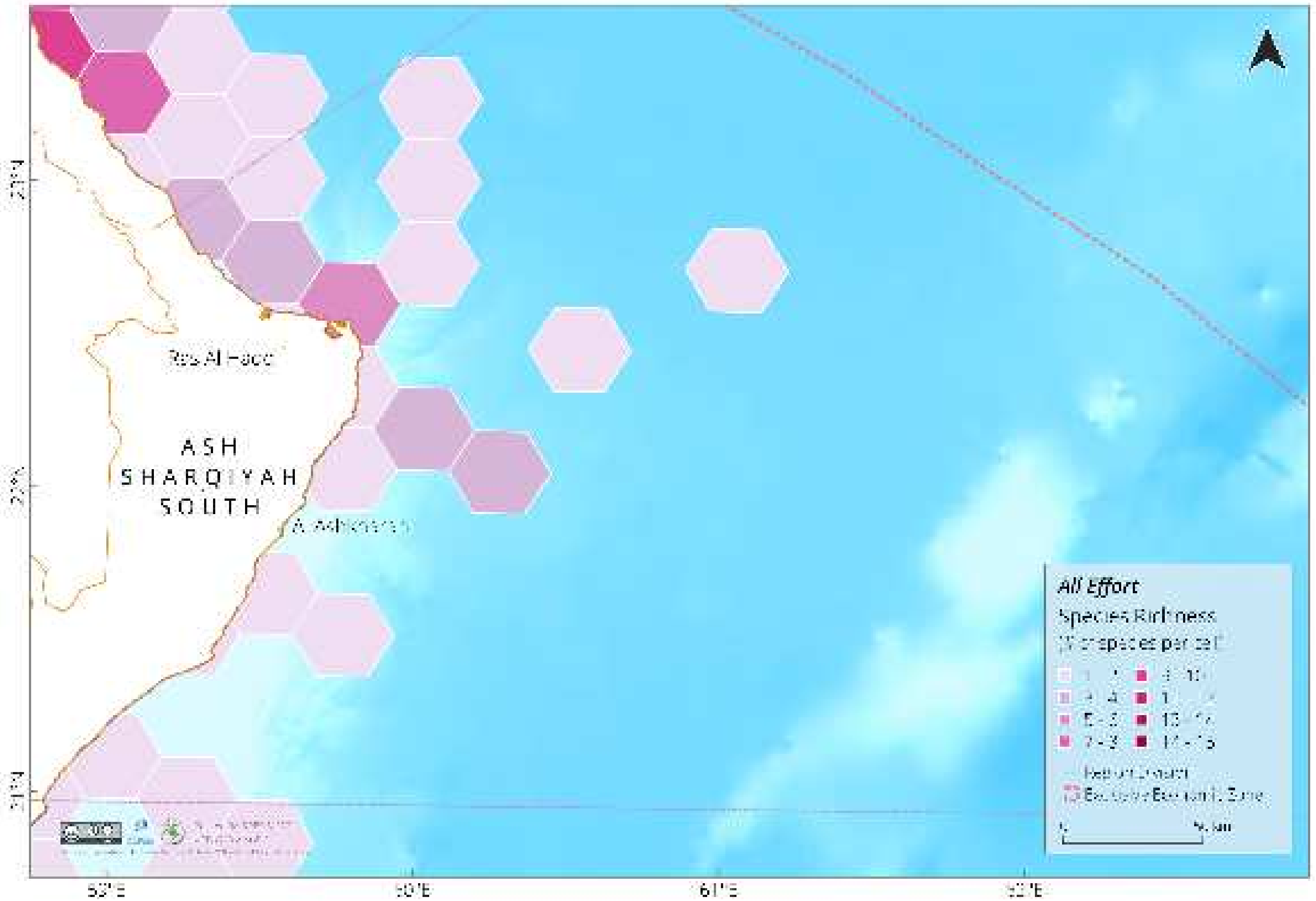


Figure 6) Summary of recorded behaviour of cetacean species sighted in the South Ash Sharqiyah region. (Non-labelled circles indicate a record of one)

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*





BACKGROUND

The shoreline of Al Wusta Governorate is largely sandy and is exposed to high energy wave action during the summer monsoon. Offshore, the area includes the most extensive and productive continental shelf regions of Oman. To the north this includes the Gulf of Masirah and to the south, Saquira Bay. Due to strong, sustained upwelling, mean monthly nightly sea surface temperatures in the winter months of January-March range from 24.3˚C to 25.3˚C, which is similar to the range of 24.2˚C to 26.9˚C in the summer months of June-August. The average NPP is relatively high throughout the year compared to other regions of Oman with a range of 1,459.0-2,355.3 gC/m²/day in the winter months, and 1,020.1-3,208.6 gC/m²/day in the summer months.

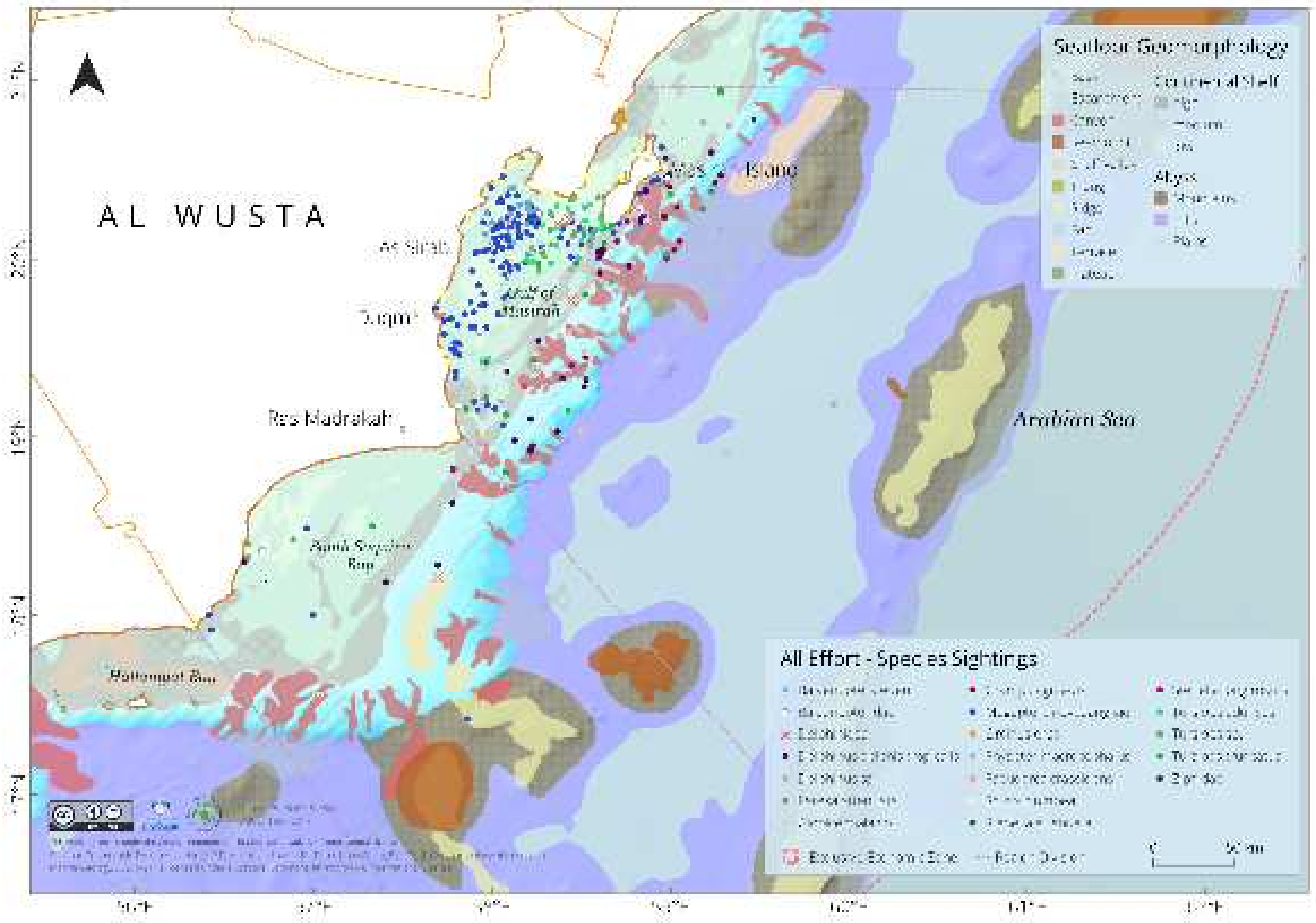
SPECIES SIGHTINGS (n = 420)

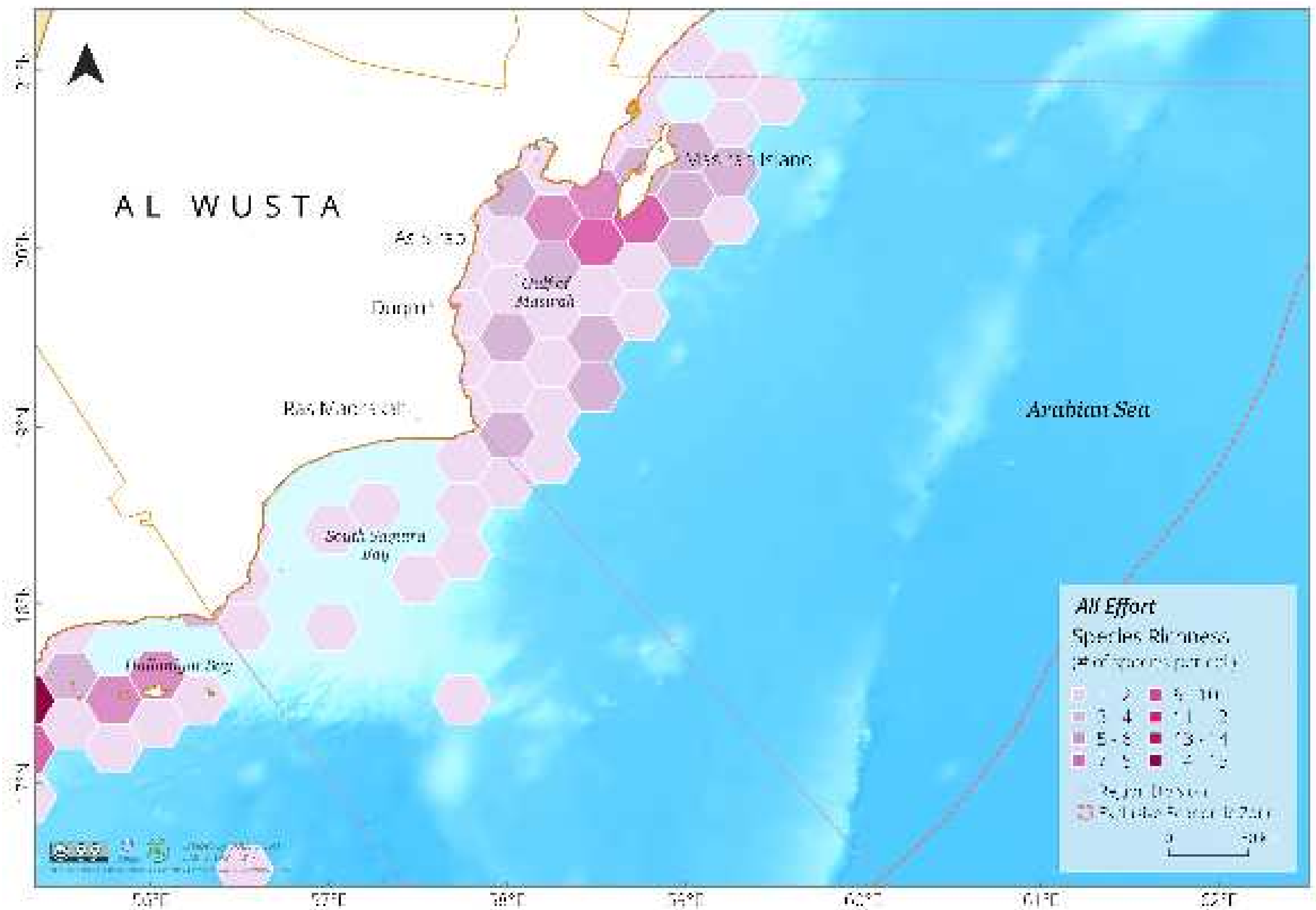
In the Al Wusta region 13 cetacean species have been recorded, with a bias in the Gulf of Masirah due to relatively high levels of survey effort. Of sightings associated with seafloor geomorphological features (n=434), a large proportion occurred over the medium continental shelf (43%), followed by the low continental shelf (19%), and high continental shelf (14%). Other notable association includes that with escarpments (8%), canyons (6%), and abyssal hills (4%). Arabian Sea Humpback Whale and Bryde's whale records dominate the central northern part of the Gulf of Masirah, whilst Bottlenose Dolphin sightings cluster in the northeast and Indian Ocean Humpback Dolphin sightings occur close to shore throughout this northern Al Wusta area.

SPECIES RICHNESS

Highest species richness in the Al Wusta region occurs to the south of Masirah Island, with up to 7 species in an individual 15km diameter hexagon. The diversity here is associated with an area of varying seafloor geomorphological features where continental shelf and slope features are found in close proximity.

AL WUSTA





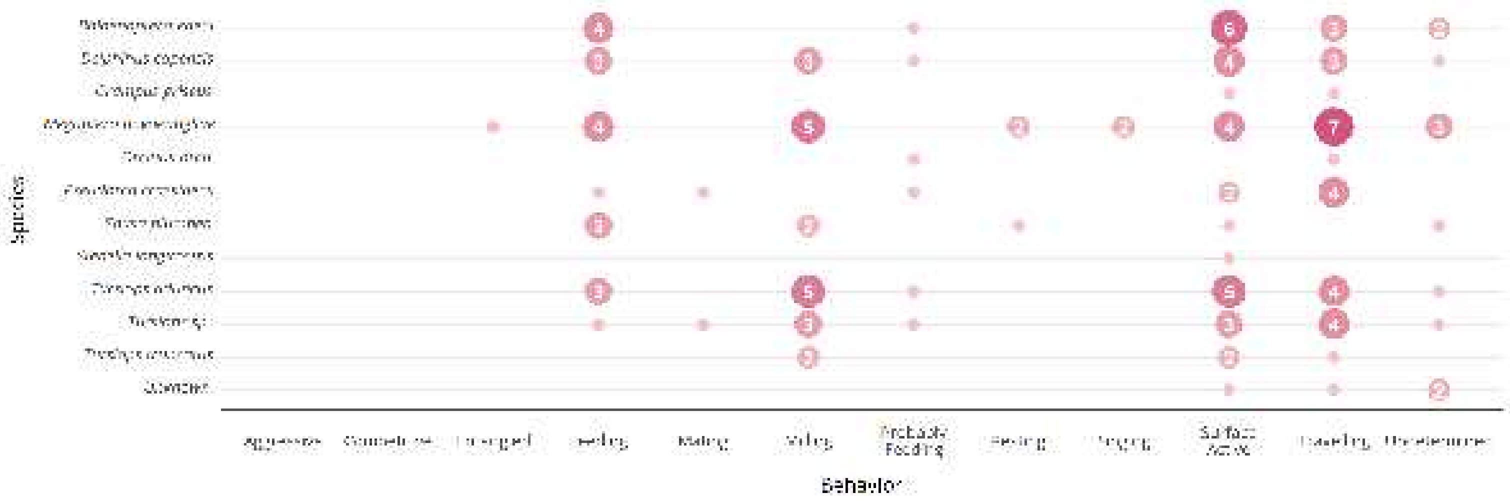


Figure 7) Summary of recorded behaviour of cetacean species sighted in the Al Wusta region. (Non-labelled circles indicate a record of one)

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*

BACKGROUND

The Dhofar Governorate is characterized by its flat coastal areas with a wider continental shelf in the northern region, and a narrower but steeper continental shelf in the southern region. The Hallaniyat Bay represents an important and productive shallow water bay which gives way to a steep continental slope that runs eastwards out to Al Hallaniyah and directly from the shoreline to the south. During the summer season from June to September, sea water temperatures are cool (23-26˚C) due to strong upwelling processes along the coast. This is reflected in the higher average NPP recorded in these months from 832-4153 gC/m^2/day). Similar numbers are recorded during the winter months of January-March with sea water temperatures of 24-26˚C, and an average NPP of 821-4553 gC/m^2/day.

SPECIES SIGHTINGS (n = 701)

In the Dhofar region 17 marine mammal species have been recorded. Sightings are clustered coastally around survey anchorages in Mirbat, Hasik and Al Hallaniyah. A large proportion (n=310) of sightings are associated with the high continental shelf (50%), compared to the medium continental shelf (2%). Other notable seafloor geomorphology features with which sightings are associated include escarpments (30%) and canyons (13%). Indian Ocean Humpback Dolphin sightings records are most evident along shoreline areas between Salalah and Mirbat, and around the mainland western shores of the Hallaniyat Bay. Arabian Sea Humpback Whale and Bryde's Whale sightings records cluster on the western side of the Hallaniyat Bay.

SPECIES RICHNESS

Species Richness in the Dhofar region is concentrated in the north with up to 15 species in an individual 15km diameter hexagon. The high species diversity is associated with a relatively small area that is nevertheless inclusive of nearshore coastal habitat, continental shelf, continental slope and abyssal seafloor geomorphology.

DHOFAR

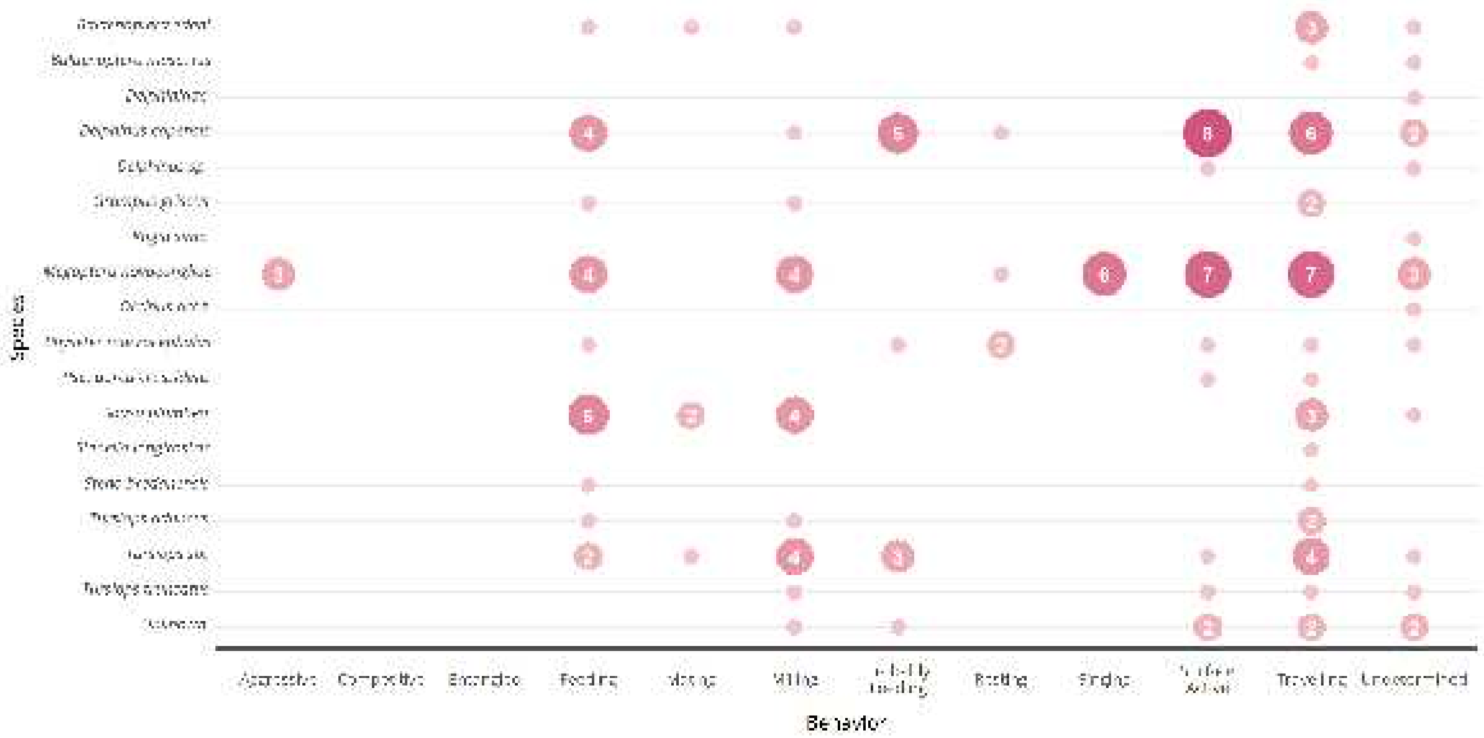
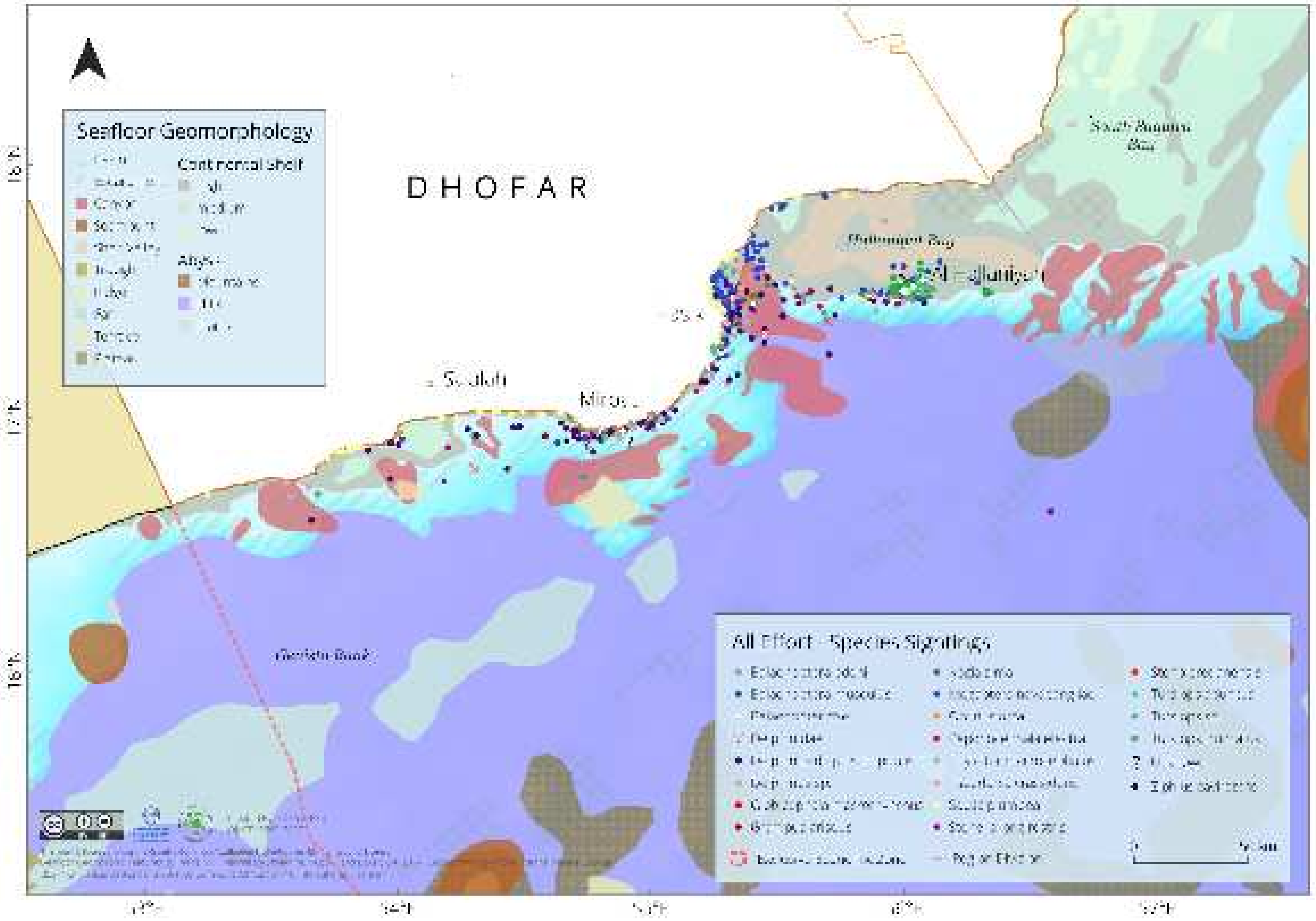
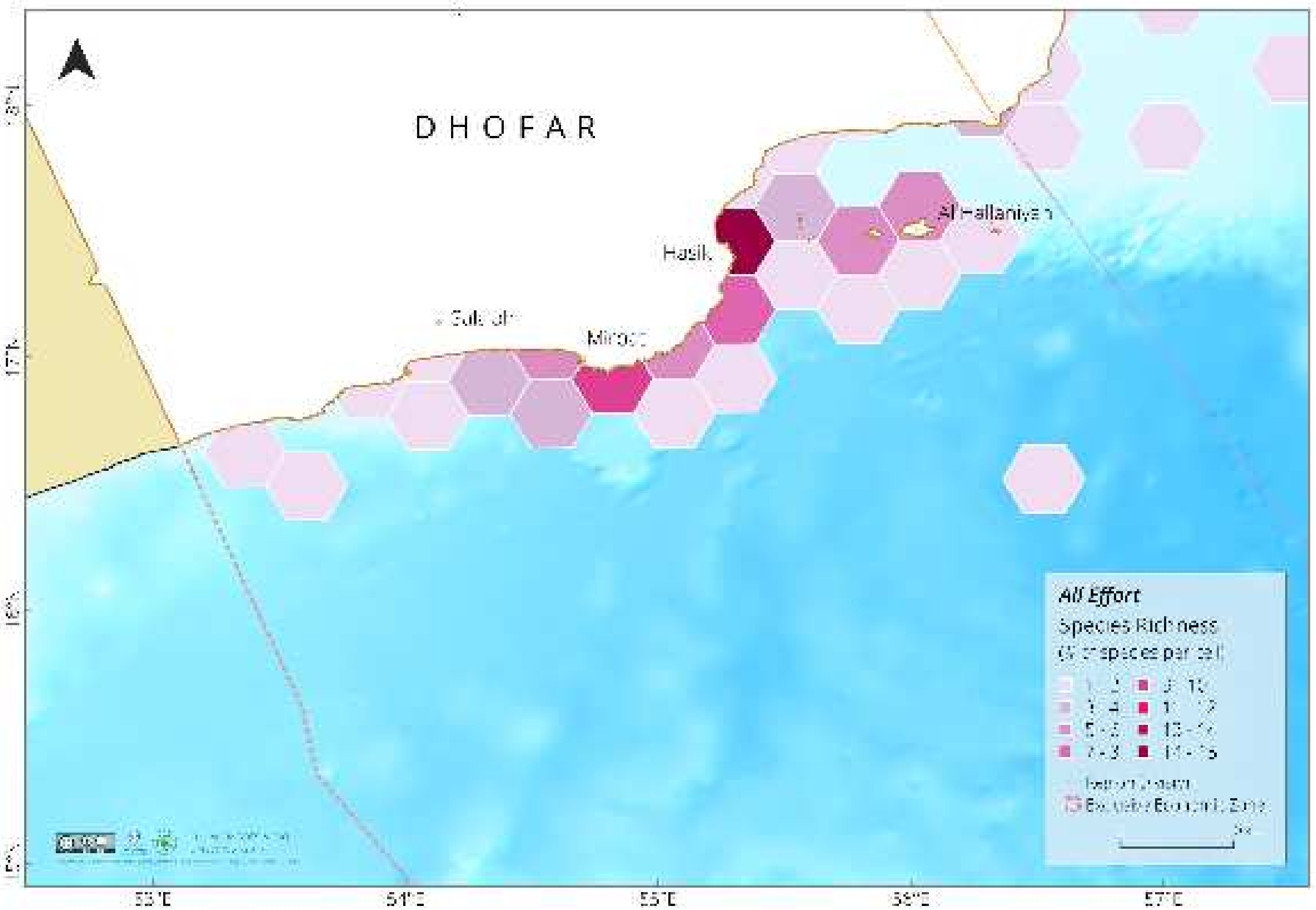


Figure 8) Summary of recorded behaviour of cetacean species sighted in the Dhofar region. (Non-labelled circles indicate a record of one)

** Note that the observed species behaviour illustrated is only a proportion of all reported sightings from OMCD shown to the right. This is due to the nature of the sampling approach where behavioural data was not always collected.*





BACKGROUND

The IUCN Joint Species Survival Commission/World Commission on Protected Areas (SSC/WCPA) Marine Mammal Protected Areas Task Force or 'IUCN MMPATF' maintains a GIS dataset of Important Marine Mammal Areas (IMMA) around the world. This dataset is drawn from knowledge provided directly to the IUCN MMPATF IMMA Secretariat by experts but may also include data consolidated from 3rd party sources where information is otherwise unavailable. The IMMAs are assessed by regional experts and a panel of independent reviewers. Information is represented, where possible, as a mapped polygon for each IMMA sub-region which has been subject to independent assessment during regional expert identification workshops, including, in the case of the information presented in this section of the Atlas, a workshop held in Salalah, Oman in March 2019.

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Errors and omissions

The IMMA e-Atlas shows the up to date and additional layers (e.g. areas of interest - AoI, candidate IMMAs -cIMMAs) not available for public download (https://www.marinemammalhabitat.org/imma-eatlas).

The IUCN MMPATF shall endeavour to maintain accurate and up-to-date data at all times. 5OES will be noted by the Issuing Authority of any Updates, Errors, and Omissions when available and will incorporate such information into future iterations of this Atlas when possible. If errors or omissions are identified, please notify IUCN MMPATF so that any errors or omissions can be corrected in future releases of the data.

Contacts: www.marinemammalhabitat.org/contacts
Postal Address: IMMA Programme - Tethys Research Institute c/o Acquario Civico Viale G.B. Gadio 220121 Milano, Italy

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CITATION

IUCN MMPATF (2019) The IUCN Global Dataset of Important Marine Mammal Areas (IUCN IMMA). (June 2020). Made available under agreement on terms and conditions of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force and accessible via the IMMA e-Atlas http://www.marinemammalhabitat.org/imma-eatlas

INTRODUCTION

THE MARINE MAMMAL PROTECTED AREA TASK FORCE (MMPATF) was established in 2013 through the participation of three stakeholders: 1) The International Committee on Marine Mammal Protected Areas (ICMMPA), 2) International Union for Conservation of nature's (IUCN) World Commission on Protected Areas (WCPA) Marine Vice Chair, and 3) members of the IUCN Species Survival Commission (SSC). Its mission is to facilitate collective action in "sharing information and experience, accessing and disseminating knowledge and tools for establishing, monitoring, and managing Marine Mammal Protected Areas (MMPAs). The MMPATF is designed to encourage the use of spatial tools to achieve MPA targets and agreements, and opportunities for cooperation among various stakeholders.

Since the establishment of MMPATF, a series of regional workshops have been held/are planned between 2016-2021 to identify Important Marine Mammal Areas (IMMAs). These workshops bring together experts with extensive knowledge of the marine mammals present in each region being assessed to identify the important habitats for marine mammals. In March 2019, the IUCN MMPATF held a meeting in Salalah, Oman. As a result of this workshop, 55 IMMAs were identified, in addition to 13 Areas of Interest (AoI). By 2021, a total of 7 regional workshops (Mediterranean-2016, Pacific Islands-2017, North East Indian Ocean and South East Asian Seas-2018, Extended Southern Ocean-2018, West Indian Ocean and Arabian Seas-2019, Australia-New Zealand waters and South East Indian Ocean-2020, and the South East Tropical and Temperate Pacific Ocean-2021) will have been completed.

The purpose of identifying IMMAs is to draw the attention of policy and decision makers to areas where effective management measures should be promoted. As such, identified IMMAs do not consider jurisdictional boundaries. In addition, although these areas have the potential to become designated as Marine Protected Areas (MPAs), IMMAs are established independent of management implications and are devised between scientists rather than by government.

The following section explores the IMMAs in Oman identified by the IUCN Joint SSC/WCPA MMPATF in the West Indian Ocean and Arabian Seas.

Of the 34 areas identified around the Arabian Peninsula (Figure 1), a total of 4 IMMAs, and 3 AoIs are in Oman waters. The detailed fact sheets of each of the 4 IMMAS are presented in the following pages. Each fact sheet provides an extensive breakdown of the qualifying criteria that were used to support the identification of the IMMA.

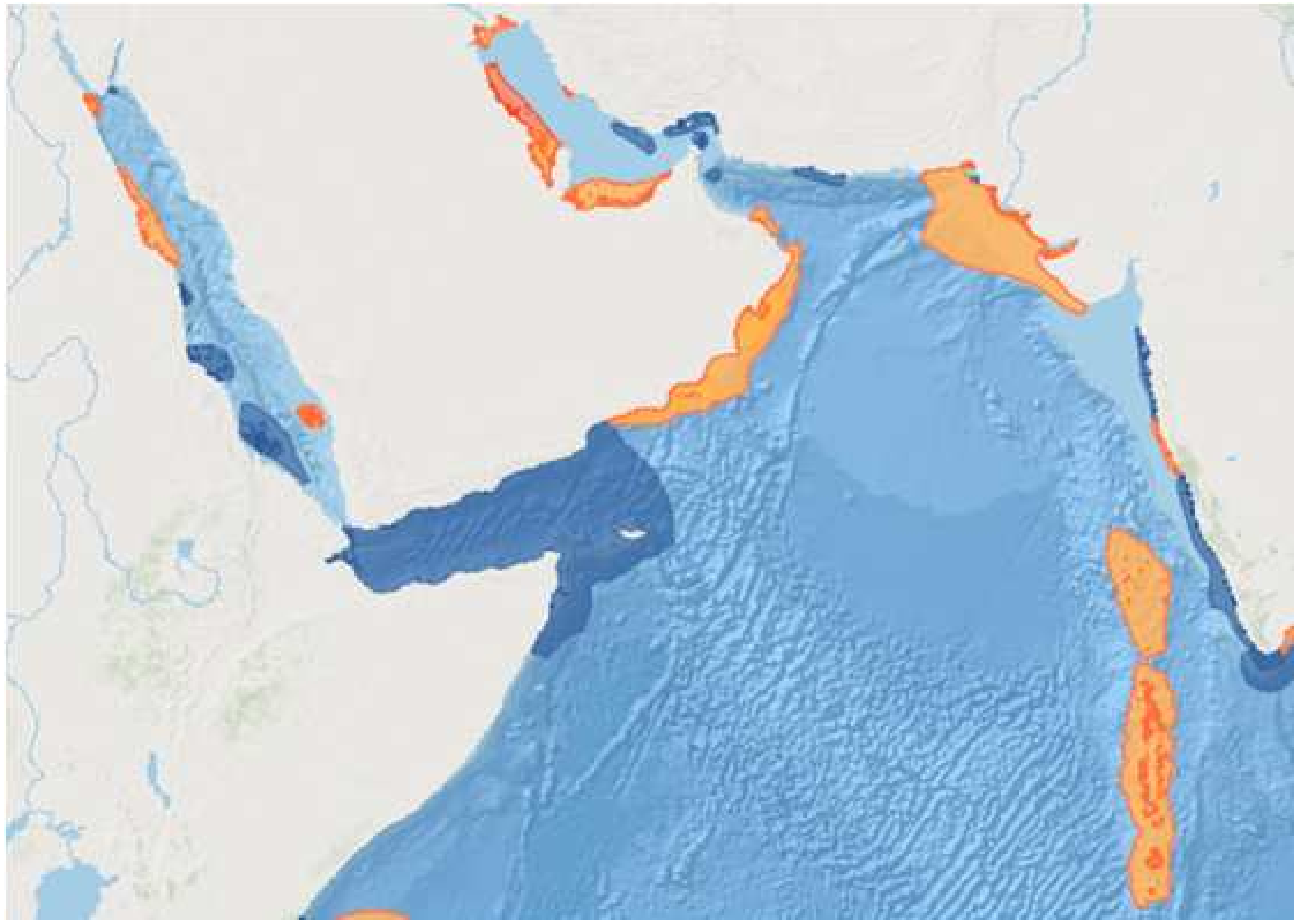


Figure 1) IMMAs, cIMMAs, and AOIs in and around the Arabian Peninsular as identified by the IUCN-MMPATF

SELECTION PROCESS

The **IMMA** selection process consists of three main stages, each of which involve leading marine mammal experts as well as IUCN MMPATF representatives.

STAGE ONE begins with a nomination of initial **Areas of Interest (AoIs)** proposed by members of the regional scientific community as potential IMMAs. The proposals are presented and evaluated by regional experts during a workshop.

STAGE TWO initiates after workshop experts review the AoIs in the region. If an AoI meets one or more of the IMMA criteria, it is proposed as a **candidate Important Marine Mammal Area (cIMMA)** to be reviewed.

STAGE THREE involves an independent panel review to determine whether a cIMMA can be accepted as a full IMMA. If confirmed, and all regional experts agree, the IMMA and supporting evidence is made publicly available in the IUCN IMMA e-Atlas.

AREA ACCOUNTS FROM IMMA

CRITERIA DESCRIPTION

The following provides a summary of the IMMA selection criteria as listed on https://www.marinemammalhabitat.org/immas/imma-criteria/ .

There are four main criteria and eight sub-criteria:

CRITERION A

SPECIES OR POPULATION VULNERABILITY

Areas containing habitat important for the survival and recovery of threatened and declining species.

CRITERION B

DISTRIBUTION AND ABUNDANCE

Sub-criterion B(i) – Small and Resident Populations
Areas supporting at least one resident population, containing an important proportion of that species or population, that are occupied consistently.

Sub-criterion B(ii) – Aggregations
Areas with underlying qualities that support important concentrations of a species or population.

CRITERION C

KEY LIFE CYCLE ACTIVITIES

Sub-criterion C(i) – Reproductive Areas
Areas that are important for a species or population to mate, give birth, and/or care for young until weaning.

Sub-criterion C(ii) – Feeding Areas
Areas and conditions that provide an important nutritional base on which a species or population depends.

Sub-criterion C(iii) – Migration Routes
Areas used for important migration or other movements, often connecting distinct life-cycle areas or the different parts of the year-round range of a non-migratory population.

CRITERION D

SPECIAL ATTRIBUTES

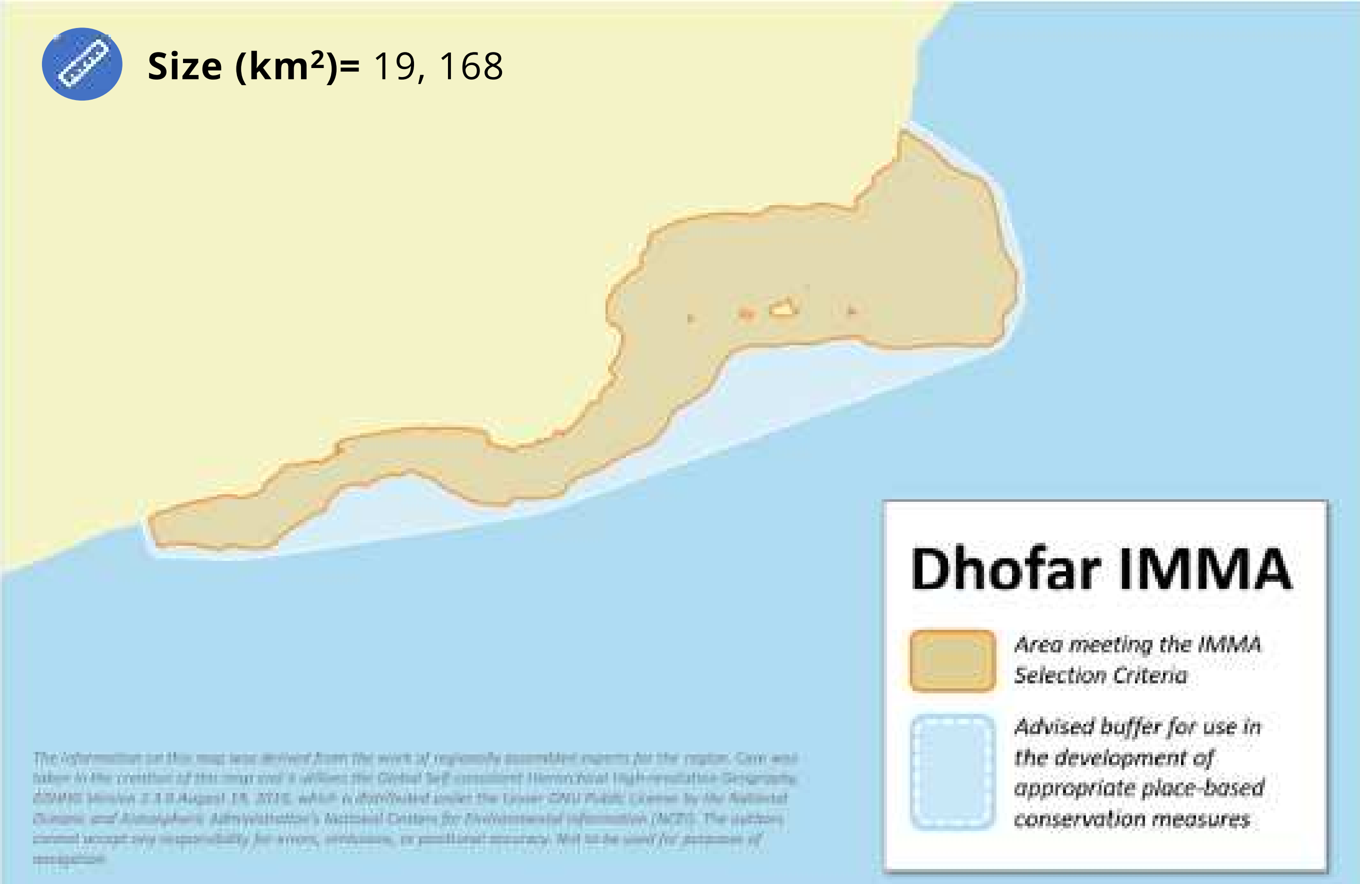
Sub-criterion D(i) – Distinctiveness
Areas which sustain populations with important genetic, behavioural or ecologically distinctive characteristics.

Sub-criterion D(ii) – Diversity
Areas containing habitat that supports an important diversity of marine mammal species.

List of IMMAs, cIMMAs, and AOIs identified around the Arabian Peninsula. Areas highlighted in bold are from Oman waters and are further discussed in the following pages.

	AREA	TYPE
1	**Dhofar**	**IMMA**
2	Farasan Archipelago	IMMA
3	Gulf of Kutch	IMMA
4	**Gulf of Masirah and Offshore Waters**	**IMMA**
5	Gulf of Salwa	IMMA
6	Indus Estuary and Creeks	IMMA
7	Lakshadweep Archipelago	IMMA
8	Maldives Archipelago and Adjacent Oceanic Waters	IMMA
9	Miani Hor	IMMA
10	**Muscat Coastal Waters and Offshore Canyons**	**IMMA**
11	Nakhiloo Coastal Waters	IMMA
12	North East Arabian Sea	IMMA
13	Northern Gulf and Confluence of the Tigris, Euphrates and Kuran	IMMA
14	Northern Red Sea Islands	IMMA
15	**Oman Arabian Sea**	**IMMA**
16	Sindhudurg-Karwar	IMMA
17	Southern Egyptian Red Sea Bays, Offshore Reefs and Islands	IMMA
18	Southern Gulf and Coastal Waters	IMMA
19	Gulf of Salwa and Northwestern Gulf	cIMMA
20	Churna-Kaio Island Complex	AOI
21	Dahlak and Adjacent Southern Waters	AOI
22	Dungonab Bay- Mukawar Island	AOI
23	**Gulf of Aden and Socotra Archipelago**	**AOI**
24	Hormoz Northern Coastal Area	AOI
25	Kanyakumari	AOI
26	Makran to Daran-Jiwani	AOI
27	**Musandam Peninsula**	**AOI**
28	**Offshore Waters of the Emirate of Fujairah**	**AOI**
29	Southwestern Coast and Waters of India	AOI
30	Strait of Tiran	AOI
31	Suakin Archipelago and Sudanese Southern Red Sea	AOI
32	Thane to Ratnagri	AOI
33	Wadge Bank to Bar Reef	AOI
34	West Hormozgan Islands	AOI

DHOFAR



SUMMARY

THE MARINE WATERS OF DHOFAR are characterised by dynamic oceanographic conditions strongly influenced by summer and winter monsoons, as well as highly variable bathymetry comprised of continental shelf and steep shelving habitats that plummet to great depths. This provides a range of highly productive habitats for a diverse array of cetacean species. These have been documented during dedicated survey work completed since 1999. The area is extremely important for Arabian Sea Humpback Whales (ASHW); data reveal a high degree of site fidelity, as well as behaviours associated with reproduction (singing and calves) and feeding. Seventeen cetacean species have been positively identified in the region thus far, ranging from resident nearshore communities of Indian Ocean Humpback Dolphins and Indo-Pacific Bottlenose Dolphins to deep-diving species such as Risso's Dolphins, Rough-toothed Dolphins and Cuvier's Beaked Whales. Recent sightings and acoustic data suggest the area is also likely to be important for Northern Indian Ocean Blue Whales.

DESCRIPTION OF QUALIFYING CRITERIA

CRITERION A

SPECIES OR POPULATION VULNERABILITY

The Arabian Sea Humpback Whale population is the only known population of Humpback Whales not to undertake long-range migrations between low-latitude breeding grounds and high-latitude feeding grounds [1,2]. The population is genetically isolated and distinct [3], and mark-recapture estimates generated from photo identification studies off the coast of Oman are fewer than 100 individuals (82 individuals 95% CI 60-111), providing the rationale for an IUCN Red list status of Endangered [4]. Dedicated field surveys, satellite tracking and passive acoustic monitoring have confirmed that the Dhofar area is one of the most important habitats for this population in Oman's waters. Within the Dhofar area, the highest density of sightings, vocalizations and occupancy (as evidenced by satellite tracks and localized behaviour) is concentrated in the Hallaniyat Bay [2,5,6,7,8,9,10,11,12]. Indian Ocean Humpback Dolphins (*Sousa plumbea*) are also observed in the Dhofar area and wider Arabian Sea Coast with a strong preference for near-shore shallow coastal habitat. Encounters were made around Hasik Bay and southwest of Salalah [2] although sightings have also been documented in intervening areas. The species is listed as Endangered on the IUCN Red List [13].

CRITERION B

DISTRIBUTION AND ABUNDANCE

Sub-criterion Bii: Aggregations | Modelling of Arabian Sea Humpback Whale sightings data in relation to survey effort using spatial eigenvector filtering to account for spatial autocorrelation, as well as results of satellite telemetry studies, confirm that the higher relative densities of whales in the Dhofar area are a reflection of their behaviour and not only survey effort [14,15,16,17]. The aggregations have been associated with feeding and breeding behaviour and in one survey period these activities were observed concurrently [5].

CRITERION C

KEY LIFE CYCLE ACTIVITIES

Sub-criterion Ci: Reproductive Areas | Passive acoustic monitoring has documented the presence of Arabian Sea Humpback Whale song between November and the end of May [12,18]. Further breeding-related behaviour has been observed in the form of competitive groups off Ras Hasik [5]. Mother and calf pairs have been observed in the Dhofar area on 7 occasions between 2000 and 2014 [10].

Sub-criterion Cii: Feeding Areas | Bubble-net feeding by Arabian Sea Humpback Whales has been documented within the Hasik/Hallaniyat Bay [5] along with 17 other feeding events recorded in the area between 2001 and 2017 [10]. Feeding records also exist for other species including Bryde's Whales, False Killer Whales, Common Dolphins, both Common and Indo-Pacific Bottlenose Dolphins and Indian Ocean Humpback Dolphins [10].

CRITERION D

SPECIAL ATTRIBUTES

Sub-criterion Dii: Diversity | The diversity in this area includes a range of species exhibiting different ecological preferences, with some species exploiting near shore shallow habitats (e.g. Indian Ocean Humpback Dolphins) and others offshore habitats (e.g. Cuvier's Beaked Whales). The range of species also represents species feeding at different trophic levels, from baleen whales to top predators, such as Killer Whales and False Killer Whales. Review of sightings data suggests that Ras Nus marks the westernmost extent of Indian Ocean Humpback Dolphin records with a lack of sightings between this point westwards to Mirbat [10]. A minimum of 17 cetacean species have been confirmed to occur in the Dhofar area, and Dwarf Sperm Whales are suspected to occur. The list of confirmed species includes: Common Dolphin (*Delphinus delphis tropicalis*), Common Bottlenose Dolphin (*Tursiops truncatus*), Spinner Dolphin (*Stenella longirostris*), Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*), Rough-toothed Dolphin (*Steno bredanensis*), Indian Ocean Humpback Dolphin (*Sousa plumbea*), Risso's Dolphin (*Grampus griseus*), False Killer Whale (*Pseudorca crassidens*), Killer Whale (*Orcinus orca*), Dwarf Sperm Whale (*Kogia sima*), Melon-headed Whale (*Peponocephala electra*), Short-finned Pilot Whale (*Globicephala macrorhynchus*), Cuvier's Beaked Whale (*Ziphius cavirostris*), Sperm Whale (*Physeter macrocephalus*), Bryde's Whale (*Balaenoptera edeni*), Arabian Sea Humpback Whale (*Megaptera novaeangliae*) and Northern Indian Ocean Blue Whale (*Balaenoptera musculus indica*). This diverse assemblage of 18 species has been recorded between 'Ras Nus' and Ras Hasik [2,5,6,7,8,9,10,11].

IMMA

Qualifying Species and Criteria

Indian Ocean Blue Whale – *Balaenoptera musculus indica*

Criterion A; C (ii)
Bryde's Whale – *Balaenoptera edeni*

Criterion A; C (i, ii)
Arabian Sea Humpback Whale – *Megaptera novaeangliae*

Criterion A; B (ii); C (i,ii)
Sperm Whale – *Physeter macrocephalus*

Criterion C (i,ii)
False Killer Whale – *Pseudorca crassidens*

Criterion C (i)
Indian Ocean Humpback Dolphin – *Sousa plumbea*

Marine Mammal Diversity

Criterion D (ii)

Balaenoptera edeni,
Balaenoptera musculus indica,
Delphinus delphis tropicalis,
Globicephala macrorhynchus,
Grampus griseus, Kogia sima,
Megaptera novaeangliae,
Orcinus orca,
Peponocephala electra,
Physeter macrocephalus,
Pseudorca crassidens,
Sousa plumbea,
Stenella longirostris,
Steno bredanensis,
Tursiops aduncus,
Tursiops truncatus,
Ziphius cavirostris

GULF OF MASIRAH AND OFFSHORE WATERS

SUMMARY

STRONG UPWELLING ASSOCIATED WITH THE SOUTHWEST MONSOON supports high primary productivity in the Gulf of Masirah region. The region is among the most important of habitats for Endangered Arabian Sea Humpback Whales; sightings, acoustic records, telemetry data and whaling records confirm its importance for feeding and breeding. The Endangered Indian Ocean Humpback Dolphin occurs along many coasts, with higher densities recorded in the Ghubbat Hashish, a large shallow bay. Bryde's Whales have been observed with calves and feeding in the northern Gulf of Masirah, and feeding east of Masirah Island. Indo-Pacific Bottlenose Dolphins were regularly observed in inshore waters during surveys in the early 2000's, but sighting rates are now low, which may be linked to bycatch and/or displacement. Pelagic species observed on the eastern side of the area include Killer Whales, False Killer Whales, Cuvier's Beaked Whales and Sperm Whales. Recorded strandings and entanglements suggest several species are threatened with bycatch in gillnet fisheries.

DESCRIPTION OF QUALIFYING CRITERIA

CRITERION A

SPECIES OR POPULATION VULNERABILITY

The IUCN Red list currently classifies Humpback Whales globally as Least Concern, whereas Arabian Sea Humpback Whales are listed by IUCN as 'Endangered' [4]. Arabian Sea Humpback Whales are non-migratory, a trait unique among all Humpback Whale populations globally. They do not migrate between low-latitude breeding grounds and high latitude feeding grounds [2,4,19,20]. The population is genetically distinct and reproductively isolated from other populations [3]. The Indian Ocean Humpback Dolphin (*Sousa plumbea*) is listed as 'Endangered' throughout its range by the IUCN Red List [13]. A total of 40 sightings of Indian Ocean Humpback Dolphins were recorded within the IMMA during dedicated vessel surveys between 1986 and 2006. However, search effort was rarely directed towards finding Indian Ocean Humpback Dolphins, but several authors have noted the regions importance for this species [21,22,23,13]. Recorded group sizes range between one to one hundred individuals, including some of the largest groups sizes ever recorded [10,22]. Although no dedicated studies have been conducted in the area, the species is known to be a nearshore limited species with restricted home ranges [13,24,25]. As such, it can be inferred that all ecological requirements for the species are likely to be contained within the IMMA. Bryde's Whales (*Balaenoptera edeni*) as a species is designated as Least Concern in IUCN Red List [26]. However, this assessment does not make a distinction between any distinct recognized forms of the species. In the Arabian Sea and Sea of Oman, illegal Soviet whaling in the mid-1960s resulted in the recorded mortality of 849 individuals [27]. There is little current information on the status of the Bryde's Whales in the region, and on whether both forms share the same status [28]. Evidence from relatively frequent strandings throughout much of the species' NW Indian Ocean range suggests they are vulnerable to entanglement in gill nets and ship strikes, as are other large whale species in the region [29,30].

CRITERION C

KEY LIFE CYCLE ACTIVITIES

Sub-criterion Cii: Feeding Areas | The Gulf of Masirah is extremely productive, especially at the end of, and directly following the Southwest Monsoon season, as indicated by some of the highest remotely sensed Chrlophyll A values of any portion of Oman's coastline [31,32,33]. This productivity is associated with a high fish biomass, supporting an expanding fisheries industry. It is also associated with a relatively high rate of observed feeding or suspected feeding behaviour for both Arabian Sea Humpback Whales and Bryde's Whales [2,22]. Analysis of stomach contents from Humpback Whales taken from the Arabian Sea (n=190) showed that over 50% had 'moderate' to 'plentiful' stomach contents [1,27]. Catch locations curated by the International Whaling Commission indicate that at least 30 of these individuals were taken from the Gulf of Masirah [34] and it is likely that they are represented in the sample of examined stomachs. Bryde's Whales are also thought to be feeding regularly in the area, supported by multiple observations during dedicated cetacean surveys of lunge feeding and/or whales in association with large shoals or sardines and other bait fish [22,35,36,37].

CRITERION D

SPECIAL ATTRIBUTES

Sub-criterion Dii: Diversity | The IMMA provides habitats for a minimum of 11 cetacean species that have been confirmed [2,5,9,10]. Available habitats vary considerably, with Indian Ocean Humpback Dolphins occupying nearshore waters (ranging from shallow bays to rocky headlands) and other species distributed exclusively offshore, including Killer Whales (*Orcinus orca*), False Killer Whales (*Pseudorca crassidens*), Spinner Dolphins (*Stenella longirostris*), Indo-Pacific Common Dolphins (*Delphinus delphis tropicalis*), Sperm Whales (*Physeter macrocephalus*) and Cuvier's Beaked Whales (*Ziphius cavirostris*), which have been recorded in deeper (>200m) offshore waters, particular to the east of Masirah Island. Data richness for the area is uneven, with the majority of observations recorded in the Gulf of Masirah and far fewer for offshore areas, including deep-water habitats and regions of very high productivity.

Qualifying Species and Criteria

Humpback Whale – *Megaptera novaeangliae*

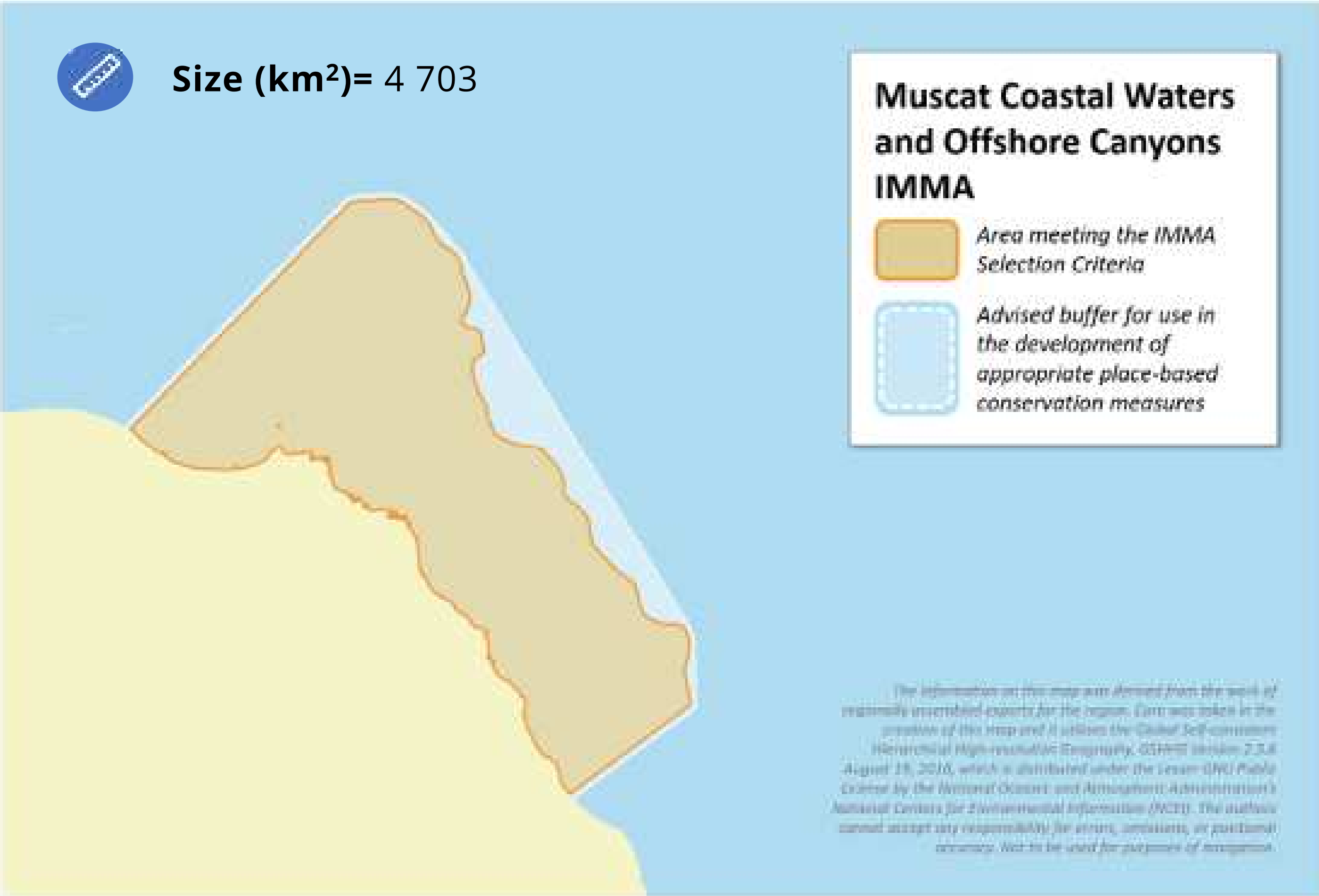
Criterion A; C) (ii)
Indian Ocean Humpback Dolphin – *Sousa plumbea*

Marine Mammal Diversity

Criterion D (ii)

Balaenoptera edeni,
Delphinus delphis tropicalis,
Megaptera novaeangliae,
Orcinus orca,
Physeter macrocephalus,
Pseudorca crassidens,
Sousa plumbea,
Stenella longirostris,
Tursiops aduncus,
Tursiops truncatus,
Ziphius cavirostris

MUSCAT COASTAL WATERS AND OFFSHORE CANYONS



SUMMARY

THE MUSCAT COASTAL AREA IN THE SEA OF OMAN comprises a range of different habitats, from low energy gently sloping sandy coastline with a wide continental shelf to the west, and a complex network of rocky headlands, inlets and islands to the east. This portion of the coast is also characterised by deep canyons and gullies offshore, providing habitat for a high diversity of cetacean species known to associate with nearshore, continental shelf and pelagic waters. Fourteen species of cetaceans have been observed in the Muscat Coastal Area, of which 7 have been observed feeding on or in clear association with suspected prey species and/or habitats. Three species, including Spinner, Common and Bottlenose Dolphins, are present year-round and have been documented with calves more often than not, indicating that the area is an important reproductive habitat for these species.

DESCRIPTION OF QUALIFYING CRITERIA

CRITERION C

KEY LIFE CYCLE ACTIVITIES

Sub-criterion Ci: Reproductive Areas | Ponnampalam [36] reports that calves were observed in 77% (n=133) of all cetacean groups observed during dedicated cetacean surveys conducted in the Muscat area between 2004 and 2006. Calves were most frequently seen in Spinner Dolphin (n=55), Common Dolphin (n=32), and Bottlenose Dolphin (n=33) groups. These three species are observed in all months of the year in the Muscat area [22,23,36,37]. While no photo-identification or genetic sampling studies have been conducted to confirm residence of the same individuals, the regularity of their presence and the frequency with which these species are observed with calves provides strong evidence that the Muscat area is important for these species' reproduction.

Sub-criterion Cii: Feeding Areas | Oceanographic data from the Muscat area indicates that it is a highly productive region, which in turn supports a thriving artisanal fishery [38]. Seven of the 14 species observed in the Muscat Area have been observed feeding in the area. Spinner Dolphins and Common Dolphins frequently occur in mixed species groups of 100 individuals or more [22,23,36,37], often also in association with artisanal fishing boats using baited handlines to fish for yellowfin tuna in among large schools of *Sardinella longiceps*. Behaviour of dolphins in these groups was often consistent with feeding (long dives, fast direction changes), although direct feeding was not always observed. Ponnampalam et al. [39] documented the stomach contents of stranded Spinner and Bottlenose Dolphins found in the Muscat area. In the case of Spinner Dolphins, myctophids (lanternfish species) comprised the most represented prey family in terms of number and frequency of occurrence (99.4% and 100.0%, respectively, for the two specimens examined), although cephalopods were also present in one specimen. Myctophids are generally found in the mesopelagic layer of deeper waters, which can be found closer to shore in the Muscat area than in the area further to the north where the continental shelf is wider. Ponnampalam et al. [39] concluded that Spinner Dolphins were most likely feeding in the deeper waters at night, and migrating closer inshore during the day, as is common for the species in other areas where it has been studied [39,40,41]. The same study documented the stomach contents of a single specimen of *Tursiops truncatus* stranded in the Muscat area, and also revealed a predominance of deep-water prey species – in this case cephalopods associated with the mesopelagic layer [39]. Stomach content analysis was not available for other species observed live or stranded in the Muscat area. However, both Common Dolphins and Bryde's Whales have been observed regularly in association with shoaling sardines, in some cases lunge feeding among them [37], Minton, unpublished data; Collins, unpublished data. Risso's Dolphins, Sperm Whales, and False Killer Whales, have also either been observed feeding, or are presumed to feed in the area based on their known prey and feeding habitats in other parts of their global range, where they are known to be associated with shelf edges and nearshore canyons and gullies, such as those found in the Muscat area [42,43,44].

CRITERION D

SPECIAL ATTRIBUTES

Sub-criterion Dii: Diversity | The Muscat area includes a range of habitats, including wide sandy coastal shelves, sheltered rocky embayments, and steeply shelving deep-water canyons close to shore. This diversity of habitats supports a range of cetacean species, some of which are confirmed to be resident year round. Fourteen cetacean species have been observed live at sea in the Muscat area according to the Oman Cetacean Database (OMCD), curated by the Environment Society of Oman. This database includes observations documented from the 1960s onward, ranging from incidental observations made by qualified observers during the course of other coastal/marine work, to those made during dedicated cetacean surveys. Records in the OMCD include those from a series of surveys conducted between 2001 and 2003, and analysed as part of a PhD thesis by G. Minton (2, 264km/104 hours of search effort) [22], and those made during a series of surveys between 2004 and 2006 and analysed as part of a PhD thesis by L. Ponnampalam (2610.4km/112.3 hours of search effort) [36]. The five most frequently observed species in both studies and in the Oman Cetacean Database as of 2019 are (in order of frequency), Spinner Dolphins, Indo-Pacific Common Dolphins, Bottlenose Dolphins, Risso's Dolphins, and Bryde's Whales, which were all represented by over 50 sightings each [22,36,37]. As described above, Spinner, Indo-Pacific Common and Bottlenose Dolphins are likely to be both feeding and breeding in the area, while Risso's Dolphins and Bryde's Whales are likely feeding. False Killer Whales were the next most regularly observed species (25 recorded observations), and when their behaviour could be accurately classified, they were most often traveling. Sperm Whales were observed on 14 occasions, including a documented observation of 35 individuals in a marguerite formation and in association with Risso's and Bottlenose Dolphins [45]. Ten observations of Arabian Sea Humpback Whales have been recorded in the Muscat Area, including two animals that were entangled in fishing gear and released through human intervention [37]. By applying spatial eigenvector filtering to models based on baleen whale sightings data collected in Oman through 2004, Corkeron et al. [14] determined that while the Arabian Sea coast of Oman was more important habitat for Arabian Sea Humpback Whales, the Muscat Area was of higher relative importance for Bryde's Whales. Other species with fewer than 10, but more than 2 documented observations at sea include Blue Whales, Pantropical Spotted Dolphins and Dwarf Sperm Whales. Striped Dolphins were documented in the Muscat area only once [37]. Species that would be expected to be observed in deeper offshore waters are most likely under-represented in the Oman Cetacean Database, as survey effort and incidental sightings are concentrated in nearshore waters. Perhaps surprisingly, to date Bottlenose Dolphin sightings in the Muscat area comprise only sightings of *T. truncatus*, with no confirmed sightings of *T. aduncus*, although this smaller tropical species is observed further south on the Arabian Sea coast of Oman. Strandings documented in the Muscat Area through 2002 reflect the same species composition and relative abundance/frequencies as those documented through live sightings, with Spinner and Common and Bottlenose Dolphins being the most frequently observed stranded species [46].

IMMA

Qualifying Species and Criteria

Spinner Dolphin – *Stenella longirostris*

Criterion C (i, ii)
Common Dolphin – *Delphinus delphis tropicalis*

Criterion C (i, ii)
Common Bottlenose Dolphin – *Tursiops truncatus*

Criterion C (i, ii)
Bryde's Whale – *Balaenoptera edeni*

Criterion C (ii)
Risso's Dolphin – *Grampus griseus*

Criterion C (ii)
Sperm Whale – *Physeter macrocephalus*

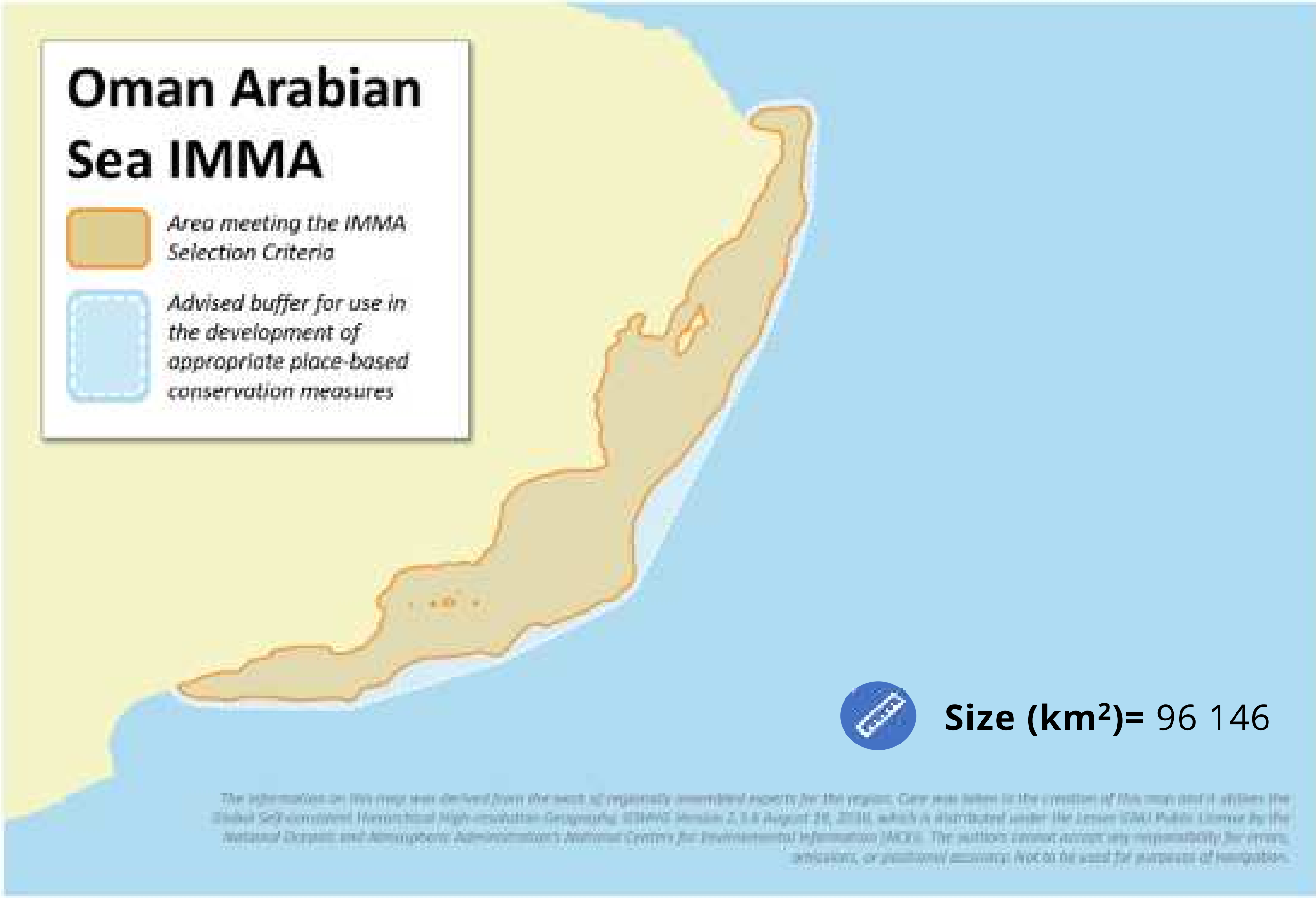
Criterion C (ii)
False Killer Whale – *Pseudorca crassidens*

Marine Mammal Diversity

Criterion D (ii)

Balaenoptera edeni, Balaenoptera musculus indica, Delphinus delphis tropicalis, Feresa attenuata, Grampus griseus, Kogia sima, Megaptera novaeangliae, Orcinus orca, Physeter macrocephalus, Pseudorca crassidens, Stenella attenuata, Stenella coeruleoalba, Stenella longirostris, Tursiops truncatus

OMAN ARABIAN SEA



SUMMARY

THE ARABIAN SEA HUMPBACK WHALE subpopulation is the only known population of Humpback Whales that does not migrate between low-latitude breeding grounds and high latitude feeding grounds. Dedicated cetacean surveys of Oman's Arabian Sea coastline, conducted from 2000 onward have confirmed that these whales are genetically distinct and geographically isolated, and thus represent a highly distinct sub-population. Boat-based surveys, acoustic surveys, satellite telemetry and photo-identification indicate that this area encompasses the most important habitat for Oman's Arabian Sea Humpback Whales. Whales mate, calve, feed and travel in this area, with the Gulf of Masirah IMMA more strongly associated with feeding, and the Dhofar IMMA more strongly associated with reproduction. This larger area includes these areas but also the wider corridor connecting the Gulf of Masirah and Dhofar, as well as the zone to the north of Masirah Island that has not been well surveyed, but where numerous anecdotal reports of humpback whales have been documented.

DESCRIPTION OF QUALIFYING CRITERIA

CRITERION A

SPECIES OR POPULATION VULNERABILITY

The Arabian Sea Humpback Whale sub-population is listed as 'Endangered' on the International Union for the Conservation of Nature (IUCN) Red List based on a mark-recapture population estimate of 82 individuals (95% CI 60-111; [4]), as well as the sub-population's documented genetic distinctiveness and isolation from other neighbouring sub-populations in the Indian Ocean [3]. While the Dhofar region (Hallaniyat Bay) and the Gulf of Masirah (GOM) have been identified as core hotspots for feeding and reproduction, Arabian Sea Humpback Whales have been documented using almost the full range of this humpback highway through direct observation during dedicated cetacean surveys, satellite tracking and passive acoustic monitoring [2,5,6,7,8,9,12,18,37].

CRITERION B

DISTRIBUTION AND ABUNDANCE

Sub-criterion Bii: Aggregations | The Arabian Sea Humpback Whale subpopulation is the only known population of Humpback Whales that does not engage in a large-scale migration between low-latitude breeding grounds and high latitude feeding grounds. It is genetically distinct and geographically isolated, and thus represents a highly distinct sub-population. Boat-based surveys coupled with acoustic surveys, satellite telemetry and photo-identification studies indicate that the Oman Arabian Sea Coast EBSA (Ecologically or Biologically Significant Marine Areas), with slightly expanded boundaries, encompasses the most important habitat for Oman's Arabian Sea Humpback Whales. While two of 14 tagged whales left the boundaries of the area, the majority stayed within these boundaries throughout the duration of their tag transmission [15,17]. Furthermore, a high rate of photo-identification re-sights between the Gulf of Masirah and Dhofar both within years and between years indicates that while some whales may engage in longer-range movements to Yemen and/or India, at least a portion of the sub-population seems to remain on the Arabian Sea coast of Oman year-round and in multiple years [2,15,17]. Additionally, mark-recapture estimates based on the same photo-identification data collected off the coast of Oman between 2000 and 2004 indicate that fewer than 100 individuals were using the habitats encompassed in the area [2,4]. Modelling of Arabian Sea Humpback Whale sightings data in relation to survey effort using spatial eigenvector filtering to account for spatial autocorrelation, as well as results of satellite telemetry studies, confirm that the higher relative densities of whales in the Dhofar and Gulf of Masirah areas a reflection of their behaviour and not only survey effort [14,15,16,17]. The aggregations have been associated with feeding and breeding behaviour and in one survey period these activities were observed concurrently [5]. While densities of whales in these areas may be lower than those on other Humpback Whale breeding and feeding grounds, the densities recorded here are higher than any other area in the Arabian Sea Humpback Whale's range to date, and the areas clearly serve the same purpose as feeding and breeding grounds do for the species elsewhere.

CRITERION C

KEY LIFE CYCLE ACTIVITIES

Sub-criterion Ciii: Migration Routes | Location and track data derived from the satellite telemetry revealed a predominance of localized behaviour and transits between the Hallaniyats Bay area and the Gulf of Masirah. Transitory movements of Arabian Sea Humpback Whales through the Dhofar area have been revealed by behaviour mode index of static space state modelling of satellite telemetry data. These records are noted from five of 14 Arabian Sea Humpback Whales instrumented with tags in the Dhofar and Gulf of Masirah areas between 2014 and 2015 [15]. Habitat utilization kernel density estimates indicate high site fidelity for the majority of tagged individuals [9,15,17]. Only two of the 14 tagged individuals moved outside of Omani waters and the area bounded by this area. Of these two, one male, remained mostly within the boundaries of the area but moved further southwest into Yemeni waters. The other, a female, crossed the Arabian Sea to the southern tip of India, but then returned to the Gulf of Masirah where she was originally tagged [15,17]. The documented movement between Oman and India, coupled with an increasing number of sightings and recordings of song documented from the coasts of Pakistan and India, provides evidence that some proportion of the Arabian Sea Humpback Whale population is using the eastern portion of the Arabian Sea as well as Oman's coast. The Oman Arabian Sea area encompasses the most heavily used habitat for whales that are present, year-around, off of Oman's coast.

Qualifying Species and Criteria

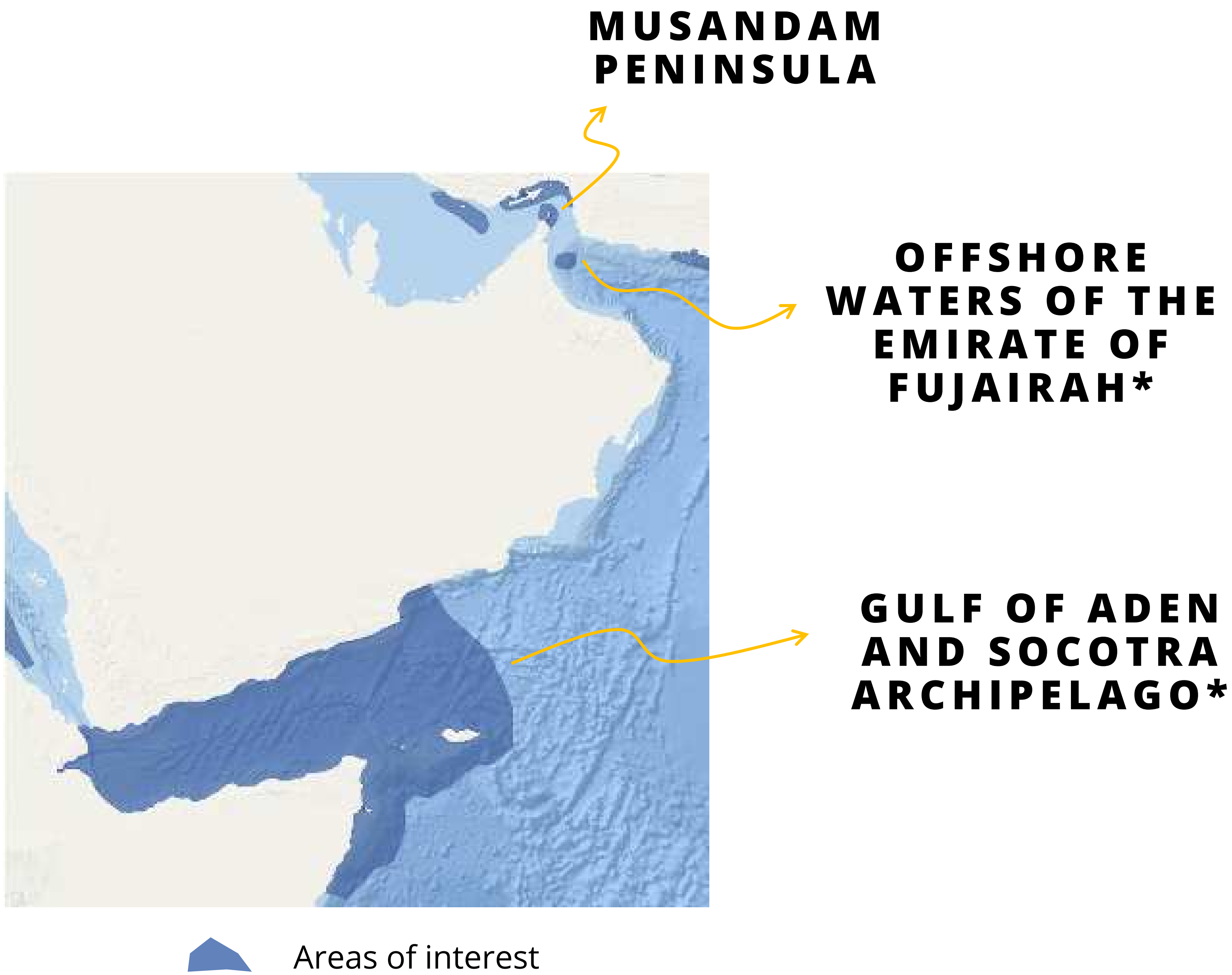
Humpback whale – *Megaptera novaeangliae*

Criterion A; B (ii); C (iii)

Marine Mammal Diversity

Balaenoptera edeni,
Balaenoptera musculus indica,
Delphinus delphis tropicalis,
Globicephala macrorhynchus,
Grampus griseus, ,
Kogia sima,
Orcinus orca,
Peponocephala electra,
Physeter macrocephalus,
Pseudorca crassidens,
Sousa plumbea,
Stenella longirostris,
Steno bredanensis,
Tursiops aduncus,
Tursiops truncatus,
Ziphius cavirostris

AREAS OF INTEREST



* Two additional AoIs which may be considered for future IMMA status have bene identified in neighbouring Yemen (the Gulf of Aden and Socotra Archipelago AoI) and UAE (the Offshore Waters of the Emirate of Fujairah). Both of these include small areas of overlap with Oman's EEZ and species are highly likely to regularly move between the waters of these neighbouring countries.

REGION: WESTERN INDIAN OCEAN AND ARABIAN SEAS

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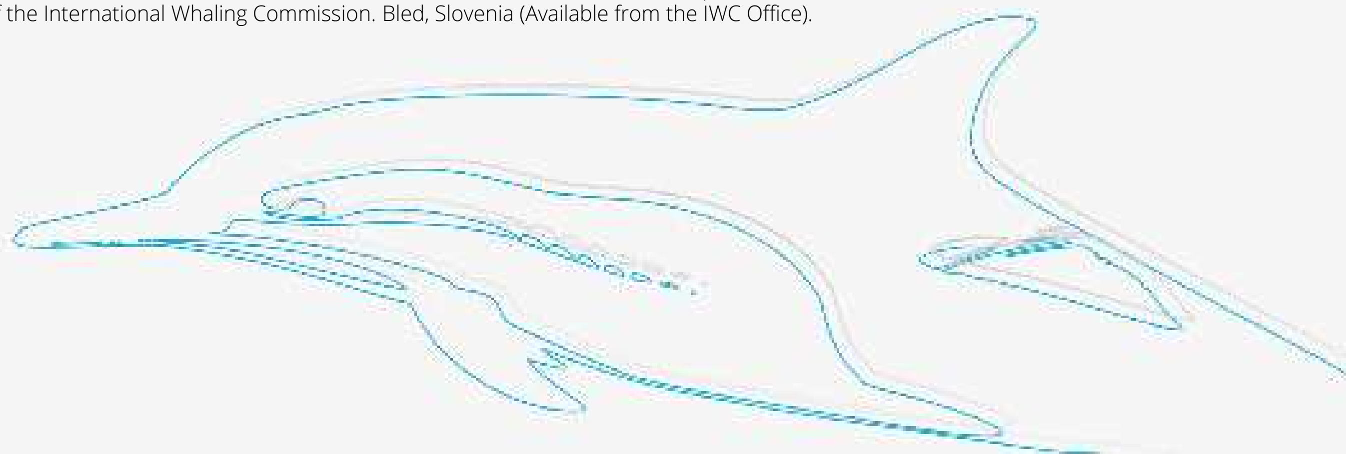

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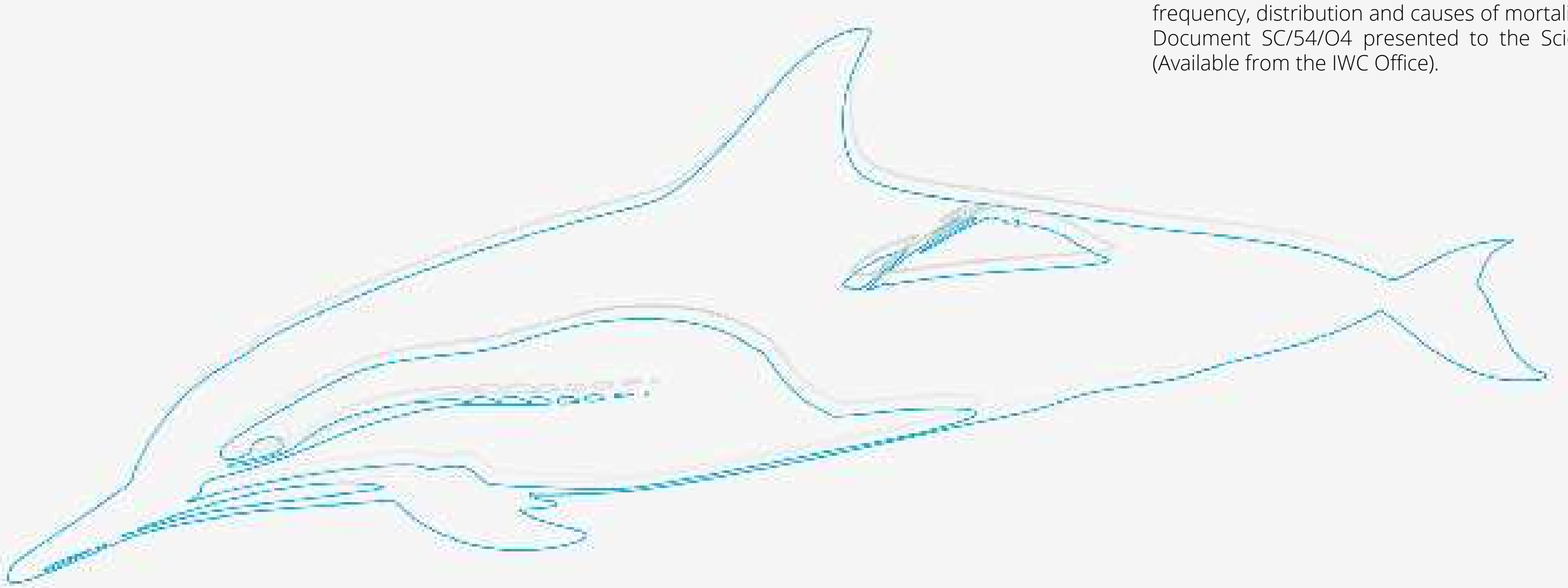

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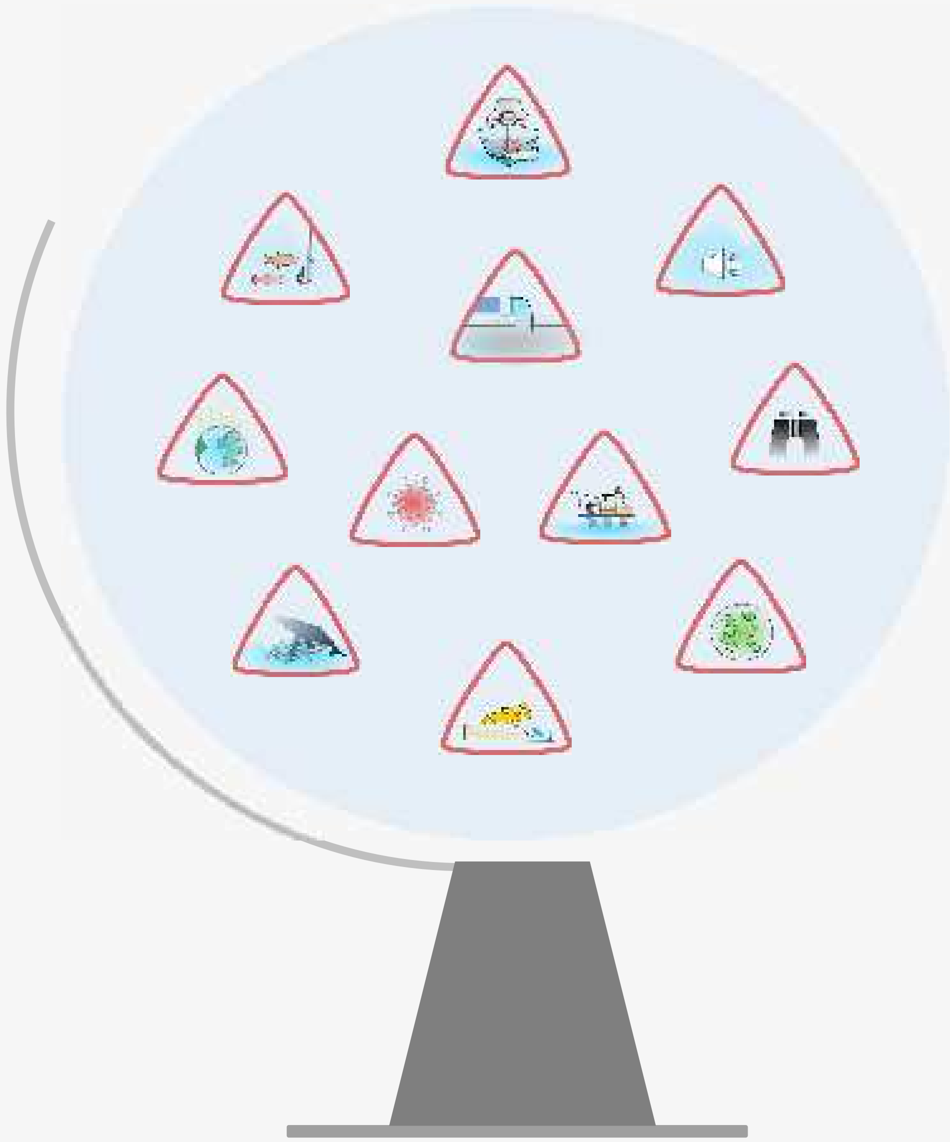
THREATS TO 3 CETACEANS



INTRODUCTION

THREATS TO CETACEANS result from both human activities and natural causes. In Oman, among the most significant anthropogenic threats to cetaceans are those related to underwater noise, vessel collisions, fisheries interactions (especially bycatch), habitat degradation, pollution, oil and gas development and marine tourism activities [1,2,3,4,5]. Natural factors that may affect cetacean mortality include disease, parasites, predation and toxic algal blooms (biotoxins) [2,6,7]; these factors may also interact synergistically with those induced by human activity, potentially exacerbating the overall impact. The effects of climate change, which may be considered 'natural' but are ultimately related to, and caused by, human activities, act synergistically and cumulatively with other threats as well as causing direct impacts. These include those related to changes in sea surface water temperatures, increasing intensity and frequency of extreme weather events, modification of shallow water benthic habitats, and large scale shifts in prey distribution and abundance [8].

Impacts may be at the individual level, such as entanglement in fishing gear, which causes the death of hundreds of thousands of whales and dolphins worldwide every year [9], or at a population/ecosystem level, such as the slow progression of habitat degradation and/or reduction of prey availability, causing long term displacement, decline or even extirpation of populations from optimum habitat [10].

In addition to previously well-documented impacts on cetaceans, there are emerging threats in Oman which now require consideration, such as disturbance from unregulated marine tourism activities (including those directly targeting cetaceans through whale and dolphin watching) [11]. Marine tourism activities are currently localised and of relatively low intensity, but ultimately impacts that cause behavioural change can reduce reproductive output over time, especially where population numbers are low, such as in the case of the Arabian Sea Humpback Whale [11]. As in the case of other threats, marine tourism activities may also compound the effects of other impacts.

There are important distinctions to be made between definitions used in the language of threats to cetaceans, which include [10]:

IMPACTING FACTOR
(e.g. the passage of an approaching vessel)

TEMPORARY
Short-term effect on the individual (e.g. a startle reaction)

PERMANENT
Long-term effect on the individual (e.g. a serious behavioral disruption which may affect its survival)

LONG-TERM (ON POPULATION)
(e.g. if a large number of individuals or the entire population is affected)

Some of the more common threats to cetaceans in Oman are introduced in the following pages.

DOCUMENTED THREATS IN OMAN

SHIP STRIKE

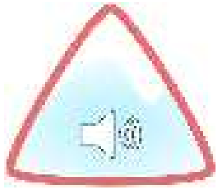
Collisions between cetaceans and vessels.

CLIMATE CHANGE

The long-term change in climatic conditions, including the global increase of ocean temperatures.

BYCATCH

The indirect/accidental capture and/or entanglement of marine life in fishing gear.



UNDERWATER NOISE

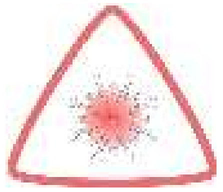
The generation of anthropogenic noise that propagates through the marine environment.

TOURISM

Vessel-based tourism including whale and dolphin watching activities.

OFFSHORE OIL & GAS

Exploration and production processes of the offshore O&G industry, including prospecting, seismic surveys, use of drilling platforms, well testing, extraction and transport of hydrocarbon products, and related activities.



DISEASE

Illnesses caused by organisms (infectious agents) including bacteria, viruses, parasites or fungi.

POLLUTION

The introduction of contaminants to the marine environment, including chemical and biological sources.

OVERFISHING

The removal of a species from the marine environment at a rate that is not sustainable.

BIOTOXIN

Toxic substances of a biological origin such as those associated with Harmful Algal Bloom.

COASTAL DEVELOPMENT

Anthropogenic changes in the coastline including construction activities, maintenance dredging, reclamation, pipe and cable laying, etc.

DOCUMENTED THREATS IN OMAN

DOCUMENTED
Published local reference available

OBSERVED
Noted during research surveys but no supporting publication in Oman

UNDETERMINED
Potential threat pending further research

REFERENCES

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SHIP STRIKE

IMPACTS TO CETACEANS from the increasing number of vessels in the world's oceans occur on both short and long-term timeframes, depending on the specific characteristics and movements of the vessels, and ecological and biological conditions within the area.

In its most dramatic and acute form, direct mortality to cetaceans can result from ship strikes. The number of vessel-cetacean collisions worldwide has significantly increased since the 1950s, due in part to the rising numbers of vessels and in part to the increasing abundance of some populations of cetaceans following the cessation of years of intensive industrial whaling that reduced numbers of large whales to a fraction of their normal levels [12,13]. In the Northern Indian Ocean region, a three-fold increase in container traffic has been documented between 2004 and 2014 [20]. Vessel collisions can impact almost all species of cetaceans with those whose habitat overlaps with increased vessel traffic (especially shipping lanes), running a higher risk of being struck. Some species are also more vulnerable than others, particularly large whales that are less able to avoid vessels and are governed by behavioural characteristics that include spending a relatively high proportion of time on the surface, such as Sperm Whales and, in some parts of the world, Right Whales [12].

Relatively little data is available on the rates of ship strikes anywhere in the world, with most incidents going unrecorded, but a wide diversity of vessels is known to be implicated, including cargo ships, naval vessels, cruise ships, ferries and jetfoils, sailing vessels, fishing vessels, whale-watching vessels and even scientific research vessels [12,13,14].

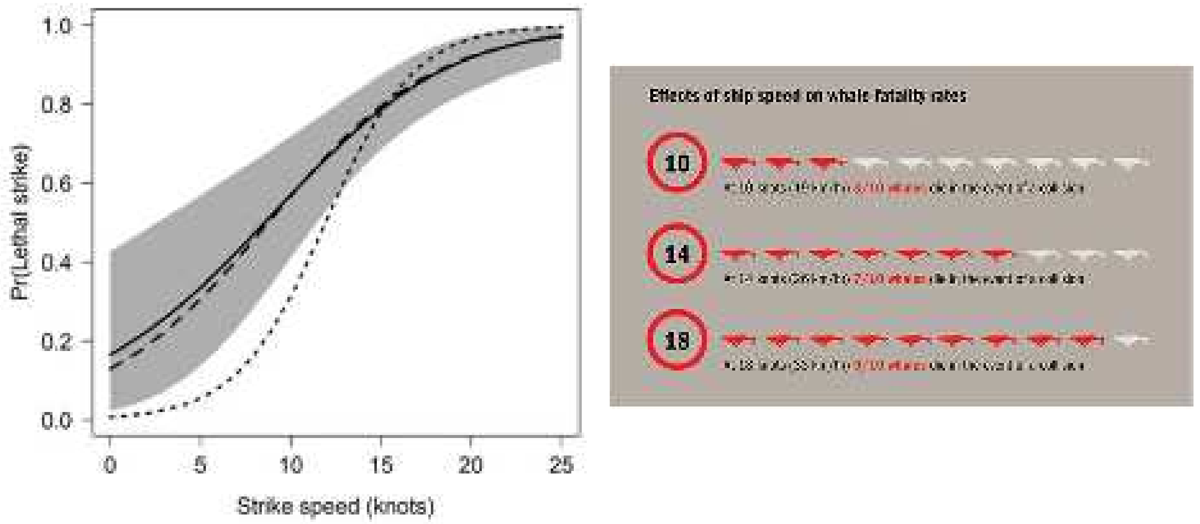


Figure 1- Left: Probability of a lethal whale strike given strike speed. The dashed line gives predictions from a logistic regression, the solid line gives posterior mean estimates from a Bayesian implementation of probit regression, and the dotted line gives logistic regression estimates reported by Vanderlaan and Taggart [15]. The gray area represents a 95% credible interval from the Bayesian analysis. Source: Conn and Silber, 2013 [178]. Right: Graphic interpretation of the graph shown to the left ©IFAW. Reproduced from Port of Duqm Advisory Notice under permission from IFAW (September 2014).

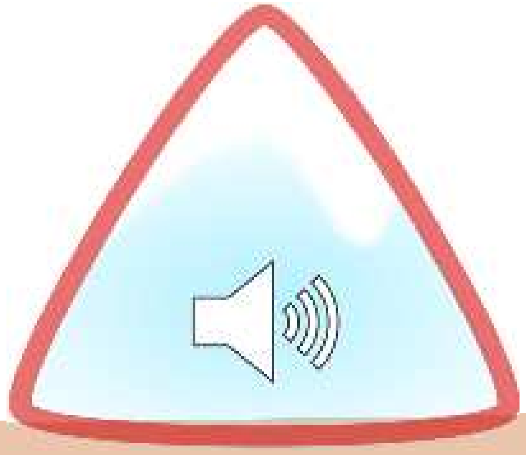
Figure 2) From left to right: Humpback injuries recorded off the Whitsunday Islands, Queensland. Copyright David Paton, Blue Planet Marine | Bryde's whale found on the bow of a passenger vessel on arrival in port in Bonaire; the crew was unaware they had hit the animal. Source: Kalli de Meyer | Propeller scars seen on a Humpback Whale nicknamed 'Bladerunner'. Source: Rosalind Butt, Eden, NSW Australia.

In general, the faster and larger the vessel, the greater the risk of serious injury, with most fatal and serious wounds caused by collisions with vessels moving at speeds exceeding 13 knots, and/or by vessels that are over 80m long (Figure 1) [13,14,15,16,17]. Collision may also leave a struck individual alive, but fatally or seriously injured including lacerations or limb amputations (Figure 2) [13,18].

As with many other threats, ship strikes may impact at the level of the individual or at a population level. As described above, individuals may emerge from a collision seriously wounded or even killed, or they may suffer only relatively minor injuries, or even escape unscathed. The long-term effect of a minor collision on the behaviour, energetics and survival rate of cetaceans is largely unknown. At a population level, the threat will depend on the proportion of individuals struck, their age, sex, social and reproductive status, as well as whether they are wounded or killed, and the overall population abundance and conservation status [14]. An example of the latter is the Arabian Sea Humpback Whale population [12], where, with a total population off Oman of less than 100 individuals, just one death could reduce the population by more than 1%. Ship strikes are considered to be a largely underestimated threat to cetaceans and international efforts to implement mitigation measures are increasing. It is notoriously difficult to detect ship strikes, with information generated from modelling studies suggesting that mortalities are significantly greater than those recorded from stranded animals alone [179]. Furthermore, the limited number of animals that strand (and often the remote locations where these strandings may occur) makes it difficult to perform post-mortem assessments to accurately determine the cause of death [180]. As with other scenarios, absence of evidence is not evidence of absence of the impact occurring. A global ship-strike database, hosted by the Scientific Committee of the International Whaling Commission, allows anyone with knowledge about a ship strike to submit information (www.iwc.int/ship-strikes).

Whilst ship strikes are theoretically a threat to all cetaceans, particularly considering the global increase in shipping/vessel traffic, a general lack of targeted research in the Northwest Indian Ocean (NWIO) on vessel-cetacean interactions for most species has resulted in limited documented occurrences for only a few species. Ship strikes are a documented threat for Bryde's Whales [2], Northern Indian Ocean Blue Whales [19], Arabian Sea Humpback Whales [20, 5] and Sperm Whales [1]. Confirmed ship strikes on some of the other marine mammal species present in Oman's waters remain undocumented at present.

Vessel traffic may also result in indirect negative consequences to cetaceans, including avoidance of areas that may be critical breeding or foraging habitat, for example, leading to associated energetic and reproductive losses over time [14]. Vessels may also cause disturbance within the lower trophic levels of the food chain, affecting the availability of prey for cetaceans and may even, in some circumstances, directly impact habitat; propeller movement from large vessels, for example, can be detected to a depth of up to 100m, with potential to disturb sediments and increase suspended matter within the water column, as well as causing damage to benthic fauna and flora [14].



UNDERWATER NOISE

SOUND PLAYS A VERY IMPORTANT ROLE in the lives of cetaceans. Sound is used in social interactions (including breeding), foraging, orientation and in response to predators [21]. Vocalisations comprise of a wide variety of sounds and cover a large frequency spectrum, ranging from very low frequency communication calls of large baleen whales to very high frequency echolocation clicks of toothed whales and dolphins. Each species has a different range of perception of sound frequencies, and produces different types and frequencies of sound. For the purposes of evaluating threats to marine mammals, acousticians group marine mammals into 'hearing groups' according to auditory response (and perceived sensitivity) to specific frequencies based on audiograms, behavioural studies and/or anatomical modelling (Table 1).

Marine mammal hearing group	Auditory weighting function	Genera (or species) included
Low-frequency cetaceans	LF	Balaenidae (*Balaena*, Eubalaenidae spp.); Balaenopteridae (*Balaenoptera physalus*, *B. musculus*)
		Balaenopteridae (*Balaenoptera acutorostrata*, *B. bonaerensis*, *B. borealis*, *B. edeni*, *B. omurai*; *Megaptera novaeangliae*); Neobalenidae (*Caperea*); Eschrichtiidae (*Eschrichtius*)
High-frequency cetaceans	HF	Physeteridae (*Physeter*); Ziphiidae (*Berardius* spp., *Hyperoodon* spp., *Indopacetus*, *Mesoplodon* spp., *Tasmacetus*, *Ziphius*); Delphinidae (*Orcinus*)
		Delphinidae (*Delphinus*, *Feresa*, *Globicephala* spp., *Grampus*, *Lagenodelphis*, *Lagenorhynchus acutus*, *L. albirostris*, *L. obliquidens*, *L. obscurus*, *Lissodelphis* spp., *Orcaella* spp., *Peponocephala*, *Pseudorca*, *Sotalia* spp., *Sousa* spp., *Stenella* spp., *Steno*, *Tursiops* spp.); Monodontidae (*Delphinapterus*, *Monodon*); Platanistidae (*Platanista*)
Very high-frequency cetaceans	VHF	Delphinidae (*Cephalorhynchus* spp.; *Lagenorhynchus cruciger*, *L. australis*); Phocoenidae (*Neophocaena* spp., *Phocoena* spp., *Phocoenoides*); Iniidae (*Inia*); Kogiidae (*Kogia*); Lipotidae (*Lipotes*); Pontoporiidae (*Pontoporia*)
Sirenians	SI	Trichechidae (*Trichechus* spp.); Dugongidae (*Dugong*)
Phocid carnivores in water Phocid carnivores in air	PCW PCA	Phocidae (*Cystophora*, *Erignathus*, *Halichoerus*, *Histriophoca*, *Hydrurga*, *Leptonychotes*, *Lobodon*, *Mirounga* spp., *Monachus*, *Neomonachus*, *Ommatophoca*, *Pagophilus*, *Phoca* spp., *Pusa* spp.)
Other marine carnivores in water Other marine carnivores in air	OCW OCA	Odobenidae (*Odobenus*); Otariidae (*Arctocephalus* spp., *Callorhinus*, *Eumetopias*, *Neophoca*, *Otaria*, *Phocarctos*, *Zalophus* spp.); Ursidae (*Ursus maritimus*); Mustelidae (*Enhydra*, *Lontra feline*)

Table 1) Proposed marine mammal hearing groups, applicable auditory weighting functions, genera or species within each proposed group. Source: Southall et al. (2019) [22]

Frequency ranges can be attributed to the hearing groups mentioned and further subdivisions are proposed within these as described below:

LOW FREQUENCY

Species in this group are considered to have ranges from 12Hz to 2kHz (or more). A subdivision within this group accounts for a 'Very Low Frequency' group that includes Blue Whales and Bryde's Whales, that have sensitivity to infra-sonic sounds (<20Hz). Within Oman, animals remaining in the broader low frequency group include Arabian Sea Humpback Whales.

HIGH FREQUENCY

The high frequency group clusters species with auditory limits between 1 and 100kHz. Subdivisions within this group are defined by larger species such as the Sperm Whale, Killer Whale and Beaked Whales that also have good hearing (and thus sensitivity) to low frequency noises as well as a hearing range that stretches into higher frequencies of other smaller species. This subgroup has also previously been referred to as 'mid-frequency' species.

VERY HIGH FREQUENCY

This group captures species including smaller cetaceans found in Oman such as the oceanic stennelids, the Dwarf Sperm Whale and others. This group has an auditory range that extends above 100kHz.

Understanding the overlaps between the frequency ranges that marine mammals use and the anthropogenic or natural noises they are exposed to, is key to understanding how these 'sources' may interfere with their 'receptors'. There are two aspects to consider here: i) *Alignment* or overlap between the source frequency and the physiology of the animal creates the potential to cause damage to hearing organs or to cause stress or behaviour change; and ii) a concept referred to as '*masking*' in which there is interference between two signals as they travel through the water [181]. A schematic representing overlaps between source levels and frequencies of ocean noise sources and marine mammal vocalisations is presented in Figure 3.

In addition to the direct threats that vessel traffic and collisions cause, noise from ships plays a central role in anthropogenic underwater noise [23]. Many cetacean populations around the world are exposed to high levels of underwater noise pollution from a variety of sources including ship noise, oil and gas exploration, military sonar, fishing activities and offshore and coastal development, with natural sources of noise also covering the wide frequency bands [24].

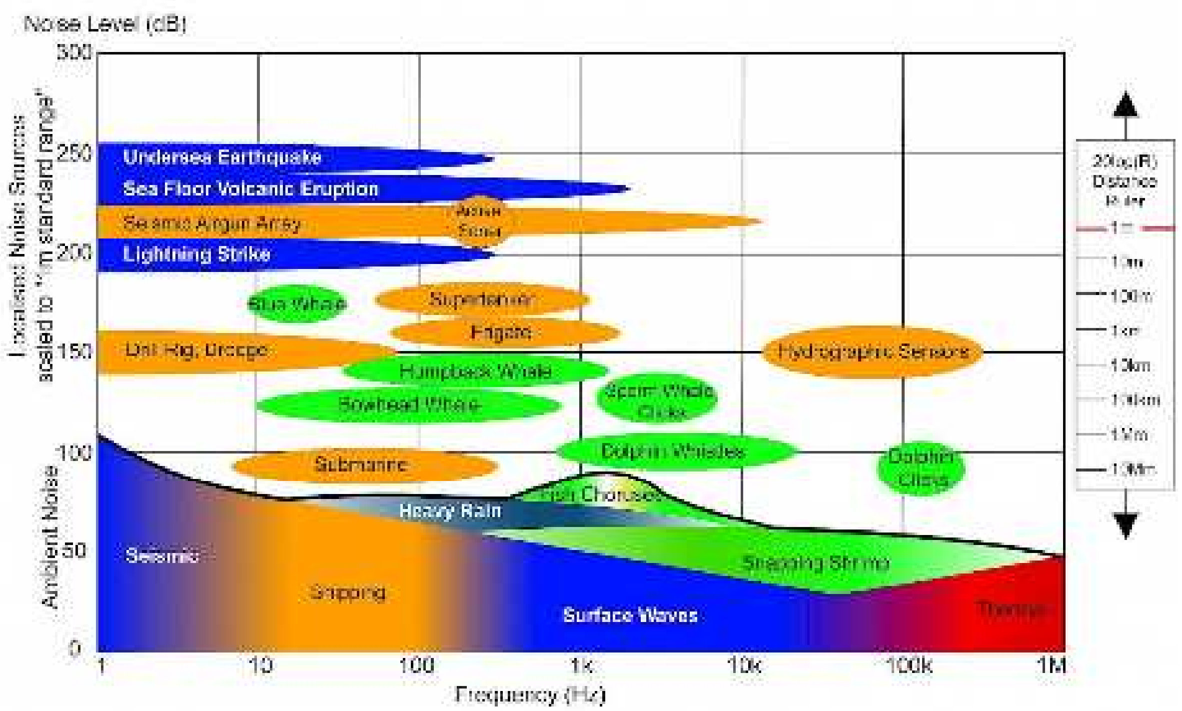


Figure 3) Levels and frequencies of anthropogenic and naturally occurring sound sources in the marine environment. Spectrum Noise Level ("Acoustic intensity per Hertz") versus Frequency (measured in Hertz or "cycles per second"). Source: OSPAR Commission (https://www.ospar.org/work-areas/eiha/noise)

Cetaceans are extremely sensitive to sound, either in terms of received intensity and frequency or of ecological fitness, with potential to affect cetaceans at the individual, population or species level [25].

Direct negative consequences of underwater noise, or indeed other forms of disturbance, at the individual or population level may include permanent changes of behaviour, short-term or long-term avoidance of certain areas and/or physiological and behavioural changes (discrepancies in growth and sexual maturity, decreased reproduction rates and lactation success, weakened resistance to disease, etc.) [14,26,27,28]. Additional time spent diving and swimming to avoid disturbance effectively results in a decrease in time spent feeding, resting or nursing, with repercussions to the individual's general health and an increased drain on energy reserves. As a result of this, negative impacts can impact fertility levels and reproductive rates of cetaceans, adversely affecting pregnant and nursing females and subsequently, the survival of young and the growth of the population [14].

The possible effects on marine mammals have been placed into the following four categories[15,16,17]

PHYSICAL & PHYSIOLOGICAL

Damage to body tissues, gross damage to ears, permanent auditory threshold shift (PTS), temporary auditory threshold shift (TTS) with eventual recovery, and chronic stress effects that may lead to reduced viability.

PERCEPTUAL

Masking of biologically significant sounds (e.g. communication signals, echolocation, and sounds associated with orientation, finding prey or avoiding natural or manmade threats).

BEHAVIOURAL

Disruption of foraging, avoidance of particular areas, altered dive and respiratory patterns, and disruption of mating systems

INDIRECT

Reduced prey availability resulting in reduced feeding rates.

Physiological consequences to noise exposure are therefore extremely varied, with the possibility to affect feeding, foraging, resting, socialising and breeding behaviours, leading to potential impacts at the population level.

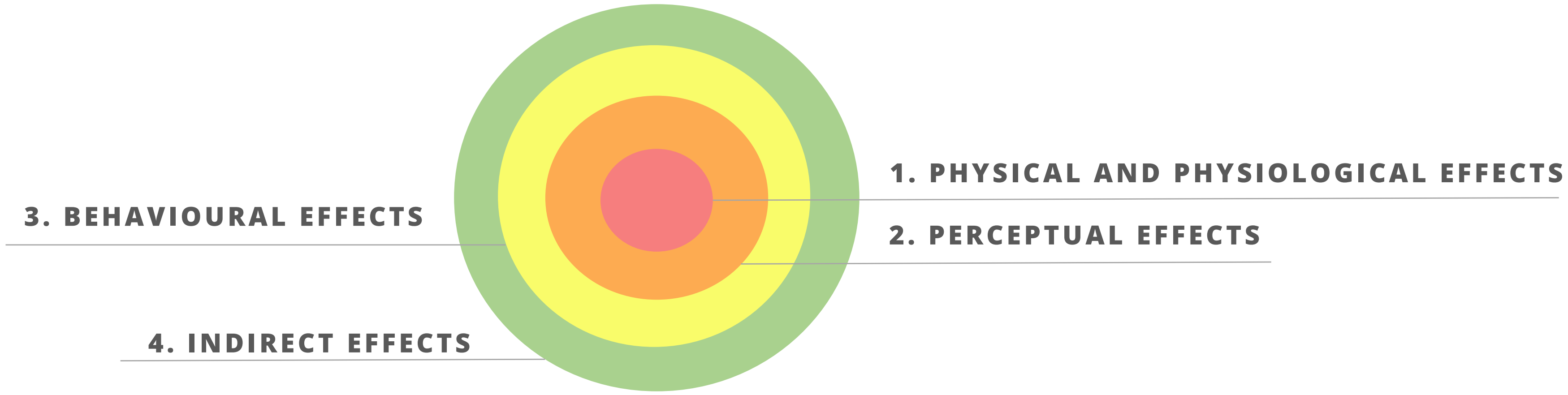


Figure 4) Possible effects of noise on marine mammals, grouped by categories. Derived from Gordon et al., 2004 [29]. Colour scheme represents the exposure level to the receptors, with red being most severe due to a loud source or at close proximity and green a week source with the receptor distant to the source.

Controlled experiments have attempted to understand the thresholds at which Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) occur in different species. The results of one study are shown in Figure 5 on the following page. However, for the purpose of understanding how this effects marine mammals over their lifespan, Ketten (2012) [30] notes that we know little about the nature of long-term noise effects in most mammals, but that post-mortem studies present evidence of auditory nerve fibre degeneration consistent with profound hearing deficits, as a means to confirm that PTS can occur, and confirming results of previous work stating that exposure to high levels of continuous noise or impulsive sound with high rise times can lead to injuries of hearing structures [31,32,33]. Figure 5 and Table 2 on the following page highlight the difference between the onset of TTS at different frequency and sound exposure levels (SELs) according to the 'hearing group' category. SELs are used as a unit of measurement for referencing energy levels received by a receptor. This unit accounts for both the amplitude and duration of the sound. For marine mammals, TTS SEL ranges may occur upwards of 157 dB re 1 μPa2 s. As presented above, anthropogenic sources of noise at and above these levels include large ships, seismic surveys and sonar operations, all of which occur in the waters surrounding Oman.

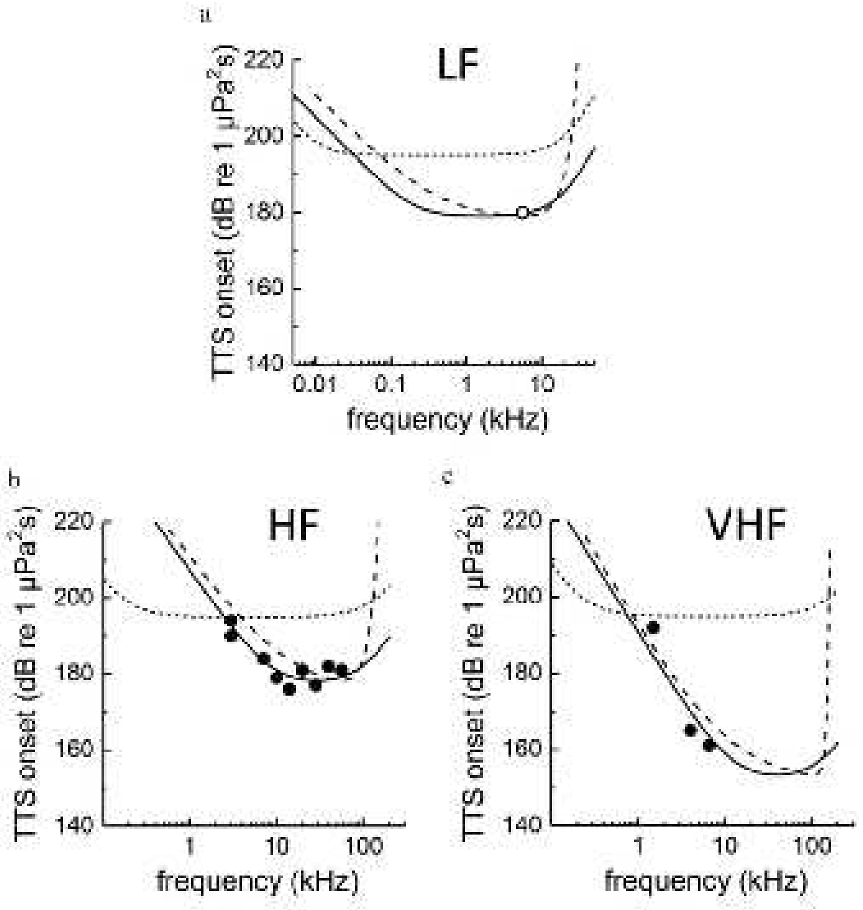


Figure 5) Exposure functions (solid lines) for Low Frequency (LF) (top), High Frequency (HF) (bottom left), and Very High Frequency (VHF) (bottom right) cetaceans generated. Open symbol for LF cetaceans indicates the estimated TTS onset at f0 based on TTS data from other groups given that no direct empirical data exist for any LF species. Filled symbols indicate empirical onset TTS exposure data used to determine exposure functions for HF and VHF cetaceans. Normalized estimated group audiograms (dashed lines) are shown for comparison with a minimum value identical to that of the associated exposure functions. Estimated exposure functions derived from M-weighting filters each respective group with a minimum value set at the estimated TTS-onset value (dotted lines) are also shown for comparison (derived from Southall et al., 2007). Source: (Southall et al., 2019) [22]

Table 2) TTS and PTS onset thresholds for marine mammals exposed to non-impulsive noise: SEL thresholds in dB re 1 μPa2 s under water and dB re (20 μPa)2 s in air (groups PCA and OCA only) Source: (Southall et al., 2019) [22]

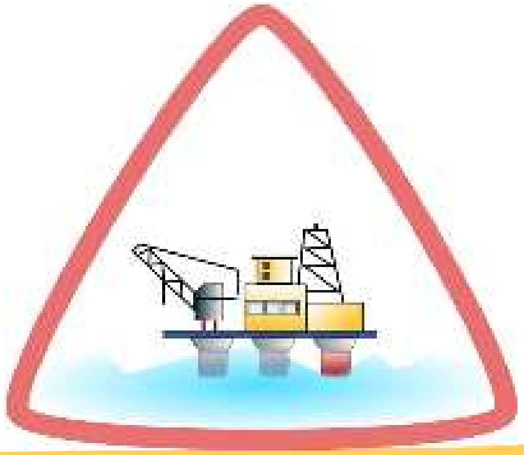
Marine mammal hearing group	TTS onset: SEL (weighted)	PTS onset: SEL (weighted)
LF	179	199
HF	178	198
VHF	153	173

Deep diving marine mammals, such as the Sperm Whale and Cuvier's Beaked Whale, can experience some of the most dramatic and immediate effects from exposure to noise. Mid-frequency sonar used during military naval activities have been implicated in mass stranding's of cetaceans in different parts of the world [34]. Multi-beam echo-sounder systems used in bathymetry surveys have also been implicated in mass strandings, including a well-documented case of 100 Melon-headed Whales (*Peponocephala electra*) in 2008 in Madagascar [35]. As well as the impact to hearing response, noise exposure to a cetacean at depth can induce a behavioural 'startle' response resulting in rapid surfacing by the animal. Deep diving species are particularly prone to this. This produces a physiological condition known as Decompression Sickness (DCS), which SCUBA divers term, the 'bends' arising from dissolved gases coming out of solution and forming bubbles in the body's tissues and fluids. This can result in haemorrhaging of organs and blocking of blood vessels and can be fatal.

Underwater noise can also lead to mortality from unexpected causes. In one example, Humpback Whales that did not leave an area of industrial underwater explosions (estimated levels of 150 dB re 1 μPa measured at one mile from the source) showed an increase in entanglement in fishing nets in the area [36]. Subsequent necropsies of stranded individuals found physiological damage to the middle ear consistent with blast injuries [37] that could feasibly have disoriented the whales leading to higher rates of collision with fishing nets.

The immediate effects of underwater noise can be difficult to determine, as noise impacts may cause widespread effects over hundreds or thousands of kilometres. Impacts may also be as a result of multiple sources of underwater noise, interacting cumulatively or synergistically e.g. where shipping lanes overlap with areas of seismic surveys, or multiple surveys are conducted in close proximity [38]. The exposure to underwater noise is considered to be an 'aggravating factor' in vessel collisions; increased underwater noise may make it difficult for individuals to detect approaching vessels or fishing gear, either against background noise, or due to hearing loss / damage caused by high noise levels. Habituation to shipping noise may also cause cetaceans not to respond (or to respond less over time) to vessel movements, thus increasing the risk of ship strikes [12,38,39,40].

Although the impacts of underwater noise on cetaceans worldwide is well documented, underwater noise has so far been noted as a specific threat only to the Arabian Sea Humpback Whale population in Oman [41]. This is, in part, due to the relatively greater level of research on this species due to its conservation status. Underwater noise, however, is likely to be a threat to all cetaceans in Oman, with some areas potentially receiving greater exposure than others, such as in the Straits of Hormuz due to shipping activity, around ports such as Duqm, Salalah and Sohar, and wherever there is extensive coastal development or offshore exploration and exploitation of hydrocarbons.



OFFSHORE OIL AND GAS

OIL AND GAS DEVELOPMENT is considered a threat to cetaceans [42] at various stages of the exploration and exploitation process including prospecting (especially during seismic surveys), construction of drilling platforms and ultimately the extraction and transport of hydrocarbon products [43]. These activities can affect the acoustic environment (see Underwater Noise section above), and cause an increased risk of vessel strikes as well as an increased likelihood of exposure to oil spills or leaks, or other industrial substances that may be directly or indirectly harmful to cetaceans [43]. As part of the broader "underwater noise" threats, seismic surveys have often been linked to displacement of cetaceans, with increasing speculation that there is a causal link between seismic noise and mass strandings of cetaceans [44,45].

Seismic surveys generally use high intensity, low frequency, pulsed acoustic waves that may travel across ocean basins for thousands of kilometres [46], especially in deeper waters [47]. As shown in the "Underwater Noise" section, Figure 3 illustrates how the generation of seismic survey noise through the use of airguns overlaps with the low frequency sounds used by mysticetes such as Blue Whales and Humpback Whales. High-frequency noises may also be produced sporadically during seismic surveys [48], potentially affecting odontocetes which rely on higher frequency vocalizations for communication [49]. Recent studies have documented ecosystem-wide impacts from seismic surveys on cetaceans, including a range of both mysticete and odontocete species [50].

Research into the habitat utilization of Arabian Sea Humpback Whales has identified both the Hallaniyat Bay and the Gulf of Masirah as potential habitat hot spots for this species [4,51,52,53]. The Gulf of Masirah is a gazetted oil concession (Block 50) and subject to both seismic exploration and test well development [4]. Over the course of 37 days of marine mammal observation during seismic surveys in this area, 68 confirmed sightings of Arabian Sea Humpback Whales were made. One whale was struck by towed survey equipment during an operational shutdown that was implemented following the observation of two whales, neither of which moved away from the approaching vessel [4].

Other species that have been observed in Oman to have been affected by offshore oil and gas development include Bryde's Whales, Northern Indian Ocean Blue Whales, Sperm Whales, False Killer Whales, Common Bottlenose Dolphins, Indo-Pacific Common Dolphins and Spinner Dolphins. These interactions with oil and gas developments in Oman have not yet been published in peer-reviewed scientific journals, but have either been reported ad-hoc during a scientific survey, or by a qualified Marine Mammal Observer during a seismic survey.

CASE STUDY: SEISMIC SURVEY EFFECT ON HUMPBACK WHALE SOCIAL INTERACTIONS

Studies evaluating the behavioural response of migrating humpback whales to seismic surveys have been conducted off the east coast of Australia revealing that the presence of vessels towing seismic air gun arrays (regardless of whether the airguns were operating) reduced the likelihood of whales socially interacting within their groups or singer groups nearby [54]. Vessels that were within 8km of a humpback whale group after the air gun was fired still elicited a change in behavioural response [54]. Whilst mitigation measures applied to seismic surveys include techniques such as ‘soft starts’, which promote a gradual ramp-up of air gun amplitude to minimize the physiological fright response or impacts to hearing, mitigation is rarely conceived to minimise disturbance leading to changes in social behaviour. However, the above mentioned studies in Australia concluded that behavioural changes have foreseeable impacts at an individual level, and on a much larger number of whales at a greater range (>4km) exposed to lower sound levels (above 105 dB re 1 µPa) (See Figure 4 and 5)[54]. This finding emphasises the need to consider the proximity-response relationship in mitigation, not only the oil and gas sector, but also in relation to other industries such as shipping, fishing, and whale watching.

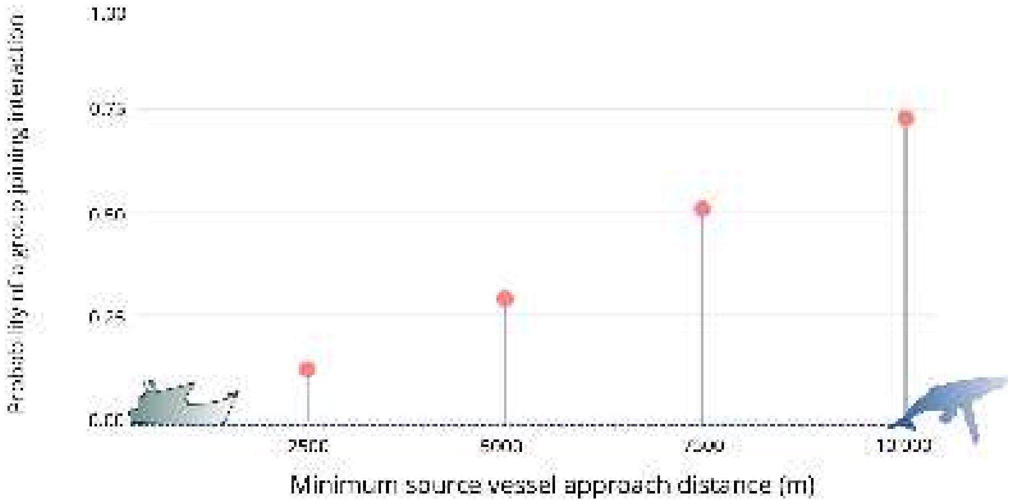


Figure 4) Effect of source vessel closest approach distance on the probability of groups joining within each 10 min time bin when there was a singer within 2 km. Groups in the control and active treatments are included. (Adapted from Dunlop et al. 2020)

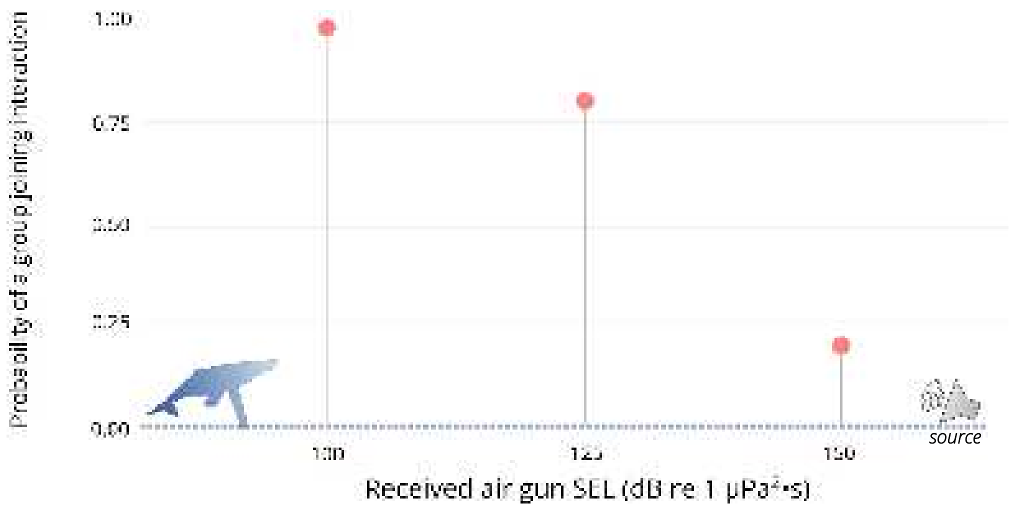


Figure 5) Effect of air gun received level on the probability of groups joining within each 10 min time bin where there was a singer within 2 km. (Adapted from Dunlop et al. 2020)

The complexity of sound waves propagation and the range of potential damage to marine mammal hearing necessitates modelling and assessment of potential threats from anthropogenic noise sources by marine mammal acousticians during the Environmental Impact Assessment process. This is common practice in the case of seismic surveys, as well as the use of multi-beam sonar and even construction and piling operations. Many countries also apply their own standard mitigation policy guidelines to such practices, as discussed in the following chapter.

FISHERIES THREATS – BYCATCH AND OVERFISHING

FISHERIES CAN IMPACT CETACEANS BOTH DIRECTLY AND INDIRECTLY, with potential direct effects including cetacean bycatch, intentional harm to cetaceans from fishermen and disturbance due to fishing activities. Indirect effects may include the reduction of cetacean prey availability or changes in the local food web (food web 'competition'), and habitat loss or damage from fishing activities such as bottom trawling and other destructive methods [55,56,57,58]. Competitive interactions between fisheries and cetaceans have the ability to negatively impact cetaceans especially where target prey for fishermen and cetaceans overlap. Discarded fishing gear (responsible for 'ghost-fishing') also poses a direct entanglement threat to cetaceans with sometimes fatal results, as witnessed on several occasions in Oman.

As of 2001, entanglement in fishing gear was the leading cause of cetacean mortality worldwide [59] and the overall impact of the fisheries industry on cetaceans remains extremely high and largely undocumented. Both deliberate kills and incidental catches of cetaceans have increased as the fisheries industry has developed [55,60]. Bycatch of cetaceans in fishing gear in some parts of the world have brought cetacean species or populations close to extinction and represents a serious threat all around the world [55,61,62,63]. The IWC's Scientific Committee and other international bodies have concluded that cetacean bycatch rates exceeding 2% (a rate that is exceeded in many regions of the world) may be unsustainable [64,65,66].

The extinction of the Baiji (*Lipotes vexillifer*) in the Yangtze River, China, was due, in part, to bycatch in a variety of fisheries, although other threats, such as depletion of prey resources, were also implicated [67,68]. The Vaquita (*Phocoena sinus*) population in the Gulf of California, Mexico, is also threatened by bycatch, and less than 20 individuals now remain [68,69,182]. The North Atlantic Right Whale is subjected to two major threats; entanglement in fixed fishing gear and ship strikes. Approximately three quarters of the population have visible evidence of interactions with fishing gear, thought to be primarily from lobster traps and gill nets [68].

Depredation (when an animal removes or damages fish captured in fishing gear) also has consequences for marine mammals, particularly in conjunction with longline fisheries. Depredation by odontocetes (notably Killer Whales, False Killer Whales and Sperm Whales) appears to have increased in frequency, severity and geographic extent within the longline swordfish and tuna fisheries [68]. Cetaceans may become entangled in, or hooked on, longline fishing gear whilst feeding or attempting to feed on captured fish. Odontocetes feeding in this manner may also be subject to retaliatory measures from fishermen; fishermen have been recorded shooting at marine mammals and using explosives as a deterrent to prevent depredation [68,70].

Figure 6) *Left*- Arabian Sea Humpback Whale in Oman entangled in discarded fishing gear. Photo by Robert Baldwin. *Right*- Humpback whale entangled in pot gear off W Australia. Photo by Leighton De Barros, Sea Dog TV International.

A wide variety of fishing methods including pelagic driftnetting, bottom gillnetting and trawling are known to result in bycatch of cetaceans worldwide, with cetacean species of all sizes being affected [55,61,63,71,72]. For example, gillnet fisheries in Ecuador, Peru and Chile interacting with a wide range of cetacean species [71]; driftnet, gillnet and anchored set nets and pots in Korean fisheries of the East Sea which are known to impact at least 10 cetacean species [73]. In another study, entanglements of 31 Right Whales and 30 Humpback Whales in the western North Atlantic were analysed; where gear type was identified, 89% of entanglements (equating to 32 events) were attributed to pot and gillnet fishing gear [74].

Recent work reviewing cetacean bycatch in the Indian Ocean tuna gillnet fisheries estimated a peak of cetacean bycatch at almost 100,000 individuals per year during the period of 2004 – 2006, decreasing to a current (2020) estimate of 80,000 individuals per year [75].

Based on the results from 10 bycatch sampling programmes, which operated from 1981 – 2016, these gillnet fisheries were responsible for the incidental capture of an estimated cumulative total of 4.1 million small cetaceans between 1950 and 2018. These figures exclude cetaceans caught but not landed, sub-lethal impacts (some of which may have resulted in subsequent mortality), or mortality associated with other tuna fisheries (e.g. purse-seine fisheries), suggesting that the total cetacean mortality from the Indian Ocean may in fact be substantially higher than current estimates suggest [75]. There is relatively little documented study of the impacts of gillnet fisheries in the Arabian region, but the reported decline of small cetaceans by 71% between 1986 and 1999 in the Arabian Gulf, may have been partially due to bycatch [76].

Owing to the dedicated recording of sightings and strandings data in Oman [2], recorded interactions between cetaceans and fisheries are documented for many of the cetacean species known to be present in Oman's waters. These include strandings where definitive signs of entanglement with fishing equipment were obvious, as well as live sightings (and in some cases, release) of cetaceans entangled in fishing equipment (OMCD). Spinner dolphins, Indo-Pacific Common Dolphins, Indo-Pacific Bottlenose Dolphins, Common Bottlenose Dolphins, Indian Ocean Humpback Dolphins, Pygmy Killer Whales, False Killer Whales, Risso's Dolphins, Dwarf Sperm Whales, Sperm Whales, Arabian Sea Humpback Whales, Northern Indian Ocean Blue Whales and Bryde's Whales are all documented as bycatch in Oman [2,5,41,53,77,78]. Striped Dolphins have also been observed as fisheries bycatch, but this has not yet been formally documented. The threat of bycatch to the remaining cetacean species in Oman is, as yet, undetermined. However, based on the continual increase in fishing effort off the coast of Oman and other parts of the Arabian Sea [79,80,81], it is considered to be significant for many species.

Threats to cetaceans in Oman's waters from overfishing are as yet undetermined, and more research is needed on this subject.

WHALE AND DOLPHIN WATCHING

THE RISE IN POPULARITY OF MARINE TOURISM, and particularly whale and dolphin watching (hereafter referred to as whale watching), has caused it to be among the growing list of threats to cetaceans worldwide. Whale watching can have positive impacts; it can make substantial, long-term inputs to local economies and provide employment opportunities [82,83] and can also act to improve the awareness and interest of both communities and individuals about whales and dolphins, and the threats they face. In 2012, whale watching was worth approximately USD 2 billion as a global industry, making it the greatest economic activity reliant upon cetaceans [84]. In addition to the economic benefits of whale watching, there are educational, conservation and research benefits, such as raising awareness of conservation efforts and collecting data from whale watching platforms [85].

However, in most places, whale watching is not regulated or licensed, which can result in difficulties in obtaining basic information about the industry (such as economic performance, carrying capacity of the industry, etc.) and, more pertinently, can lead to potentially negative impacts on cetaceans due to disturbance by participating vessels.

Whale watching in Oman is a relatively recent activity that has contributed to Oman's growing tourism industry over the last two-three decades as a result of increasing awareness of cetaceans [11,86]. The majority of operators target coastal and offshore dolphins (primarily Indo-Pacific Humpback Dolphins, Spinner Dolphins, Long-Beaked Common Dolphins and Indo-Pacific Bottlenose Dolphins). However in recent years, the Arabian Sea Humpback Whale has also become the target of small-scale, unregulated whale watching at the Halaniyat Islands [11,87]. Other species are observed as a result of opportunistic encounters, rather than as targeted species. Based on observations of whale watching vessel handling behaviour around Spinner Dolphins, Indo-Pacific Common Dolphins and Indo-Pacific Humpback Dolphins, it was suggested that vessel captains and operators in the industry required further training, guidance and monitoring to improve responsible behaviour around whales and to ensure the sustainability of the industry [11]. Potential impacts on the Arabian Sea Humpback Whales are particularly important to consider based on their extremely small population size. . Guidelines to assist whale watch operators in Oman were developed in 2013/14 as part of an IWC-supported project [11].

Impacts to marine mammals arising from whale watching have previously been considered minor when compared to other types of anthropogenic impacts such as vessel collisions, underwater noise and fishing gear entanglements [88]. However, whale watching has potential to increase direct mortality as a result of vessel strikes and to cause disturbance as a result of underwater noise and harassment. Numerous studies have determined that cetaceans change their behaviour as a direct response to the presence of whale watching vessels, including changes in swimming speed and direction, group size, group coordination, surfacing patterns and frequency, and vocalisation [84,85,89,90] (Table 3)

Behavioural responses of cetaceans to whale watching are commonly divided into short-term, long-term and non-visible impacts [84,85,88,90,91,92,93,94].

SHORT TERM

Short-term effects include changes in swimming speed, direction or behaviour (i.e. surfacing/diving, inter-breath intervals, resting etc.) [89,95,96,97,105,106]. The frequency and strength with which animals respond to these impacts can also vary depending on both the distance from the vessel(s), and the number of vessels present [96,98,100,101].

LONG TERM

Long-term effects are, by definition, harder to determine, as they require a population to have been studied prior to the onset of whale-watching activities (to provide a 'baseline' for comparison), and due to the extended lifespan and low reproduction rates of whales and dolphins [85]. The long-term effects resulting from repeated short-term behavioural changes may ultimately include reduction of fitness (long-term decline in vital rates/reproductive capacity) if essential body-maintenance behaviours such as feeding and resting are negatively affected, particularly if exposure to these impacts is prolonged [84,90,91].

NON-VISIBLE

Non-visible effects include hormonal responses which may lead to chronic stress, limiting reproduction, supressing growth and ultimately lowering survival rates. Chronic stress is also linked to disease [85,102,103]. These non-visible effects are challenging to detect or monitor, particularly in wild populations.

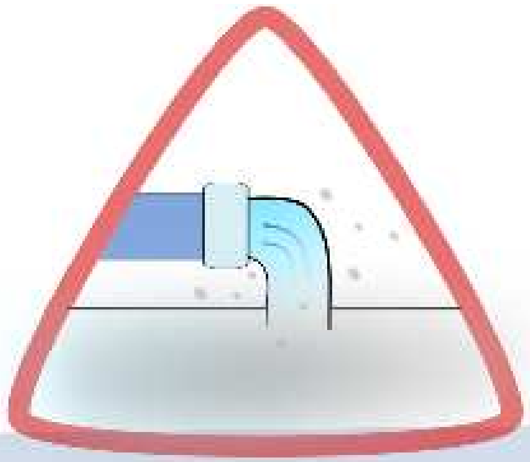
Given that whale watching can provide a livelihood for coastal communities, the negative impacts of the industry can lead to contention between industry operators, conservationists and regulators.

For particularly vulnerable populations of whales and dolphins, such as the Arabian Sea Humpback Whale, or in the absence of evidence, regulators may wish to apply the precautionary principle and carefully manage the gradual development of the industry.

Where evidence is available regulators may be able to set carrying capacity limits to control numbers of vessels accessing groups within a given area [11]. The management of whale and dolphin watching is discussed further in Chapter 4.

Table 3) Examples of behavioural changes observed in cetacean species in response to whale-watching traffic. Adapted from Parsons, 2012 [84].

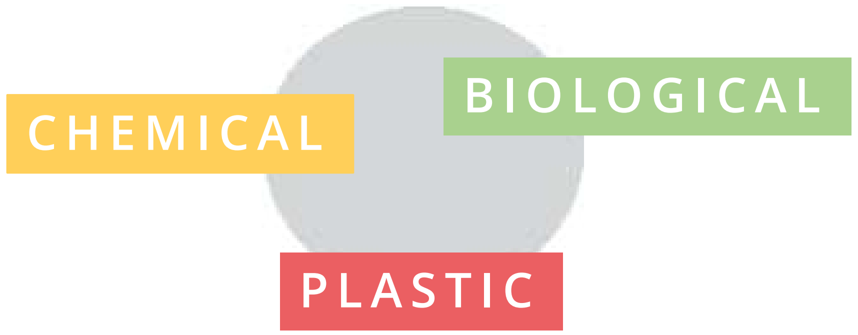
BEHAVIOUR CHANGE	SPECIES	REFERENCE
SURFACING/DIVING	Common Bottlenose Dolphin, *Tursiops truncatus*	95,104,105, 106,107
	Indo-Pacific Bottlenose Dolphin, *Tursiops aduncus*	100,108
	Indo-Pacific Humpback Dolphin, *Sousa chinensis*	109
	Costero, *Sotalia guianensis*	110
	Killer Whale, *Orcinus orca*	111
	Humpback Whale, *Megaptera novaeangliae*	112
	Fin Whale, *Balaenoptera physalus*	113
	Sperm Whale, *Physeter macrocephalus*	114,115
	Fin Whale, *Balaenoptera physalus*	113
"ACTIVE" BEHAVIOUR (e.g. tail slapping and bleaching)	Common Bottlenose Dolphin, *Tursiops truncatus*	106
	Commerson's Dolphin, *Cephalorhynchus commersonii*	116
	Killer Whale, *Orcinus orca*	117
	Humpback Whale, *Megaptera novaeangliae*	96
ACOUSTIC	Common Bottlenose Dolphin, *Tursiops truncatus*	118,119
	Killer Whale, *Orcinus orca*	120
	Humpback Whale, *Megaptera novaeangliae*	121
	Sperm Whale, *Physeter macrocephalus*	122
GROUP SIZE OR COHESION	Common Bottlenose Dolphin, *Tursiops truncatus*	123,124
	Costero, *Sotalia guianensis*	110
SWIMMING SPEED	Indo-Pacific Bottlenose Dolphin, *Tursiops aduncus*	100
	Spinner Dolphin, *Stenella longirostris*	125
	Killer Whale, *Orcinus orca*	97,111,126
	Humpback Whale, *Megaptera novaeangliae*	89,90
SWIMMING DIRECTION	Common Bottlenose Dolphin, *Tursiops truncatus*	123,124
	Indo-Pacific Bottlenose Dolphin, *Tursiops aduncus*	100
	Indo-Pacific Humpback Dolphin, *Sousa chinensis*	109
	Spinner Dolphin, *Stenella longirostris*	125
	Costero, Sotalia guianensis	127
	Killer Whale, *Orcinus orca*	97,101,111
	Humpback Whale, *Megaptera novaeangliae*	89,90,96
ALTERED FEEDING OR RESTING	Common Bottlenose Dolphin, *Tursiops truncatus*	128,129,130,131
	Indo-Pacific Bottlenose Dolphin, *Tursiops aduncus*	132
	Short-beaked Common Dolphin, *Delphinus delphis*	133
	Costero, *Sotalia guianensis*	134
	Dusky Dolphin, *Lagenorhynchus obscurus*	116,135
	Commerson's Dolphin, *Cephalorhynchus commersonii*	116
	Risso's Dolphin, *Grampus griseus*	136
	Killer Whale, *Orcinus orca*	137,138,139
	Humpback Whale, *Megaptera novaeangliae*	140



POLLUTION

CHEMICAL POLLUTION, SEWAGE AND PLASTIC DEBRIS all play a role in the degradation of habitats needed to support the biological demands of cetaceans. As with many of the other threats described here, habitat degradation may cause both direct and indirect effects on cetaceans at the individual and/or population level, highlighting the need for the proclamation, management and enforcement of Marine Protected Areas that encompass their habitat needs [141]. Whilst there are not yet any published surveys in the scientific literature detailing the threats of pollution specifically to cetacean species in Oman, it is likely that the global prevalence of pollution in the marine environment remains as much of a threat to Oman's marine mammals as it does to marine mammals elsewhere in the world. For the Indian Ocean Humpback Dolphin specifically, it is thought that exposure to environmental contaminants is likely to be very high [142] due to their narrow coastal range.

Pollution sources to the marine environment may include **chemical** and **biological** pollution, with **plastic** pollution also considered to be a major threat worldwide.



CHEMICAL

Chemical pollution may cause immediate effects on cetacean prey, such as mass mortality of fish stocks, changes in fish population (or indeed entire ecosystems), an increase in fish disease from a build-up of contaminants through the food chain, and additional knock-on effects to predatory cetaceans [141,143]. This may arise from terrestrial run-off of chemicals into waterways and subsequently into the ocean, or may result from marine-based pollution incidents such as oil or chemical spills.

BIOLOGICAL

Biological pollution such as the contamination of coastal waters with sewage, increases the changes of cetaceans coming into contact with infectious agents such as parasites (mainly nematodes), viruses and bacteria. Populations or individuals already experiencing some degree of increased stress in their environment (e.g. from underwater noise, reduction in prey availability, etc.) may be more susceptible to diseases and pathogens [141,144]. In addition to direct impacts, sewage may indirectly affect cetaceans by altering the environmental conditions (due to eutrophication from nutrient enrichment) needed to support prey populations.

PLASTIC

Plastic pollution has increased dramatically in the oceans and is now considered a major threat to biodiversity [145,146,147,148,149]. It is estimated that in the marine environment, approximately 40-80% of the larger items of marine debris are plastic, comprised of packaging, carrier bags, footwear, domestic items etc., with lost or discarded fishing gear also a significant contributor [150]. For marine fauna, the primary impacts of marine debris are from ingestion or entanglement, with ingestion of debris documented in 48 (56% of) all cetacean species globally [145,151]. This may occur actively or incidentally during feeding, and in some cases, it is suspected to play a role in stranding behaviour [150]. Ingestion of plastic debris (including micro- and macroplastics), also increases interference to, and blockages within, the digestive tract of cetaceans, with gastric impaction, stomach rupture, emaciation and laryngeal entrapment all documented in response to plastic ingestion [150,152,183]. In addition to physical trauma, the ingestion of plastic debris also increases the risk of metabolism of pollutants/toxins [144,145,150,153,154]. Entanglement in debris may result in drowning, suffocation or strangulation, or may interact synergistically with other threats, e.g. sub-lethal entanglement may make responsive behaviour (such as moving away from approaching vessels) difficult [12,155]. Additional sub-lethal effects may occur as a result of entanglement or ingestion, such as reduced hunting/feeding capacity and may lead to malnutrition, reduced growth rates, disease and reduced reproductive output, thereby ultimately causing population level effects [145,156,157].

COASTAL DEVELOPMENT

HABITAT DEGRADATION CAN OCCUR AS A RESULT OF A RANGE OF ANTHROPOGENIC ACTIVITIES. Any coastal development or offshore construction that changes the immediate marine habitat and environment, either directly due to construction activities, or indirectly by affecting other marine life (e.g. prey species), may have a knock-on effect on cetaceans. Coastal development may include the excavation or reclamation of shallow or intertidal seabed areas, dredging to create or maintain channels and basins, borrowing and dumping of dredge spoil, percussive or bored piling work, the laying of pipes and cables and many others [158], all of which can degrade the habitat and environment of cetaceans, particularly those which show a preference or coastal environments, such as Arabian Sea Humpback Whales and Indian Ocean Humpback Dolphins.

In areas where rapid or expansive coastal development occurs, activities can result in physical loss of habitat, or serious degradation of a habitat's ability to provide critical resources needed to support cetaceans [158]. In areas known to be preferred habitat of particular species, continued active coordination between scientists, government departments and industries, can enable the study of development pressure on key species' behaviour, abundance and long-term survival, as demonstrated in some parts of the world [158,159]. This interdisciplinary approach is crucial when considering the broad range of ways in which coastal development threatens cetaceans, including habitat destruction or degradation, reduction in prey availability, generation of underwater noise and increased risk of vessel strike. Compiling data through this type of interdisciplinary approach supports the evolving understanding of how these factors may affect local populations of cetaceans.

In Oman, coastal development is documented to be a risk for Indian Ocean Humpback Dolphins [2,160,161], Indo-Pacific Bottlenose Dolphins [2,51] and the Arabian Sea Humpback Whale [41,53]. The Indian Ocean Humpback Dolphin has a preferred habitat of very shallow coastal waters, making it especially vulnerable to anthropogenic coastal pressures such as land reclamation, dredging and port and harbour development [2,160,161]. At the coastal town of Duqm, development of a large, industrial port and dry-docks is ongoing; during a 2010 survey, noise from the initial phases of development was detected acoustically up to 40 nm away [53]. The port is already operational in some capacity, with vessel traffic diverted inshore across known Arabian Sea Humpback Whale habitat in the Gulf of Masirah from the main shipping lanes to the east of Masirah Island [53]. Additional coastal development is also either underway or planned, including a proposed bridge to Masirah Island from the mainland, a large fishing port south of Duqm and a proposed offshore oil loading terminal, all within known Arabian Sea Humpback Whale habitat [41]. Coastal development threats have also been observed to affect Bryde's Whales in Oman's waters, although this information is yet to be published.

CLIMATE CHANGE

THE CURRENT RATE OF CLIMATE CHANGE IS THEORIZED TO BE OUTSIDE THE 'EVOLUTIONARY EXPERIENCE' OF EXTANT CETACEAN SPECIES, and climate change-related concerns are likely to be exacerbated where populations, especially those of precarious conservation status, are already negatively impacted by other factors [141,162]. Global warming of the oceans may impact cetaceans in several ways: The transmission of sound used by whales for communication and hunting due to significant alteration in physical oceanography from climate change [141,162,163]. Increased water temperatures may also increase both the incidence and the rate of transmission of pathogens, leading to increased disease and immune system stress, particularly affecting those individuals or populations already living in a state of elevated stress [163]. Perhaps more significantly, changes in prey abundance or distribution may result in changes to the distribution patterns of cetaceans [164,165], which may in turn also lead to increased competition for prey and habitat resources among species [166].

The ability to assess the vulnerability of marine species (especially large marine vertebrates such as cetaceans) to climate change is fairly recent [8] and as such, there are no published details of how climate change threatens the cetaceans of Oman specifically. Application of an ecological trait-based vulnerability index over several cetacean species in the Madeira archipelago showed that Sperm Whales, Fin Whales, Bryde's Whale and the Atlantic population of Common Bottlenose Dolphins were the most vulnerable species [8], due to their specific ecological traits in this specific region. However, the threats from climate change are very wide ranging and complex and, in the most part, cannot be readily mitigated. Nevertheless, governments, corporations and citizens of the world must all take every action possible to minimise anthropogenic contributions to climate change for the sake not only of whales and dolphins, but for humanity and the planet as a whole. Addressing the other more manageable impacts to cetaceans outlined in this chapter will also allow populations to potentially cope better with this overarching, looming global threat.

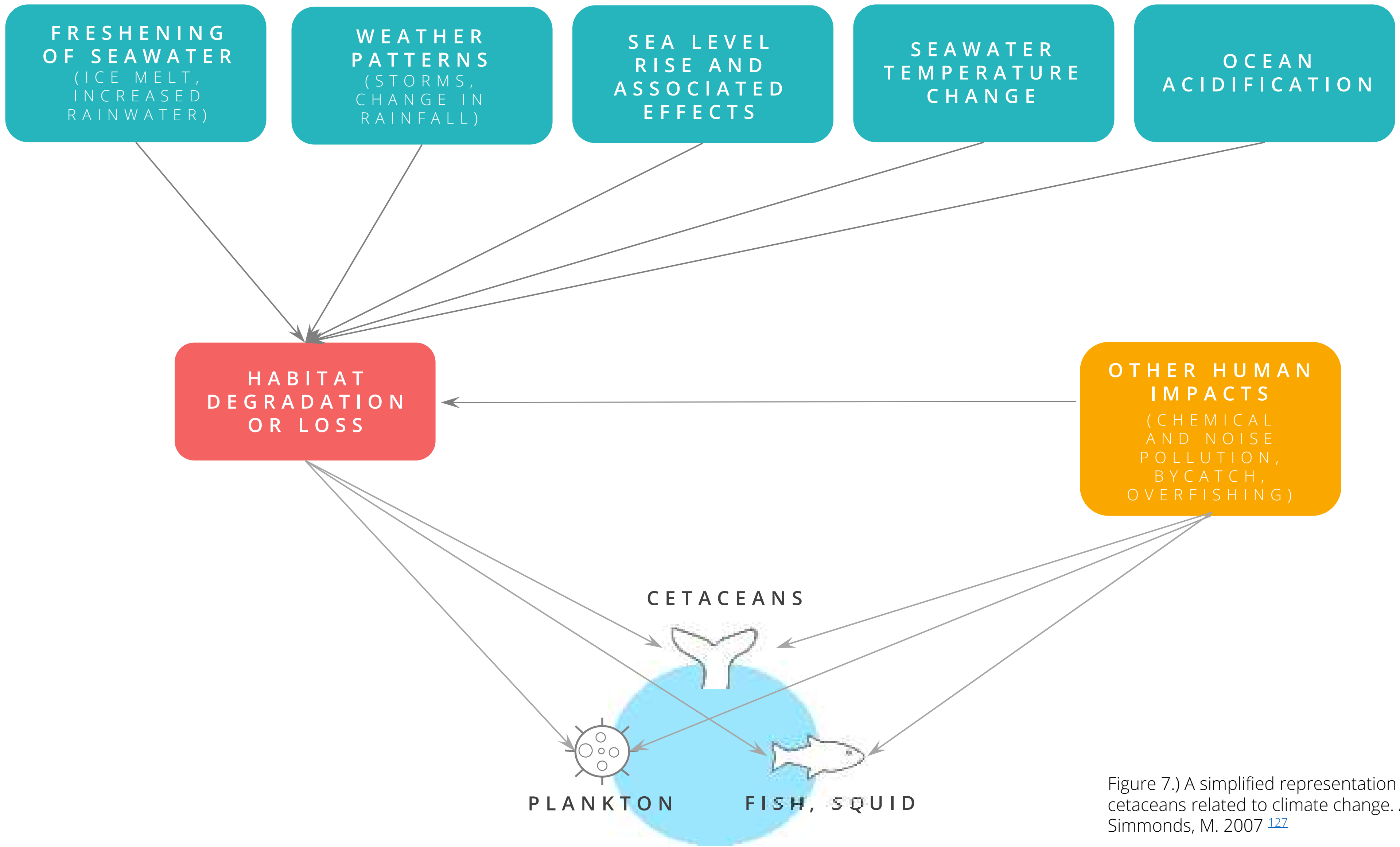
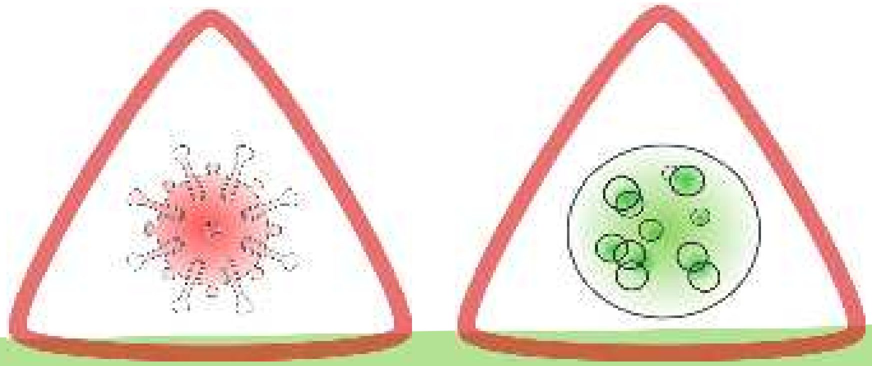


Figure 7.) A simplified representation of the major impacts to cetaceans related to climate change. Adapted from Elliott, W. and Simmonds, M. 2007 [127]



BIOTOXINS AND DISEASE

IN ADDITION TO ANTHROPOGENIC THREATS mentioned in this chapter, there are numerous natural threats to cetaceans. Parasitic infections are thought to be relatively common [2], whilst in Oman specifically, harmful algal blooms (HABs) and disease are considered to be potentially significant natural threats [1,2] (Figure 8). Stress-inducing factors such as high pollutant levels, reduced prey availability and increased seawater temperatures have been documented elsewhere in the world to trigger the occurrence of morbilliviruses [2], although establishing a definitive cause of mortality in cetaceans can be difficult.

Harmful algal blooms (HABs) often occur as a natural phenomenon when optimal temperature and nutrient conditions occur, and both HABs and even blooms of non-toxin-producing algal species may have devastating impacts at the lower end of the food chain [168]. Blooms of toxin-producing species may present severe threats to marine mammals or even to humans, when toxins are transmitted through the food chain via contaminated zooplankton or fish [168] with research showing that the occurrence of HABs is often spatially correlated with the mortality of marine mammals [169]. Worldwide, HABs have been implicated as causal factors in the deaths of Humpback Whales, North Atlantic Right Whales, Bottlenose Dolphins, Common Dolphins and Minke Whales [6].

HABs are a well-known occurrence in the Arabian region, with widespread fish and turtle mortality reported in Oman during HAB events (often referred to as 'red tide' events) [1,2]. The abundance and distribution of algal blooms in Oman's coastal waters, however, remains poorly investigated [170]. Death by ingestion of contaminated fish due to toxin-producing algal blooms was postulated as the cause of the death of more than 30 dolphins along the coast of Oman in 1990, including the Indian Ocean Humpback Dolphin [171], and also in dolphin deaths that occurred at the same time as mass turtle mortalities along the Arabian Sea coast of Oman in 2001[1].

Figure 8) Stranding of cetaceans, such as Common Bottlenose Dolphins (*Tursiops truncatus*) at Ajiah near Sur on Nov 2002, occur for many reasons, including anthropogenic and natural causes. Biotoxins can result in acute, multiple mortality and may impact a range of age groups.

Reported occurrences of HABs that coincided with mass die-offs of cetaceans in the region are, however, often the only historical data available to suggest that toxins from red tide events may have played a part in these mortality events [2]. Analysis of the species composition of one of these red tide events in 2001 identified the presence of two species (*Karenia selliformis* and *Prorocentrum spp.*) that have both been implicated in the deaths of marine mammals elsewhere in the world [1]. Due to the close relationship between environmental conditions and the community structure of phytoplankton, it is suggested that any variation in the periodicity or intensity of the Southwest monsoon may have a large impact on the fisheries resources of Oman [172] and in turn, those higher trophic levels such as cetaceans which rely on fish as prey items. Accurate prediction of how global climate change may impact on marine HABs is still fraught with difficulties [168].

Figure 9) *Top*- Photos obtained from an unmanned aerial system of two adult Arabian Sea Humpback Whales in the Gulf of Masirah, November 2019. *Bottom*- Small to very large tattoo-like skin lesions covering an estimated 60% of the back and flank of an adult male in the Gulf of Masirah, November 2015.

Soviet whaling data from vessels operational in the 1960s off Oman documented the presence of various pathologies in captured Arabian Sea Humpback Whales, including liver disease [173]. Data from dedicated Arabian Sea Humpback Whale surveys off Oman between 2000 and 2017 have also revealed the common presence of suspected tattoo-like skin disease (TSD) in the resident population [5,7] (Figure 9). TSD is caused by poxviruses [174,175] and is characterised by irregular skin lesions of a grey, black, whitish or yellowish colour, which can be identified by eye by experienced observers [7]. During surveys carried out between 2000 and 2011, TSD affected 13 of 60 whales, and 6 of 36 adult Arabian Sea Humpback Whales within the study sample [7]; including data up to 2017, this number increased to 38 (of 93) individuals with TSD, 2 of which were juveniles [5]. Data reported from the 2000–2011 surveys represented the first published report of TSD in a member of the Balaenopteridae family and the first documentation of TSD in the Arabian Sea [7]. Documented results and additional field observations indicate that the number of whales with TSD has increased since photo-ID studies began in the region in 2000 [5,7].

In Odontocetes, a high occurrence of TSD in adults is suggested to reflect a depressed immune system [176]; it is suggested that the high prevalence, increase over time, and progression in some individuals may reflect underlying health issues within the Arabian Sea Humpback Whale population, such as an immunological inability to clear the disease [5,7]. Analysis of images captured during the same period (2000-2017) was also conducted for the presence of epizoites, including whale-lice and sessile whale barnacles [5]. The presence of whale-lice over large areas of the body in cetaceans is considered to be an indication of poor health [177]. However infestations in the Arabian Sea Humpback Whale population were limited to some individuals, and did not indicate a reduction in swimming speed ability or poor health [5].

To date, there have been no other documented occurrences of TSD or other diseases in cetacean populations of Oman, although this is likely to reflect the comparative lack of research on species other than the Arabian Sea Humpback Whale, rather than a simple lack of disease or parasites in other cetaceans in the region.

SUMMARY

"AT THE GLOBAL LEVEL, CETACEANS ARE ADVERSELY AFFECTED BY DIRECT HUNTING, BYCATCH, AND HABITAT DEGRADATION CAUSED BY POLLUTION AND HUMAN DEVELOPMENT" [10]. Figure 9 presents a summary of these activities, among others, that may impact cetacean habitats and populations [141]. Due to the large number of threats facing cetaceans worldwide, and their wide range of effects, it can be challenging to accurately determine which threats represent causal factors in cetacean population declines. Many of the impacts on cetaceans are chronic, but when operating in synergy may have a more rapid effect [10,141]. Since cetaceans are particularly vulnerable to the complex interactions of so many threats, in part due to their low reproductive rates and long lifespan, detecting and managing the long-term effects of human activities on cetacean populations remains a principle concern for conservation scientists [10].

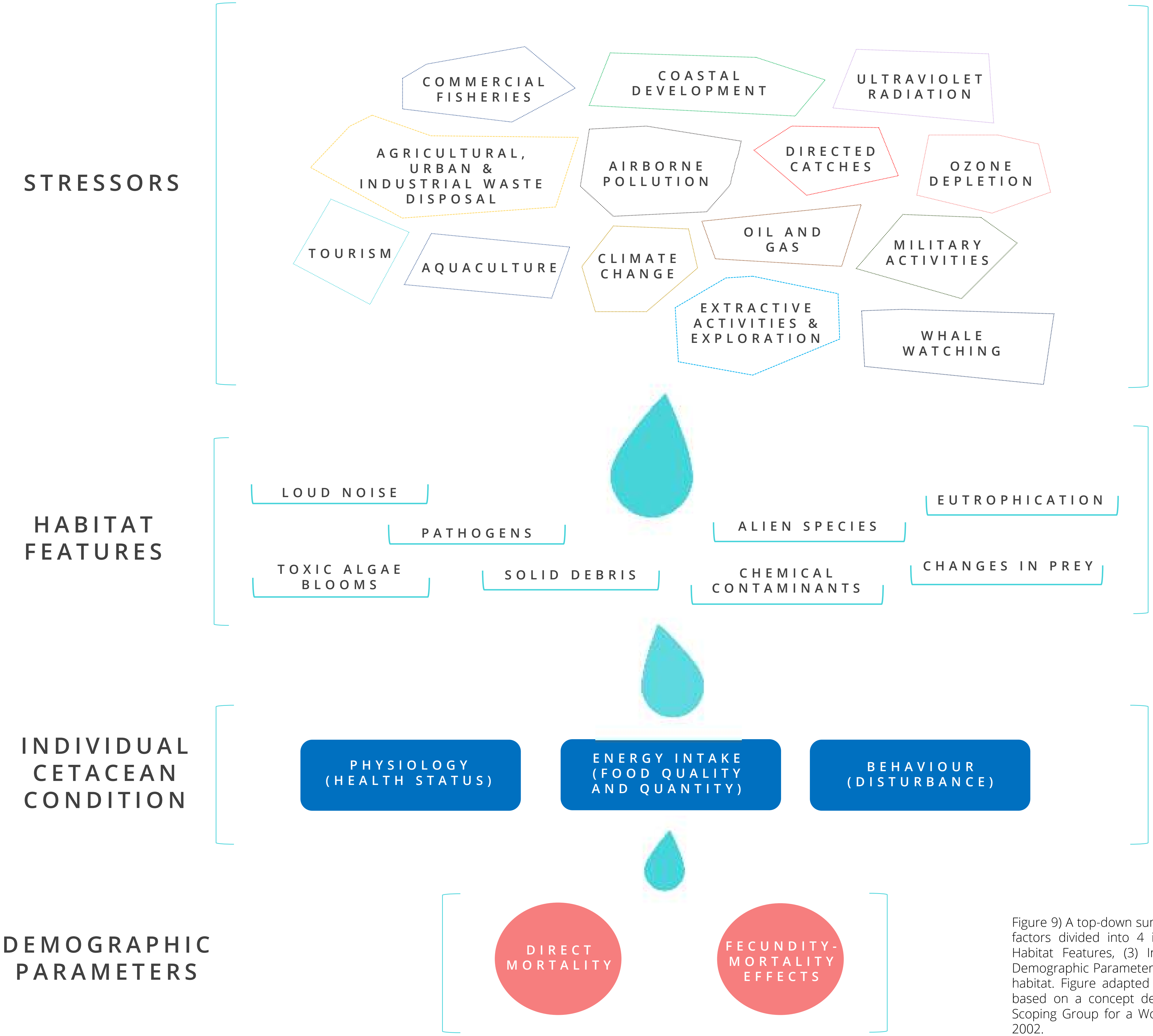


Figure 9) A top-down summary of the natural and anthropogenic factors divided into 4 interrelated stages – (1) Stressors, (2) Habitat Features, (3) Individual Cetacean Condition, and (4) Demographic Parameters - that may impact cetaceans and their habitat. Figure adapted from Simmonds and Nunny (2002) [141] based on a concept developed during a meeting of the IWC Scoping Group for a Workshop on Habitat Degradation, Rome, 2002.

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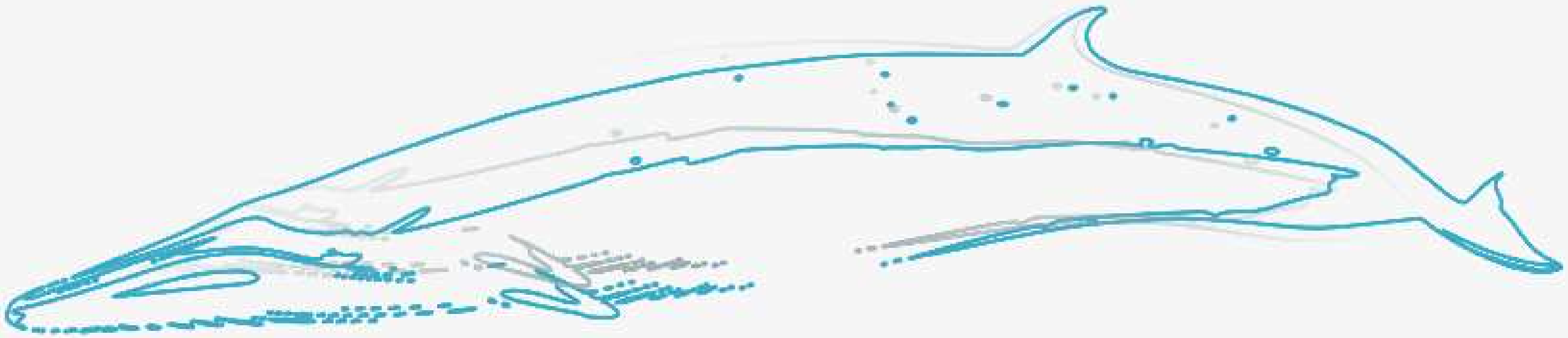

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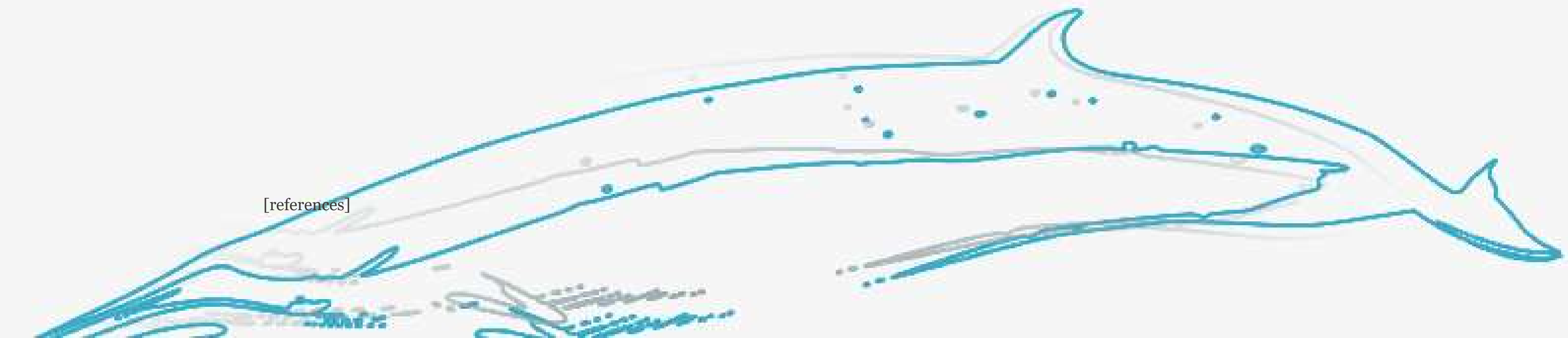

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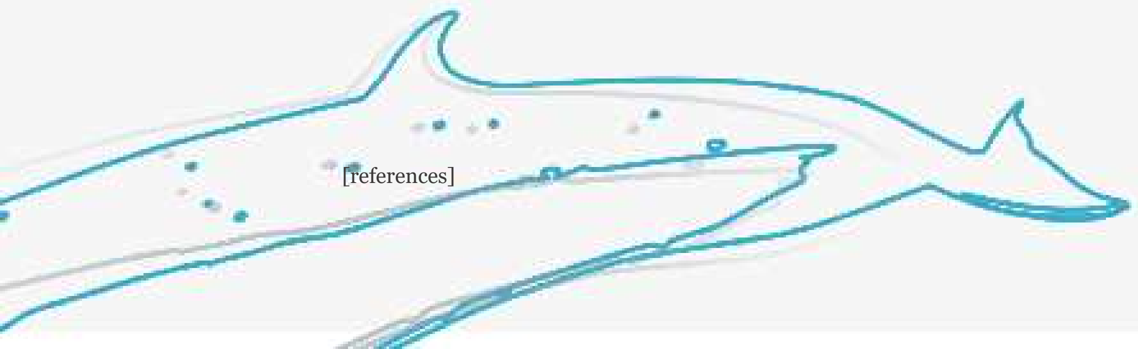
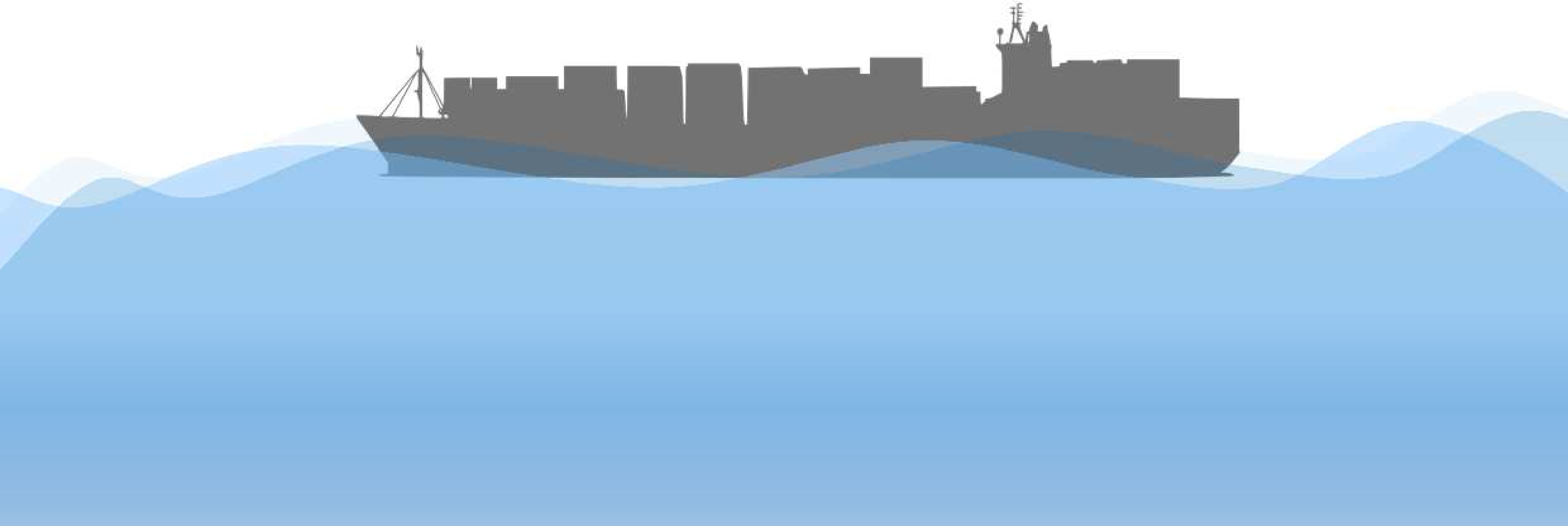


THREAT SPECIFIC

4

MITIGATION MEASURES

SHIP STRIKE



IMO POLICY

A REVIEW OF IMO POLICY ON SHIP STRIKES [1] highlights that among the roles of the IMO is the encouragement of applications from member states and organisations for new ship strike mitigation proposals. Related to this, the IMO has specific remit for the development of vessel operation conventions, protocols, codes and recommendations for addressing safety, environmental protection, legal matters, technical cooperation and efficiency of shipping. Codes and recommendations are generally non-binding guidelines to be adopted under law by member states at their discretion.

Submission of proposed ship strike mitigation measures to the IMO is a recent phenomenon and all resulting active actions have occurred within the last 15 years. The first adopted action was a 'Mandatory Ship Reporting' system for whales and ship strikes off the east coast of the USA; some examples of implemented submissions to the IMO by member states can be seen in Figure 1 below. These include ship strike mitigation measures implemented in waters of the USA, Canada, Panama, Argentina, New Zealand and Spain.

Measure	Situation to which it might be applied	Implementation process (and observations)	Examples
KEEPING VESSELS AWAY FROM WHALES			
Permanent routing measures through TSS, ATBA or port approach routes	Long-term patterns of whale distribution are sufficiently predictable and well understood to enable a robust analysis of the risk reduction that might be achieved.	Implemented through IMO or national regulation if within territorial sea. Proposals should follow the IMO process including data on the problem, the risk reduction achieved and implications for shipping. (Generally well respected by industry.)	Bay of Fundy, Canada Boston, USA California, USA Panama
Seasonal routing measures	Similar requirements to permanent routing but applicable where there are strong seasonal patterns in whale distribution	As above	Roseway Basin, Canada Great South Channel, USA
Recommended (voluntary) routes	Similar requirements to permanent routing through TSS or ABTA but not mandatory	Implemented by IMO or coastal state as a non-mandatory measure	Peninsula Valdez, Argentina Hauraki Gulf, New Zealand Glacier Bay, USA Ports on US east coast
Short-term (days – weeks) and Dynamic routing measures	Implemented in response to short- term observations of whale aggregations or known high risk areas. Need almost real-time reporting systems that can identify such aggregations	Voluntary measures that need to be communicated to mariners. (Can be difficult to encourage compliance.)	DMAs off US east coast Gibraltar Strait, Spain

Figure 1) Excerpt of the summary table of ship strike mitigation measures that have been implemented worldwide. Further details of the measures given as examples can be found in SC/65b/HIM05, with a bibliography of studies relating to these examples, including evaluations of effectiveness in SC/66a/HIM04.

Given this recent trend, as well as a newly established cooperative link between IWC and IMO, there is a realistic opportunity for the IMO to be approached with a proposal from Oman for ship strike mitigation. Development of a successful proposal will necessitate discussion between relevant authorities in Oman, supported by key organisations and personnel involved in cetacean research.

INTERNATIONAL MARITIME ORGANIZATION

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THE PROCESS FOR APPLICATION OF A PROPOSAL BY A MEMBER STATE IS SUMMARISED BELOW

1 MEMBER STATE TO PREPARE AND ENDORSE A PROPOSAL CONTAINING

- Need for proposed action
- Adverse effects on maritime interests and safety
- Status of neighbouring states
- Regulations and policies in the region and risk assessment documentation
- Existing nature of vessel traffic and existing navigation rules

2 PROPOSAL IS SUBMITTED BY MEMBER STATE AND PASSED TO IMO COMMITTEES

- Marine Environment Protection Committee
- Sub-committee on Safety of Navigation
- Marine Safety Committee (MSC)

3 THE DETAILS OF THE PROPOSED ACTION ARE TRANSFERRED INTO ACTION BY NATIONAL AUTHORITIES THROUGH RECOMMENDATIONS, GUIDELINES AND/OR LAW

INTERNATIONAL MARITIME ORGANIZATION

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Silber et al., [1] reported that the IMO proposal process is generally successful where proposals provide *'a strong statement of needs, accompanied by relevant documentation including an assessment of impact to maritime industries and a robust risk reduction analysis.'*

THE IMO DOCUMENT ENTITLED 'GUIDANCE DOCUMENT FOR MINIMIZING THE RISK OF SHIP STRIKES WITH CETACEANS was circulated to member states in 2009 and provides a useful point of reference and shared rationale for cetacean management. The table below reviews selected paragraphs from this IMO guidance. These key points can be used to communicate the relevance of the programme to authorities and industry partners in areas of potential conflict.

DOCUMENT SECTION	SELECTED GUIDANCE SUMMARY
4.0	Collisions recognised in causing damage to vessels, including hulls, propellers, shafts, rudders, steering arms, etc.
5.0	Acknowledgement of the impact strikes have on a wide number of whale species, including severe injury and lethal strikes.
6.0	Definition of the problem; species, characteristics, distribution, seasonality and behaviour. Vessel traffic patterns and characteristics contributing to the problem.
7.1	Maritime safety of primary concern.
7.2	Minimise strikes to whales with minimum disruption to shipping.
7.3	Use best available and latest information to determine the risk of whale/ship interaction.
7.4	Mitigation measures based on best available science & tailored to time and area when whales are present.
7.5	Actions taken to address ship strikes to be part of a broader protection/recovery plan.
7.6	Consider a range of solutions to address ship strikes.
7.7	Periodic review of actions to determine effectiveness and refine where necessary.
8.0	Consider taking the most feasible and expedient actions first.
9.0	Gathering of information from dedicated scientific monitoring, ship reports and data available from other stakeholders.
10	Education and outreach, such as Notice to Mariners, brochures, signage, educational media, documentaries.
11	Technological Development including enhancing detection at sea through acoustics, modelling or direct tracking of whales.
12	Operational Measures such as speed restrictions, (re)routing, etc.
15	Dissemination of ship strike reduction strategy to stakeholders.
16	Governments advised to report on progress to IMO. Reporting of ship strikes to International Whaling Commission Database.

[ship strike – IMO policy]

INTERNATIONAL MARITIME ORGANIZATION

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OMAN MANAGEMENT AND MITIGATION:

PORT OF DUQM

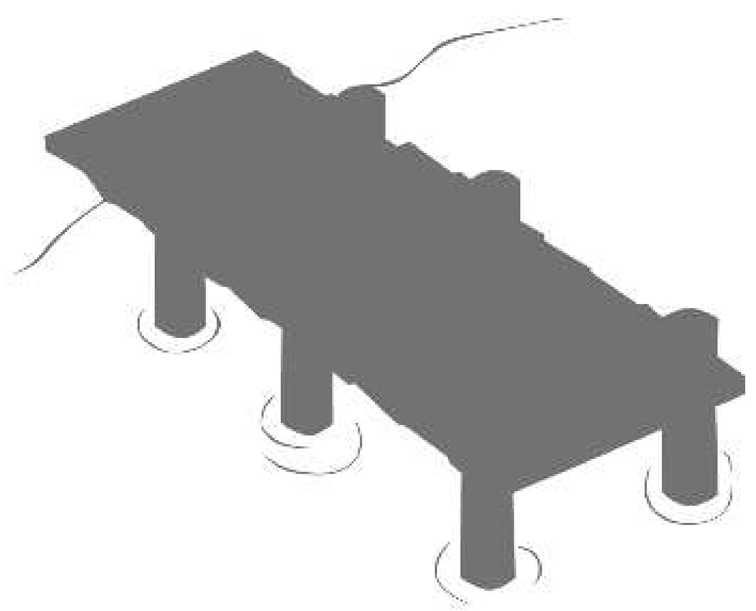
Figure 2) Aerial photo of the Port of Duqm

INAUGARATED IN 2013, THE PORT OF DUQM IS LOCATED IN THE ARABIAN SEA ON THE SHORES OF THE GULF OF MASIRAH. As presented in this Atlas, the Gulf of Masirah is recognised as an area of sensitive marine habitat and particularly as critical habitat for the Endangered Arabian Sea Humpback Whale (ASHW). Recognising the precarious conservation status of this species, and after witnessing the presence of a mother and calf pair inside the port basin during Port development, the Port of Duqm (PODC) commissioned a Whale Management and Impact Mitigation Plan (WMIMP) to coincide with the start of operations. The aim of the plan is to provide a management system to help mitigate the potential impacts of ship strikes on whales and to respond to marine wildlife incidents following either ship-strike, entanglement in fishing gear, or stranding.

The primary objectives of the plan are:

To generate and maintain an awareness of the sensitivity of the marine habitat and wildlife in the vicinity of the port

Encourage the participation of other community stakeholders in the plan including maritime service industry, tourism sector and local fishing community



To define institutional and employee responsibility for whale management and impact mitigation in the area

To provide concise procedures for:

- Detection, reporting & recording of large whale sightings and incidents
- Avoidance of incidents through defined management and mitigation measures
- Response to ship strike, entanglement and marine wildlife stranding incidents

Arabian Sea Humpback Whale with calf sighted in the Port basin in 2012

The adoption of a whale management programme by Port of Duqm Company (PODC) is the first example of such a commitment in the Arabian region, indeed in the entire Northern Indian Ocean region.

ميناء الدقم
PORT OF DUQM

https://www.portofduqm.om/

THE 'DETECT-REPORT-RESPOND' SYSTEM detailed within the plan is designed to manage the risk of ship strikes for the benefit of whale conservation, as well as to ensure compliance with Safety of Life at Sea (SOLAS) requirements. The Detect-Report-Respond procedures are intended to allow smooth transfer of information from those making observations at sea to the 24-hour port control office at PODC with quick reference aids to enable decision making for any necessary response.

The Detect-Report-Respond procedures follow the steps outlined below:

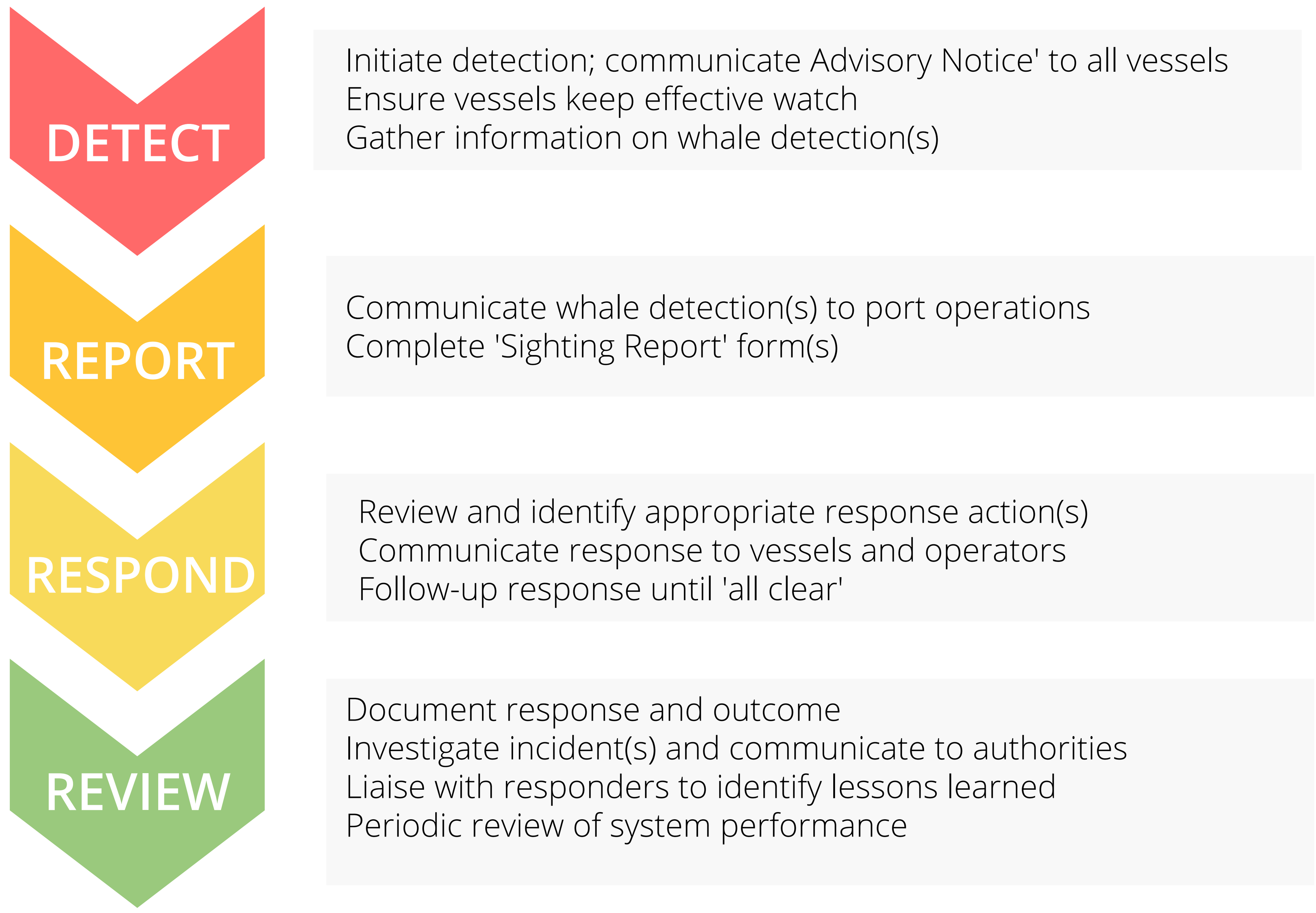
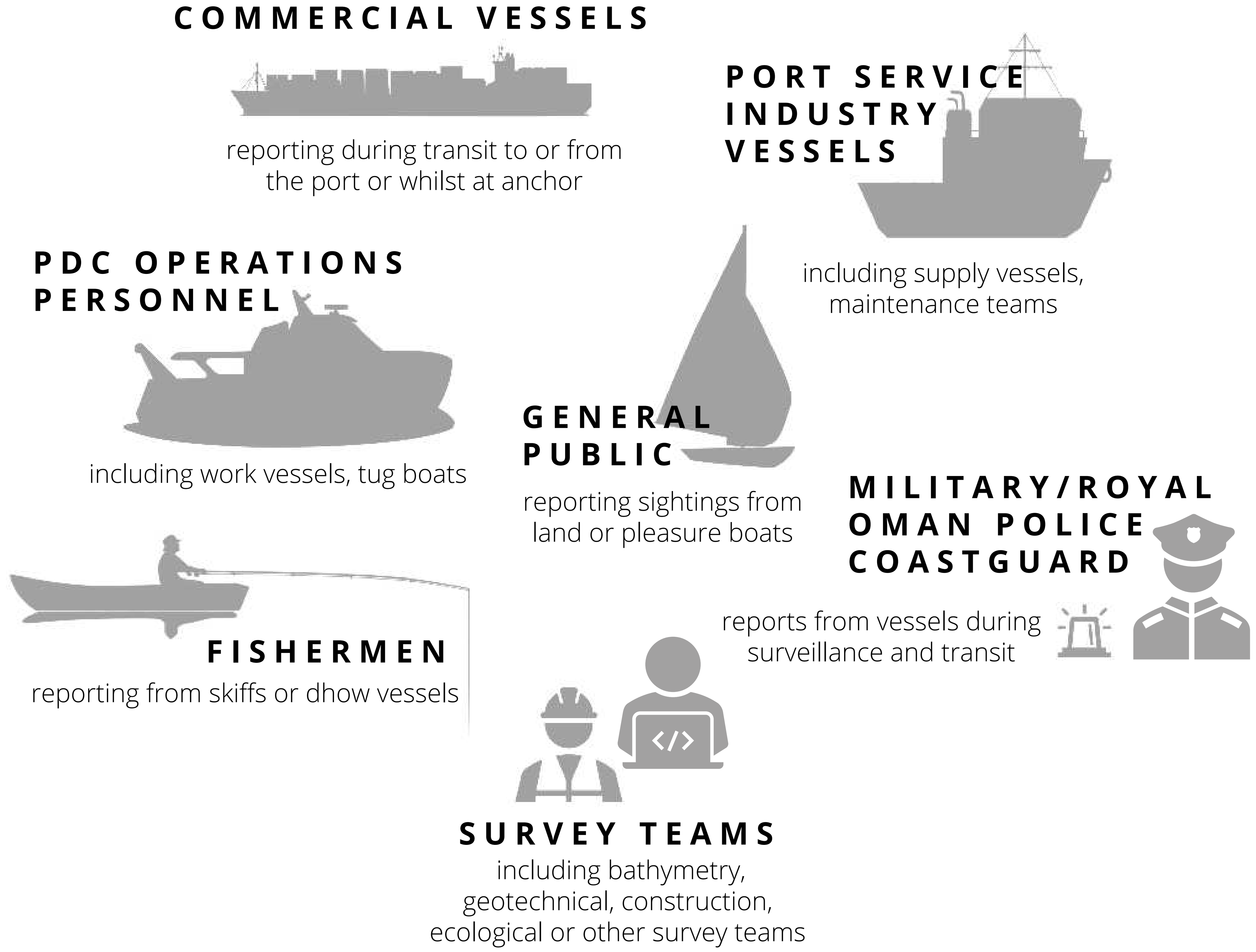


Figure 3) Source: PODC WMIMP

Awareness, coupled with effective communication is the most important aspect of ship strike prevention; the WMIMP therefore targets the following groups to report sightings:



TO ENSURE THAT THE WMIMP REMAINS ACTIVE and that effective communications are upheld with visiting vessels, there are certain actions that PODC follows. These include providing the WMIMP Information Pack to all operative PODC stations and vessels as well as resident local operating companies, and providing the WMIMP procedures and appropriate training to port control staff and resident local operating companies. In addition, 24 hours prior to arrival at port, all vessels, crossing the 200m isobaths into the Gulf of Masirah are provided with a 'General Advisory Notice' (see Figure 4) and the following recommended VHF communication message:

> *"Please be advised you are passing through waters recognised as critical whale habitat. This area is governed by the Port of Duqm Whale Management and Mitigation Plan. You are requested to maintain speed of less than* ***10 knots*** *during approach to the port, and to keep a* ***continuous watch*** *for surfacing whales.* ***Report all sightings*** *on channel 14 with the following information: numbers of whales sighted, vessel position at time of sighting, distance and bearing to whale(s).* ***Maintain a minimum distance of 500m from whale(s)*** *and await any further advice from Port control for additional* ***avoiding action."***

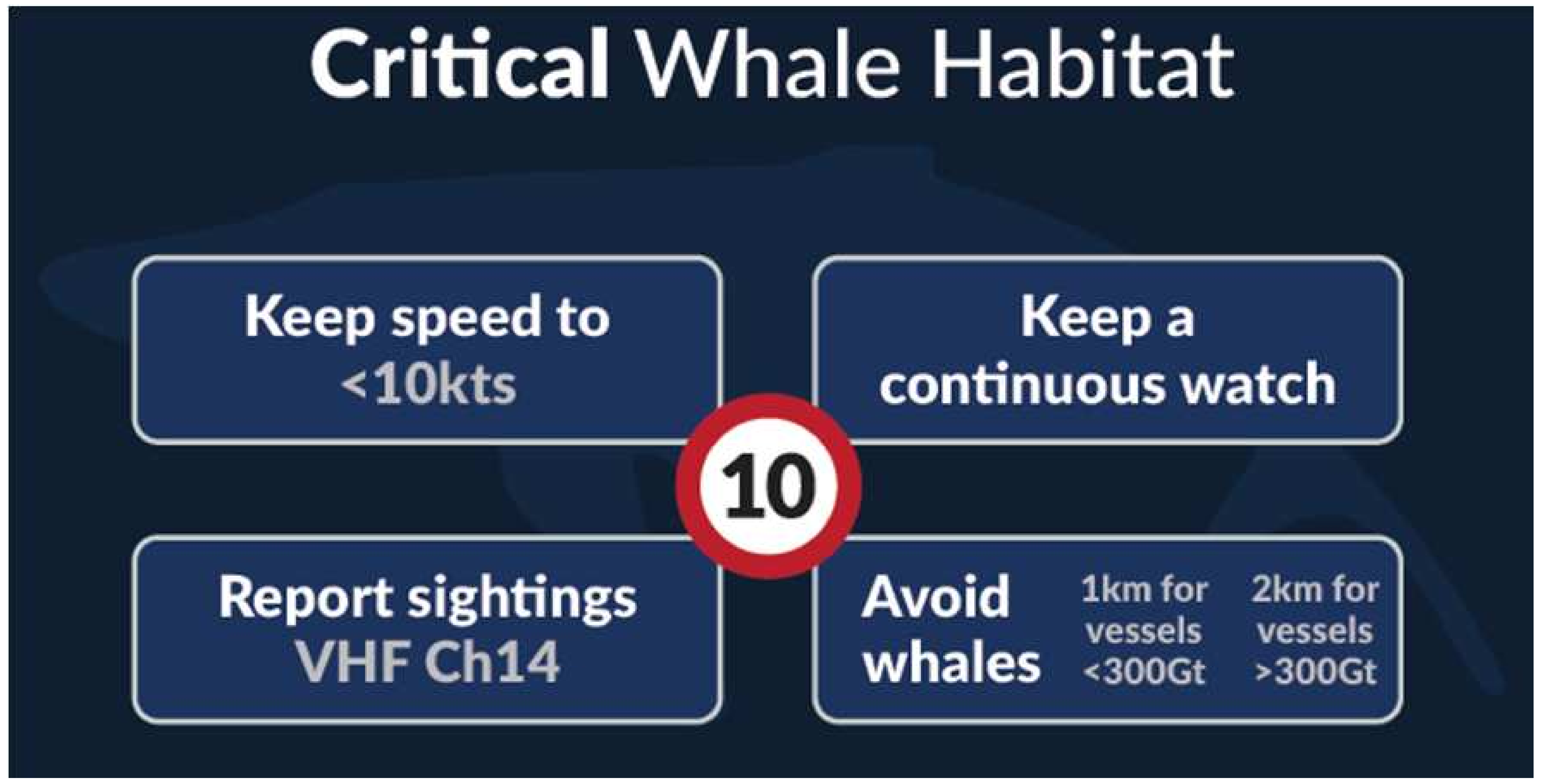


Figure 4) General advisory actions to be communicated to all vessels. Source: PODC WMIMP

DETECTIONS SHOULD BE REPORTED AS SOON AS POSSIBLE, with details recorded in the order shown below. The urgency of responding to sightings is dictated by whether they have been reported within 6 hours of detection (for immediate attention), or more than 6 hours after detection (for archiving only). Within the WMIMP, guidance for collection of information and whale identification, and behaviour guides are provided to aid the accuracy and ease of reporting. In addition to this guidance, a standardized 'Sightings Record' form is provided to enable standardised transfer of all sightings information to Port Control.

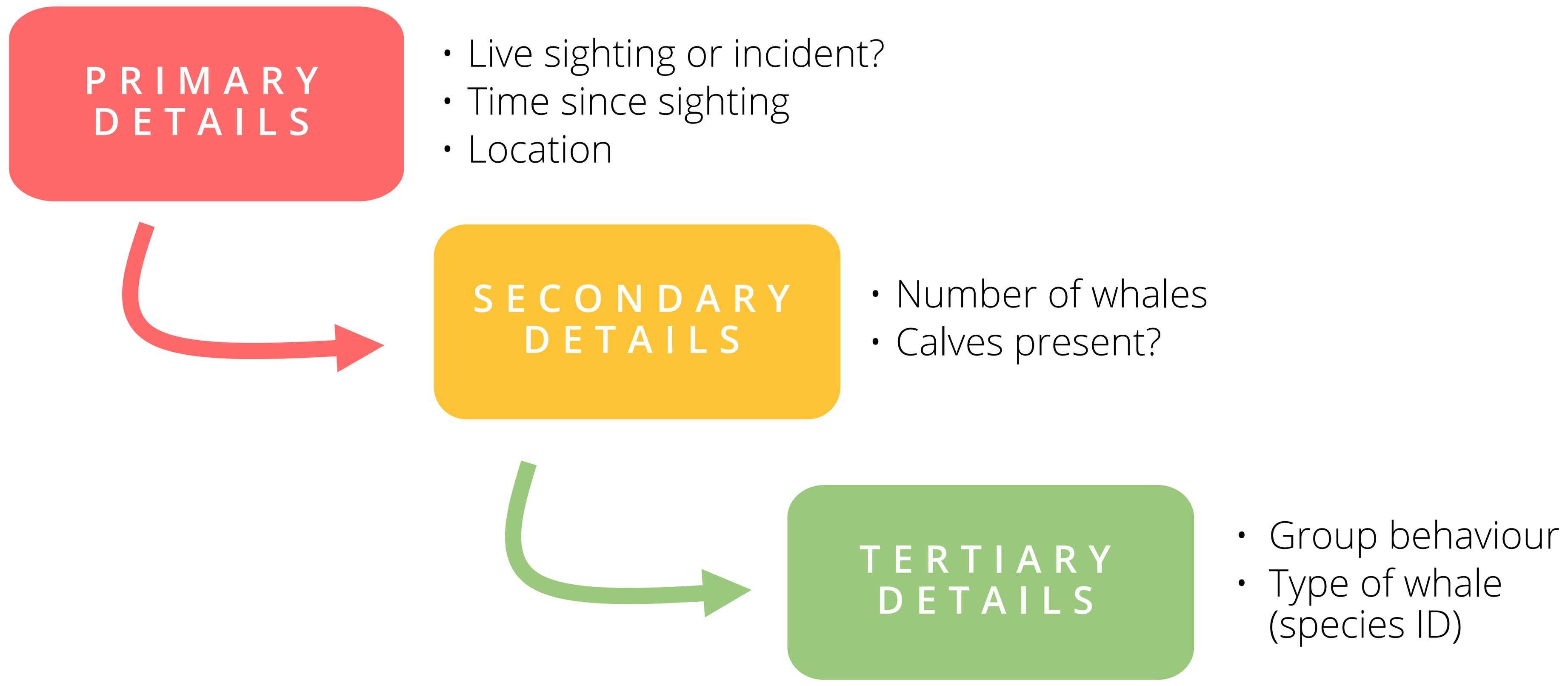


Figure 5) Priorities for information collection from observers. Source: PODC WMIMP.

The WMIMP details the response system to be implemented once whales have been detected and reported; this can either be operated manually, or through the use of specialised D-R-R software to provide response advice for operators. A series of questions about the sighting/incident help to define the nature of an event and therefore, the most appropriate response. Figure 5 details the logical process for assigning the appropriate response according to the outcome of the questions.

Once the appropriate response has been assigned, specific details of the event are communicated to all relevant vessels/third parties and Port Operations, with potential response actions including shutdown, exclusions zones (specific area and/or duration) or exclusion distances. For dredging, hydrographic surveys, construction and other large scale/noisy activities, additional mitigation measures may apply.

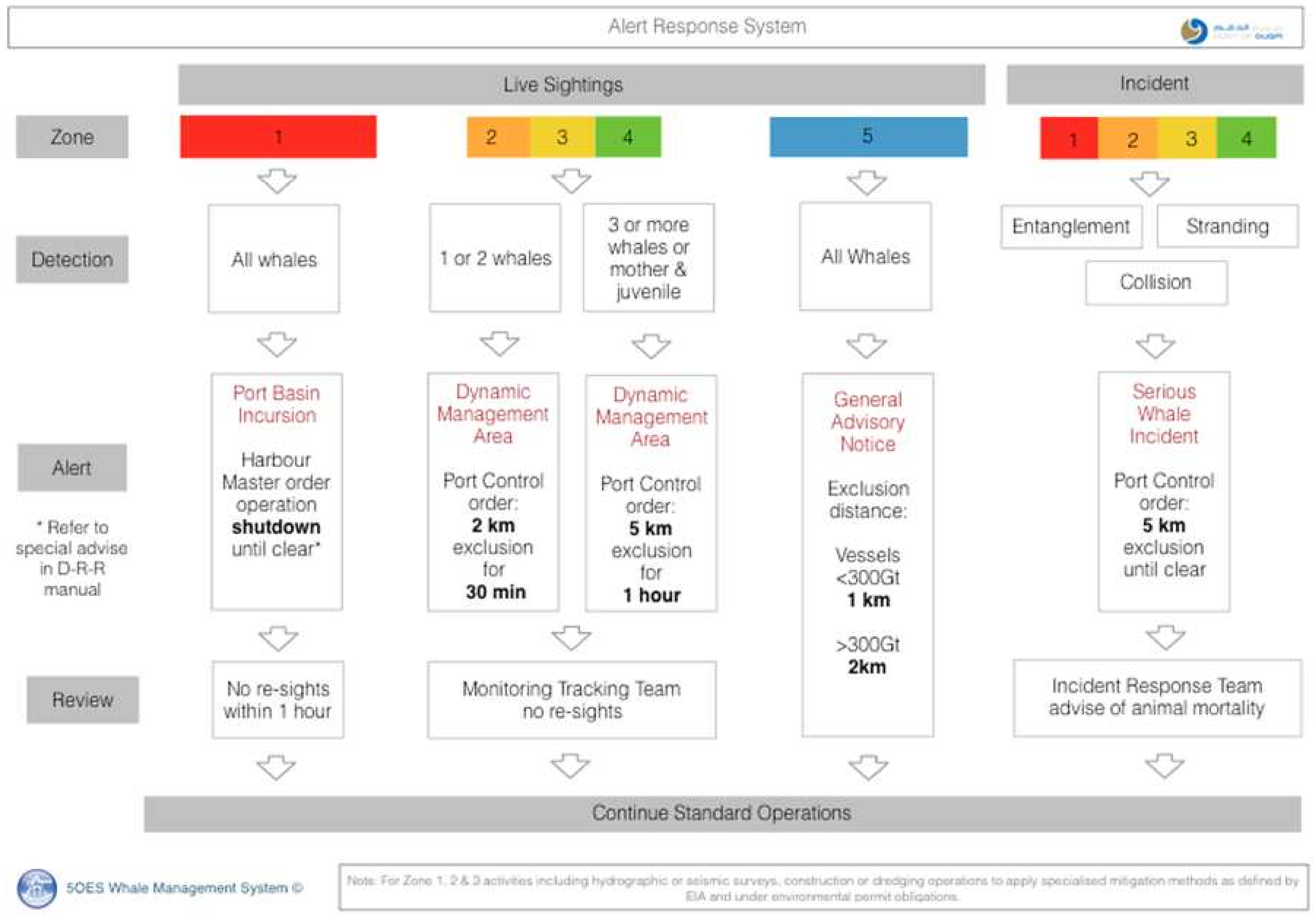


Figure 6) Whale Alert Response System. Source: PODC WMIMP

THE AREA SURROUNDING THE PORT HAS ALSO BEEN DIVIDED INTO ZONE, reflecting the concentration of activities and the consequent threat level to whales. Response procedures are then assigned to each zone based on their classification. The zonation includes Harbour, Approach Channel, PODC jurisdictional area, Critical Habitat (Gulf of Masirah) and Oman EEZ.

Whale Alert responses are divided into categories as described below.

GENERAL ADVISORY NOTICE

Communicated to all vessels on entry and departure to the Gulf of Masirah, applies to all whale sightings.

DYNAMIC MANAGEMENT AREAS (DMA'S)

Temporary exclusion zones around reported sightings or incident areas, the size and duration of which are defined by number of whales sighted, and/or presence of calves, and whale behaviour.

PORT BASIN INCURSION

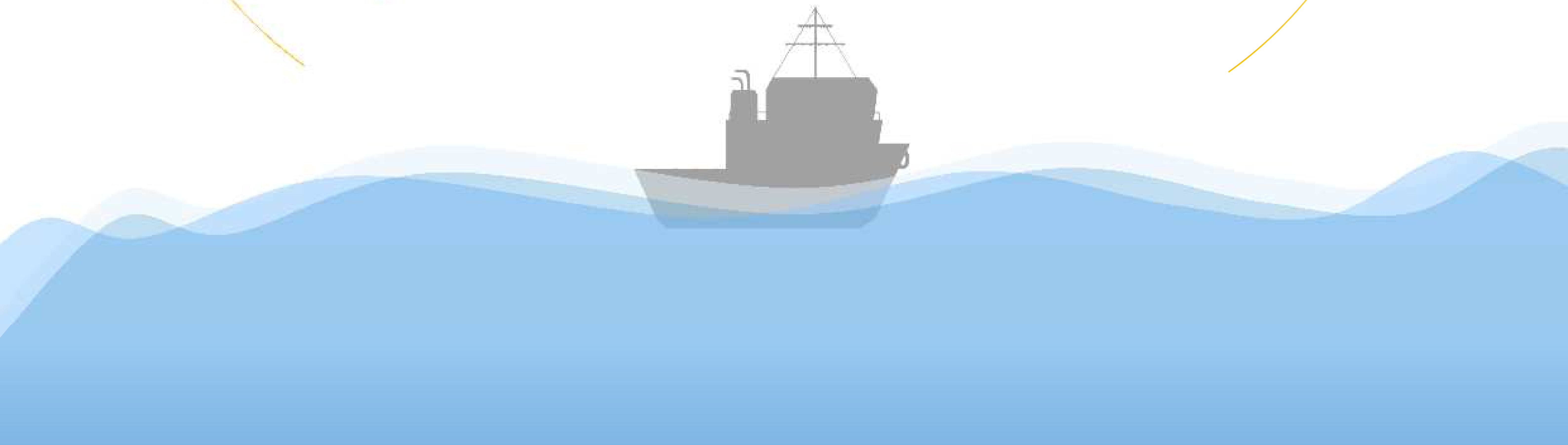
Suspension of operations due to whale presence in the port basin or approach channel requires input from the Harbour Master, but is considered preliminary advice until the situation is fully appraised and relevant response options can be assessed.

Incidents including entanglements, collisions and strandings at the Port of Duqm should initially be coordinated by PODC Port Control, with all incidents communicated to both SEZAD and MECA. The WMIMP also covers incident response priorities, details of a comprehensive stranding and collision/entanglement response procedure, and lays out a 'call chain' for the path of information and assistance requests. Also included within the WMIMP are field response protocols for live entanglements at sea, live strandings on the beach, live strandings in the intertidal zone or shallow water, and dead strandings. Additional species identification information is also provided.

Figure 7) Arabian Sea Humpback Whale Advisory Notice for the Port of Duqm, Oman. Source: 5OES/PODC

https://www.portofduqm.com/

UNDERWATER NOISE



IMO REDUCTION OF VESSEL NOISE

IN 2014, THE IMO APPROVED AND PUBLISHED GUIDELINES for the reduction of underwater noise from commercial shipping to help address the adverse impacts of underwater noise on marine life. These guidelines focus on the primary sources of underwater noise generated by commercial shipping and associated activities. The guidelines highlight that ship design and operational parameters (including existing mandatory requirements) dictate both the cost-effectiveness and the technical effectiveness (either individually or combined) of any measures considered [2]. These non-mandatory technical guidelines are intended to provide general advice about the reduction of underwater noise to ship designers, shipbuilders and ship operators, but do not address the introduction of noise from military vessels (naval and war ships) or noise intentionally generated by ships for other purposes such as sonar or seismic activities. A large proportion of underwater noise associated with commercial shipping is produced as a result of propeller cavitation, although other sources include hull form, on-board machinery and operational and maintenance activities such as hull cleaning [3]. Also included in the IMO guidelines are objective standards against which to measure underwater noise in order to gauge meaningful improvements.

The guidelines specific to ship builders and designers include considerations such as the use of computational models to assist in the reduction of noise through optimized hull design and propeller design, estimation of the interaction of these design components to produce low-frequency noise, and estimation of the high-frequency noise created by on-board machinery.

Other recommended noise mitigation measures include vibration isolation mounts for machinery, structural damping, acoustic absorption and insulation[2]. The best opportunity for implementing measures to reduce underwater noise is at the initial ship design phase. Retrofitting noise-reduction measures to existing ships may be prohibitively expensive in some cases, but is achievable in some instances, for example installation of new state-of-the-art low-cavitation propellers, wake conditioning devices, and air injection to propellers (e.g. in ballast condition) [2].

Operational and maintenance considerations that help to reduce the generation of underwater noise include the regular and correct polishing of propellers to reduce fouling and consequent cavitation, hull cleaning/coating to maintain lower drag and improved energy efficiency of the ship, selection of appropriate ship speed, and rerouting/operational decisions to reduce adverse impacts.

The reduction of the speed of a ship can be an effective measure to reduce underwater noise, particularly if this reduction in speed takes the vessel below the cavitation inception speed (the speed at which propeller cavitation starts). Other benefits to reducing vessel speed may also be realised, (e.g. reduction in ship strike risk, fuel savings, energy efficiency, and reduction of CO, and NO emissions [35]) all of which can be considered against business and operational requirements using a cost-benefit analysis approach. Speed reductions or changes in route to avoid sensitive marine areas (migratory pathways or areas of critical habitat) will also help to reduce the adverse impacts of underwater noise on marine life.

[noise – IMO reduction of vessel noise]

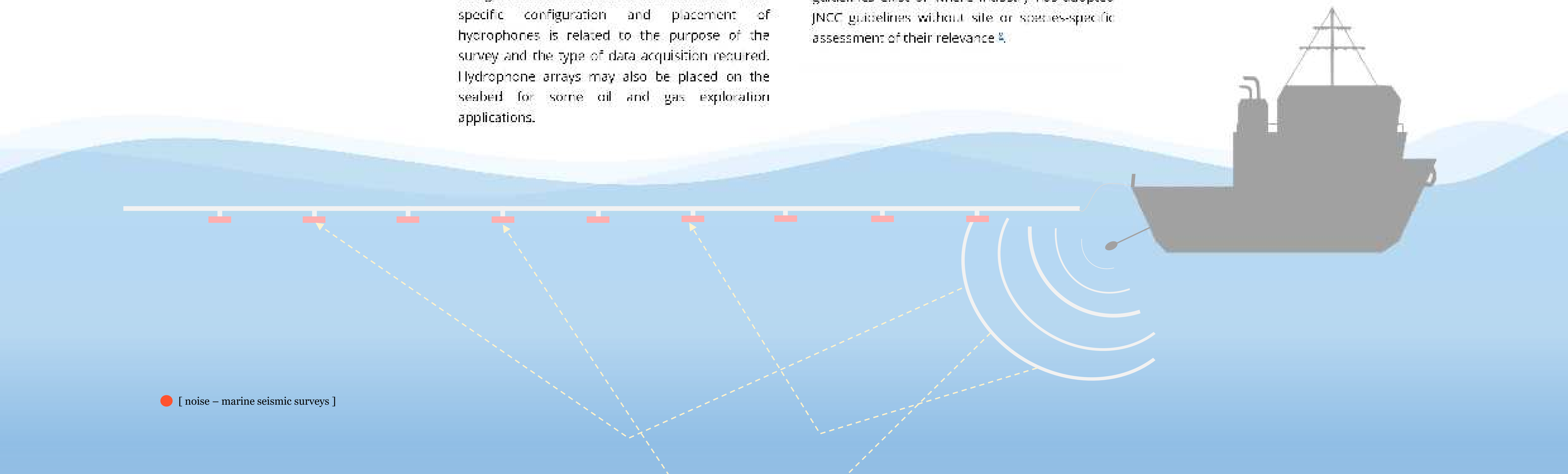
MARINE SEISMIC SURVEYS

THE ACQUISITION OF MARINE SEISMIC DATA INVOLVES GENERATION OF SEISMIC WAVES, usually achieved with high-pressure air discharges into the marine environment, with some of these generated acoustic waves reflected back to hydrophone receivers from the interfaces that separate different stratigraphic layers of the seabed. Marine seismic surveys usually consist of one or two ‘source arrays’, with several hydrophones assembled in a specific configuration along a receiver cable known as a ‘streamer’ [4]. The specific configuration and placement of hydrophones is related to the purpose of the survey and the type of data acquisition required. Hydrophone arrays may also be placed on the seabed for some oil and gas exploration applications.

Air guns, typically towed behind seismic vessels, produce the necessary seismic signal through sudden discharge of high pressure air into the water column. High-capacity compressors can deliver compressed air at a pressure of 2000 psi, with a short recharge time, such that a shot is fired every 10-15 seconds [4]. The potential impacts on marine mammals associated with these activities are explored in Chapter 3 in more detail.

The first regulatory body to adopt marine mammal mitigation measures for use in seismic surveys was the UK’s Joint Nature Conservation Committee [5]. Still in use as a global standard, these guidelines have come under heavy scrutiny and criticism by marine mammal scientists [6] and since this time numerous other versions of such guidelines have been introduced to the industry [7].

Particular concern has been expressed about the potential impacts of seismic survey emissions for areas in the Indian Ocean where no statutory guidelines exist or where industry has adopted JNCC guidelines without site or species-specific assessment of their relevance [8].



[noise – marine seismic surveys]

CASE STUDY 1: NON-REGULATORY GUIDANCE

IN RESPONSE TO THE CRITICISMS OF JNCC GUIDELINES, more detailed guidelines have been developed. In 2013, a methodological guide was published by CMS and ACCOBAMS (Agreement for the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area) for guidance on underwater noise mitigation measures, which have since been updated in 2016 (v2) and 2019 (v3) [7]. The guidance covers suggested mitigation measures for both continuous noise (mainly contributed by commercial shipping) and impulsive noise (as defined by the European Commission, sources of which include; seismic surveys using airguns, offshore construction using pile-driving, military sonar and the use or disposal of explosives [36]).

Mitigation measures stipulated in the latest guidelines for stationary noise sources such as pile-driving, drilling, dredging and detonations include the use of the following technologies [7]:

- BIG AIR BUBBLE CURTAINS (BBC)
- HYDRO SOUND DAMPER (HSD)
- SMALL AIR BUBBLE CURTAINS (SBC)
- COFFERDAMS
- IHC NOISE MITIGATION SYSTEM (IHC-NMS)
- BEKA SHELLS
- TUNEABLE RESONATOR SYSTEMS

These sources of noise generally act in one of three main ways; ***1)*** *acting to breakup or disturb the propagation of sound waves through the water through the use of bubbles or bubble nets (tuned to resonant frequencies),* ***2)*** *solid barriers around the noise source to dampen it, for example using large steel tubing or double walled systems filled with air, and* ***3)*** *the use of resonating systems, tuned to optimally attenuate noise in a specific frequency band. Research and development of alternative technologies are ongoing.*

Real-time mitigation measures more commonly used for marine seismic surveys include the use of:

ACOUSTIC MITIGATION DEVICES (AMD)

used to drive away groups of, or individual marine mammals

SOFT SPOT PROTOCOL (ramp-up)

This entails starting seismic emissions at low power and gradually emissions increasing until full or desired power is reached.

In theory, this will alert marine mammals in the area to the presence of the seismic array and allow them to move away.

MARINE MAMMAL OBSERVATION PROTOCOL

Marine Mammal Observers (MMOs) are position on seismic vessels or support vessels and have the authority to initiate the delay or cessation of seismic noise emissions if marine mammals are observed within a designated exclusion zone.

PASSIVE ACOUSTIC MONITORING PROTOCOL (PAM)

PAM is used to help detect marine mammals and subsequently alert MMOs to their likely presence. It also allows monitoring to continue during darkness, or during periods of bad weather.

The CMS-ACCOBAMS mitigation framework guidance for seismic surveys is presented below.

MITIGATION FRAMEWORK FOR SEISMIC SURVEYS

PLANNING PHASE (EXPECTED OUTCOMES OF AN EIA)

1. Consider the use of techniques other than seismic survey for the acquisition of data
2. Literature review to determine the species, habitat use, abundance and seasonality of marine mammals in the area, and commission field studies where such information is non-existent or inadequate
3. Define no-survey zones (e.g. Marine Protected Areas, Marine Mammal critical habitat)
4. Select seismic survey periods to coincide with areas and times of lowest ecological sensitivity
5. Use sound propagation modelling, coupled with analysis of marine mammal habitat use and behaviour, to define the extent of exclusion areas

REAL-TIME MITIGATION PRACTICES

1. Use MMO's to according to defined visual monitoring protocols
2. Deploy PAM to support MMOs
3. Implement the soft-start protocol and other industry-standard mitigation measures

PORT ACTIVITY

1. Detailed reporting of real-time mitigation

The CMS-ACCOBAMS guidance emphasizes that

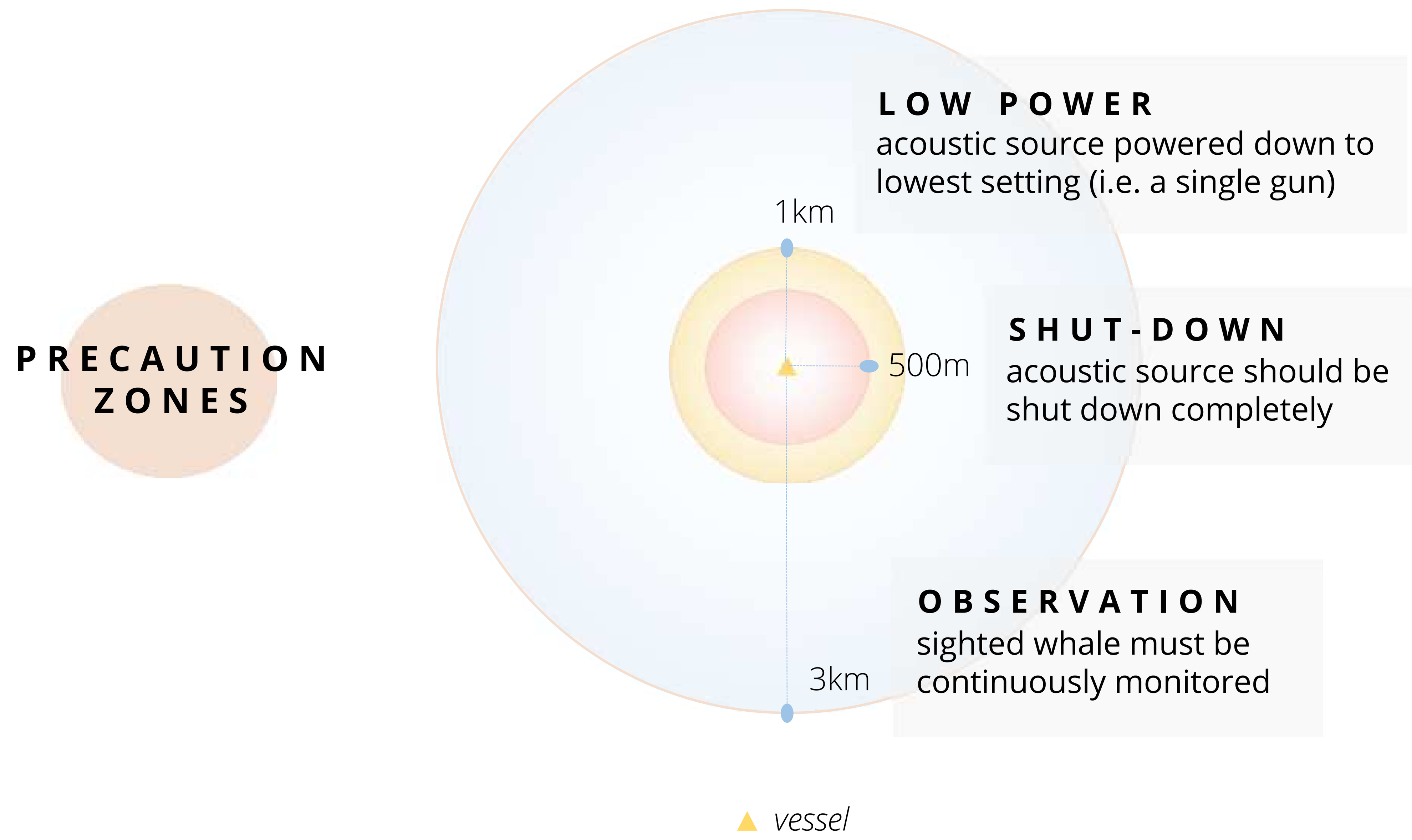
"Airgun use should be avoided, as far as possible, in areas of importance for cetaceans".

[noise – marine seismic surveys]

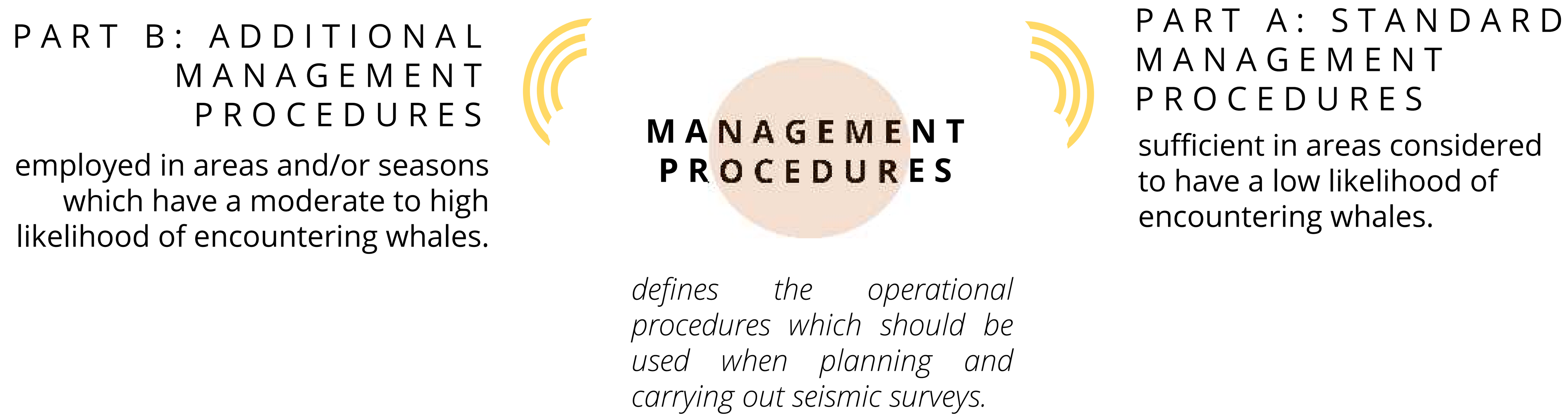
CASE STUDY 2: POLICY AND REGULATION

THE AUSTRALIAN GOVERNMENT (Department of the Environment, Water, Heritage and the Arts) published its policy on the interaction between offshore seismic exploration and whales in 2008 [9]. The approach employs a tiered mitigation strategy according to areas of important/sensitive whale habitat. It aims to "provide practical standards to minimise risk of acoustic injury to whales; provide a framework that minimises the risk of biological consequences from acoustic disturbance... in biologically important habitat areas or during critical behaviours; and provide guidance to both proponents of seismic surveys and operators... about their legal responsibilities under the EPBC Act 1999." [9]. The policy statement applies to all baleen whales and larger toothed whales, but does not apply to smaller dolphins and porpoises.

The management and mitigation measures stipulated in the policy statement are divided into two categories:



**to be used based on likely sound levels surround the seismic sound source(s)*



PART A: STANDARD MANAGEMENT PROCEDURES

All seismic survey vessels operating in Australian waters during any time of year must undertake the **following Part A: Standard Management Procedures** during surveys, regardless of location.

A.3.1 PRE START-UP VISUAL OBSERVATION

At least 30 minutes of observation.

A.3.2 SOFT START

Sequential ramp-up of acoustic source over 30 minutes, initiated by firing a single airgun (preferably the smallest, in terms of energy output and volume).

A.3.3 START-UP DELAY

Soft-start procedures to resume after any whale sighted during soft-start has left the low power zone, or when 30 minutes since the last sighting have passed.

A.3.4 OPERATIONS

Continuous visual observations during survey operations. Acoustic sources to be powered down to lowest possible setting when data is not being collected. If whales are not sighted during shut-down/low-power mode, operations require soft-start (*A.3.2*) and start-up delay (*A.3.3*) procedure. If whales are sighted, or observation monitoring ceases, restart of operations requires pre start-up visual observation (*A.3.1*), Soft-start (*A.3.2*) and start-up delay (*A.3.3*) procedures to be followed.

A.3.5 STOP WORK

If a whale is sighted within the 3 km observation zone, it must be continuously monitored whilst in sight. If sighted within, or about to enter, the low-power zone, acoustic source to be powered down to lowest possible setting. If sighted within, or about to enter, the shut-down zone, acoustic source should be shut down completely. Start-up delay (*A.3.3*) procedures then apply.

A.3.6 NIGHT-TIME AND LOW VISIBILITY

When visual observations cannot extend to the 3km observation zone. Start-up may commence with *A.3.2* soft-start procedure providing certain conditions are met. Operations may proceed, again providing certain conditions are met. During low visibility, when conditions allow, continuous observation should continue with focus on the low-power zone and shut-down zone. Procedures as for Stop Work (*A.3.5*) apply if a whale is detected.

PART B: ADDITIONAL MANAGEMENT PROCEDURES

Additional management measures include the use of MMOs, additional measures during night-time/poor visibility, the use of spotter vessel(s) and aircraft, increased numbers of precaution zones and buffer zones, PAM and Adaptive Management.

Once an Environmental Impact Assessment (EIA) has been conducted and accepted by the competent authorities, proponents of seismic surveys are granted permits on the condition that management procedures are followed. Once seismic surveys are underway there is also a requirement for regular reporting to the regulator. Infractions of the permit conditions are assessed and any necessary action is then taken by the regulator.

DEVELOPING AN APPROACH

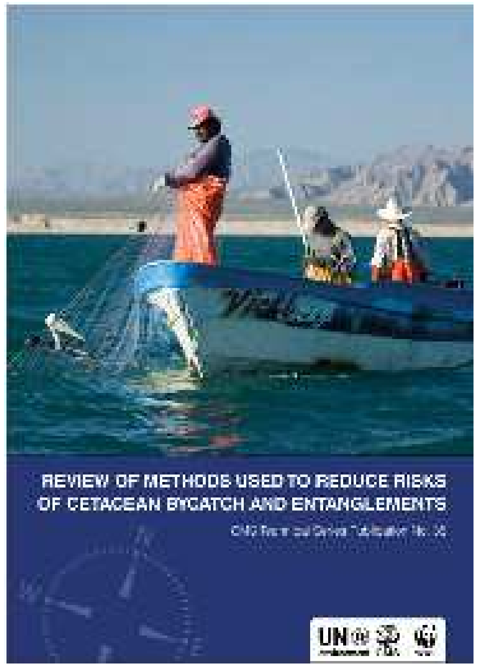
THERE ARE NUMEROUS EXAMPLES OF POLICIES SIMILAR TO THAT ISSUED BY THE AUSTRALIAN GOVERNMENT GLOBALLY[9]. Where national policy is absent, regulators are dependent on recommendations provided via the EIA procedure, which may be inadequate and/or may also result in unforeseen cost implications for the seismic survey proponents if the environmental sensitivities of an area are only revealed at this stage of the process. Proactive establishment of policy-based on scientific research provides reassurance to regulators and transparency for seismic survey proponents and area concession holders, and allows for effective and consistent management of potential impacts to marine mammals. Policies under consideration in new areas should take account of the latest advances in the scientific understanding of the potential impacts of seismic surveys on marine mammals as well as the local context of species and habitats.

We also advise review of New Zealand's seismic survey code of conduct.

FISHERIES

A REVIEW OF METHODS USED TO REDUCE THE RISKS OF CETACEAN BYCATCH AND ENTANGLEMENTS was published by CMS in 2018 [10]. The review covered **methods used to reduce the risk of contact between cetaceans and fisheries,** and **methods used to reduce the risk of serious or fatal injury if entanglement occurs**. There are relatively few examples of the effective implementation of successful mitigation measures which has been attributed to the lack of compliance and enforcement of proposed measures [10].

For large whales, in most cases, there is insufficient data available to determine whether measures aimed at reducing entanglements have been successfully making evaluations of the effectiveness of specific measures problematic [10]. Estimates of expected risk reduction, rather than observed incidents, must therefore inform the implementation and evaluation of measures; this is of particular importance when considering populations for which dynamics and status may be influenced by even rare incidents of entanglement mortality [10].



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> **"THE MOST GENERALLY EFFECTIVE MITIGATION OF CETACEAN BYCATCH AND ENTANGLEMENT IS REDUCTION IN EFFORT, STARTING WITH THOSE FISHERIES THAT HAVE THE LARGEST BYCATCH"** [1]

FISHERIES-BASED MANAGEMENT INITIATIVES TAKEN TO REDUCE THE RISK OF CETACEANS COMING INTO CONTACT WITH FISHERIES ACTIVITIES/GEAR

GEAR MODIFICATIONS/ ALTERNATIVE FISHING GEAR

Gear modifications include measures such as bycatch reduction devices (BRDs) or 'exclusion grids' on nets [11,12], which effectively enable bycaught cetaceans to escape through hatches. The risk of bycatch in creel/pot/trap fisheries gear can be reduced by modifying the amount of line floating in the water column, or through the use of remote releases for gear [10,13].

Both lines and nets may also be tensioned to reduce the risk of entanglement. Many such modifications to fishing gears have been attempted with mixed results in mitigating bycatch [10,14,15].

CLOSED AREAS/ FISHING BANS

Area-based fisheries management is often associated with bans (for example, on high-risk practices like drift netting), Take Reduction Plans, creation of protection and management zones or time-area closures [10].

This approach has the potential to be effective when addressing areas on a large enough scale for the management of threats to be effective [16]. It also relies on timely intervention and adequate enforcement, acknowledging that it is rare to achieve 100% compliance with area closure and fishing bans. Seasonal closures may be effective in areas where cetacean presence is limited to predictable periods (e.g. during migration) [10]. Very often restrictions are enforced too late to be fully effective as population declines have already reached a critical point [10]. Additional and/or alternative measures may then be required.

PINGERS/ ACOUSTIC ALARMS

'Pingers' are a form of acoustic alarm that are battery-powered acoustic devices designed to be attached to nets in the water, which produce sounds aimed at deterring cetaceans from the vicinity. Both cetaceans and fishers benefit if the pingers are working well, with the latter resulting in additional encouragement of their use [10].

However, their application has been limited to date due to an ineffectiveness in deterring some species (such as harbor porpoises), cost reliability and compliance issues as a result of differences in auditory ranges for different species [10,17,18,19,20].

REDUCE FISHING EFFORT

There is a proportional relationship between entanglement risk and reduced fishing effort and the most effective single means for reducing bycatch is therefore to reduce effort [10].

However, as human populations continue to grow and the demand for seafood increases, there is clearly a need to balance reduction of fisheries effort with social and economic drivers, some of which depends on a shift in attitudes within fisheries policy and management such that long-term sustainability of resources if afforded due attention [21].

GEAR LOSS AND DISCARD- *"GHOST FISHING"*

Bycatch rates may be reduced by ensuring fishing gear is not left in the water for an unnecessarily long period of time, the most extreme example of which occurs when gear is lost or discarded at sea. Discarded or lost gear continue to be a potential cause of bycatch in what is known as 'ghost fishing' [10]. This has no benefit to the fishing industry, but severely impacts marine wildlife as well as threatening commercially value fish species and habitats. In some fisheries the target species may be sufficiently valuable such that economic profit can be obtained even if gear is regularly lost or discarded [10].

Fisheries management schemes therefore need to include adequate incentives to minimize discard and maximize retention of gear.

[fisheries]

EXAMPLES OF EFFECTIVE AND INEFFECTIVE CASES TO ADDRESS FISHERIES BYCATCH

The collapse of the cod fishery in Newfoundland and Labrador revealed a strong inverse relationship between fishing effort and the rate of Humpback Whale entanglement [27].

A porpoise alarm (PAL) was used in German and Danish gillnet fisheries which revealed a significantly lower bycatch rate of harbor porpoise in the western Baltic Sea but no reduction in bycatch rate in the North Sea [25].

Crab fishery boats in Alaska restricted to fish for very short, predetermined periods often resulted in high gear loss rates due to working in poor weather conditions [26].

Successful reduction of injury and death of the Common Bottlenose Dolphin by restricting gear to certain mesh sizes (small (≤ 5inch), medium (≥5 inch to <5 inch), and large (≥ 7inch)), in addition to regulation of night-time fishing at specific times of the year [23].

A bycatch reduction device (BRD) was used in the Pilbara Trawl fishery in Western Australia to allow Bottlenose Dolphins to escape through a bottom-opening escape hatch or the mouth of the net. Bycatch was reportedly reduced by approximately 45% [11].

Acoustically reflective nets with barium sulphate and physically stiffened nylon gillnets did not reduce bycatch of the Franciscana dolphin (Pontoporia blainvillei) in Argentina [2]

In the Pilbara trawl fishery of Western Australia, pingers were ineffective in preventing Bottlenose Dolphins from entering the trawl [11].

Numerous attempts to recover a Critically Endangered Mexican endemic porpoise, the Vaquita (Phocoena sinus), by eliminating gillnets and restricting allowable fishing areas, which met with many socio-political and enforcement challenges [24].

"MANAGEMENT MEASURES THAT REDUCE THE RISK of any form of cetacean entanglement will not alter the ratio of lethal/non-lethal incidents, but those measures designed to minimize the likelihood of mortality if entanglement does occur will affect this ratio" [13].

MEASURES TO REDUCE THE RISK OF SERIOUS OR FATAL INJURY IF ENTANGLEMENT DOES OCCUR INCLUDE:

GEAR MODIFICATION

Weak links inserted in ropes attached to flotation devices that leave a clean (knot-free) end to the line may allow large whales to physically break free of gear in which they become entangled.

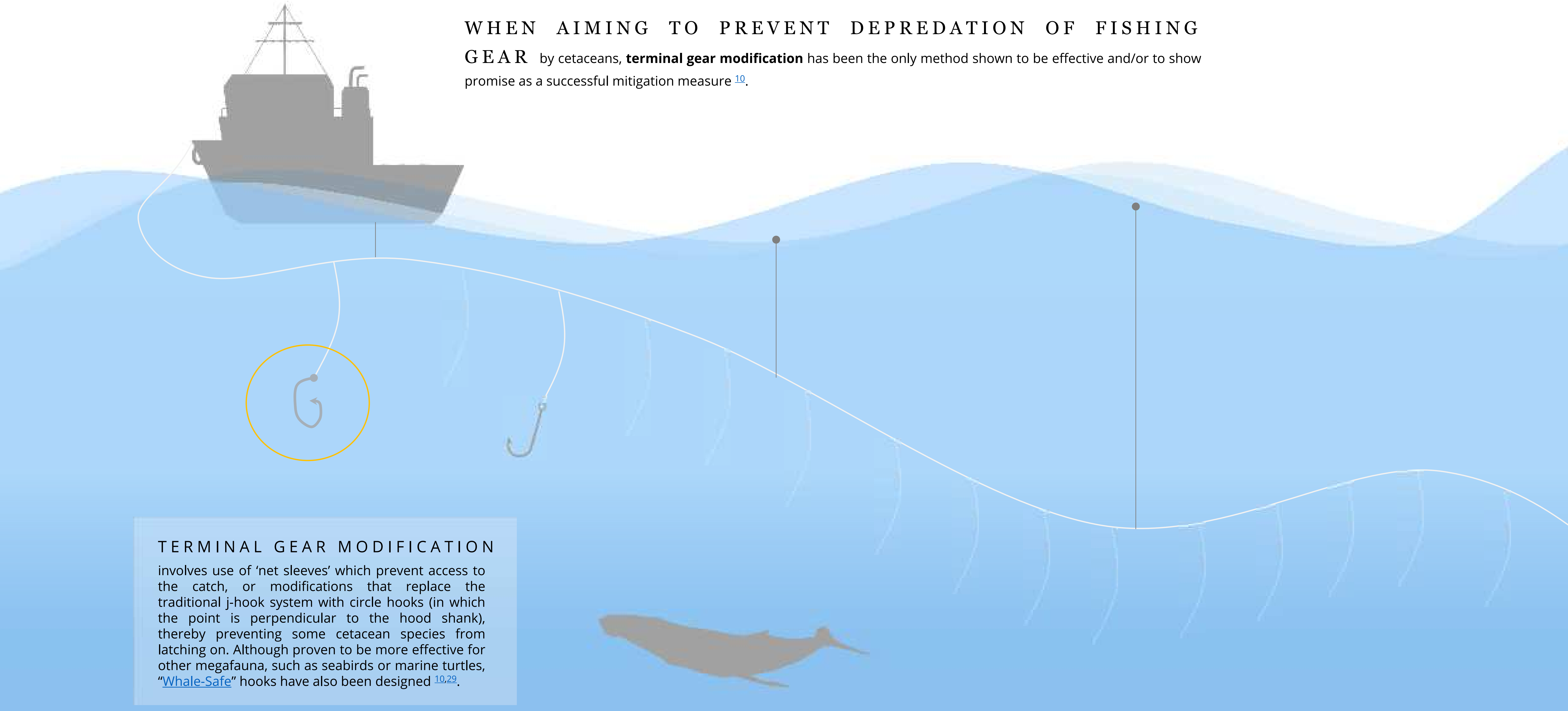
NON-ENTANGLEMENT GEAR

Fishing gear such as herring weirs or pound nets generally allow small cetaceans that become trapped within their boundaries (not entangled) to feed and breathe whilst trapped, with the result that any animals that can be subsequently released in reasonable health [10,28].

ENTANGLEMENT RELEASE PROGRAMS

Cetaceans that are caught in gillnets generally do not survive as they are unable to reach the surface to breathe. The IWC has recognised that only a small fraction of entanglements that occur are likely to be successfully disentangled, but nevertheless promoted entanglement release training especially for species/populations of low abundance.

Overall, the most effective strategy to mitigate cetacean bycatch and entanglement is through a reduction in fishing effort in specific, defined areas [10]. Where proper enforcement of effort reduction (either through time-area closures, bans or other restrictions) is unsuccessful, modifying gear to reduce risk of contact or entanglement provides for additional measures to reduce risk. However, long-term compliance with mitigation measures (and/or the use of expensive technology) can be problematic in some circumstances, such as in developing countries or in artisanal fisheries [10].



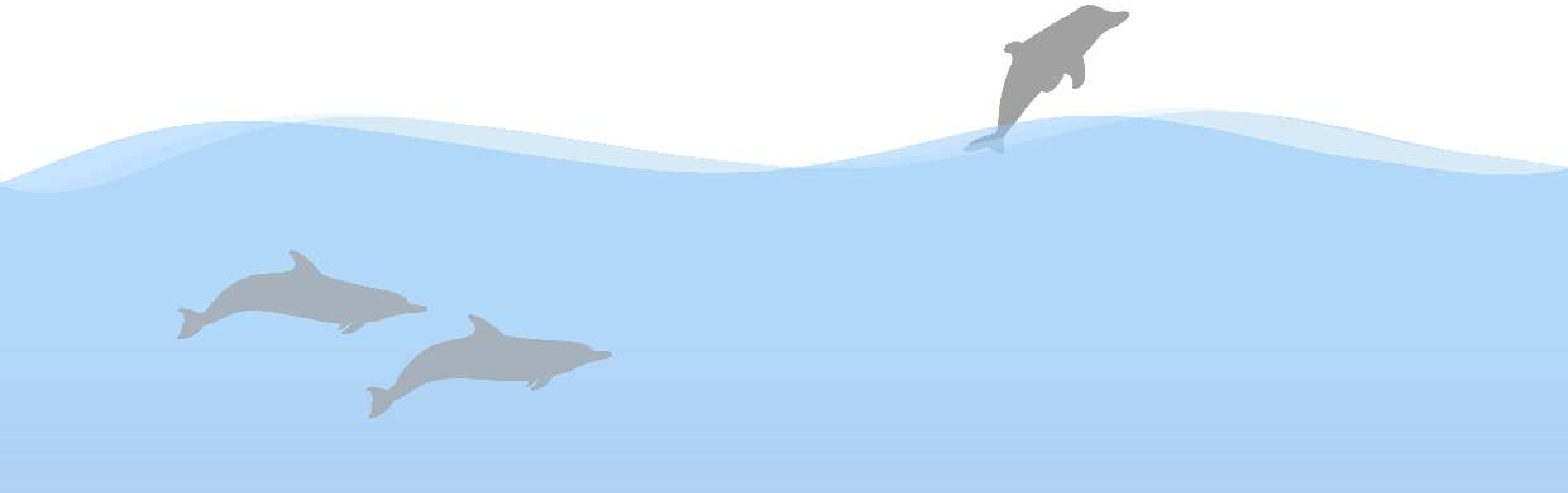
WHEN AIMING TO PREVENT DEPREDATION OF FISHING GEAR by cetaceans, **terminal gear modification** has been the only method shown to be effective and/or to show promise as a successful mitigation measure [10].

TERMINAL GEAR MODIFICATION

involves use of 'net sleeves' which prevent access to the catch, or modifications that replace the traditional j-hook system with circle hooks (in which the point is perpendicular to the hood shank), thereby preventing some cetacean species from latching on. Although proven to be more effective for other megafauna, such as seabirds or marine turtles, "Whale-Safe" hooks have also been designed [10,29].

[1] Leaper, R. and Calderan, S. 2018. Review of methods used to reduce risks of cetacean bycatch and entanglements. UNEP/CMS Secretariat, Bonn, Germany. 76 pages. CMS Technical Series No. 38.

WHALE AND DOLPHIN WATCHING



THE FIRST FORMAL WHALE AND DOLPHIN WATCHING TOURS in Oman were initiated through a single operator in Muscat in 1998, and over the following 10 years the industry grew to 15 operators. Between 2006 and 2007, a survey was conducted of tourists who had been on dolphin watching tours off Muscat and were asked to assess safety, educational value, perception of boat drivers' behaviour around dolphins and overall satisfaction [30]. Although tourists were generally satisfied with tours, the surveys also revealed a lack of awareness about potential impacts and threats to dolphins from the operations. The tourists' assessment of good boat driving behaviour contrasted with assessment by trained observers, which revealed a lack of adherence to best-practice industry standards. Recommendations were subsequently made to address the behaviour of boat drivers, as well as provision of more educational information (e.g. through a trained guide) and a review of safety standards on vessels. It was also proposed that a collective raising of industry standards in Oman would positively contribute to tourism value [30].

[whale and dolphin watching]

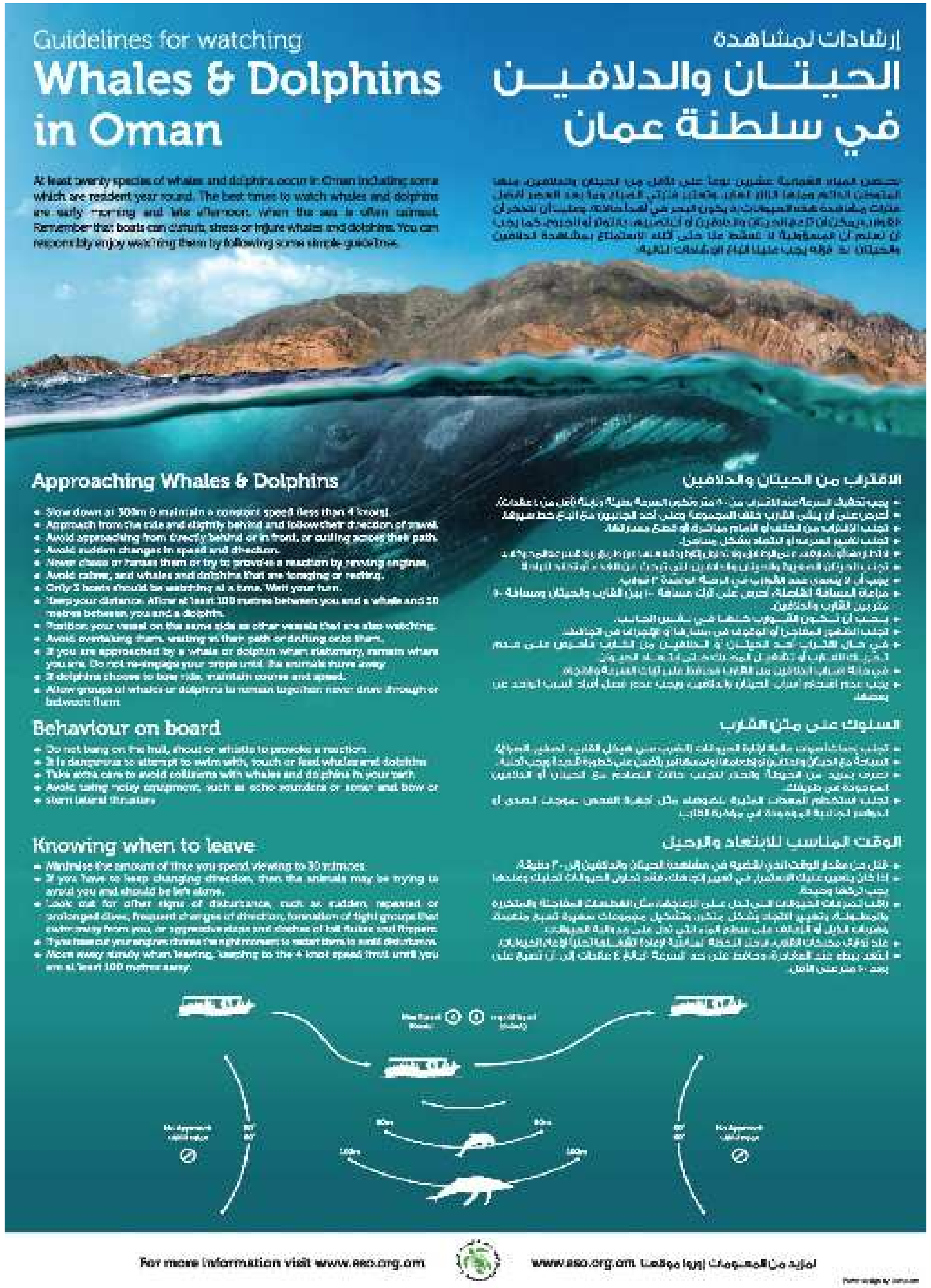


Figure 8) One of the many project outputs includes this informative whale and dolphin watching guideline created for vessels to reference when out at sea

IN 2013/14, A COLLABORATION between the Ministry of Environment and Climate Affairs, the Environment Society of Oman, Five Oceans Environmental Services LLC (5OES) and members of the IWC Scientific Committee, resulted in the drafting of whale watching guidelines for tour operators throughout the Sultanate [31]. This was in response to growing concerns about human safety, Oman's reputation in this sector of the tourism industry, the sustainability of the industry itself and potential impacts to whales and dolphins.

This collaborative project also compiled a database of operators, revealing that although the number of businesses operating tours in Muscat had fallen to 11, additional operations had started up elsewhere in the country. Spinner Dolphins (*Stenella longirostris*) and Indo Pacific Common Dolphins (*Delphinus delphis tropicalis*) were found to be target species off Muscat and Ras al Hadd, whilst the Indian Ocean Humpback Dolphin *(Sousa plumbea)* were targets in the fjords of Musandam and coastal waters near Salalah. At least one operator in Dhofar was also found to offer 'swim with dolphin' tours.

One of the primary aims of the project was to address the potential for unregulated tourism targeting Arabian Sea Humpback Whales [31], which are potentially vulnerable to whale watching activities, especially due to their precarious conservation status.

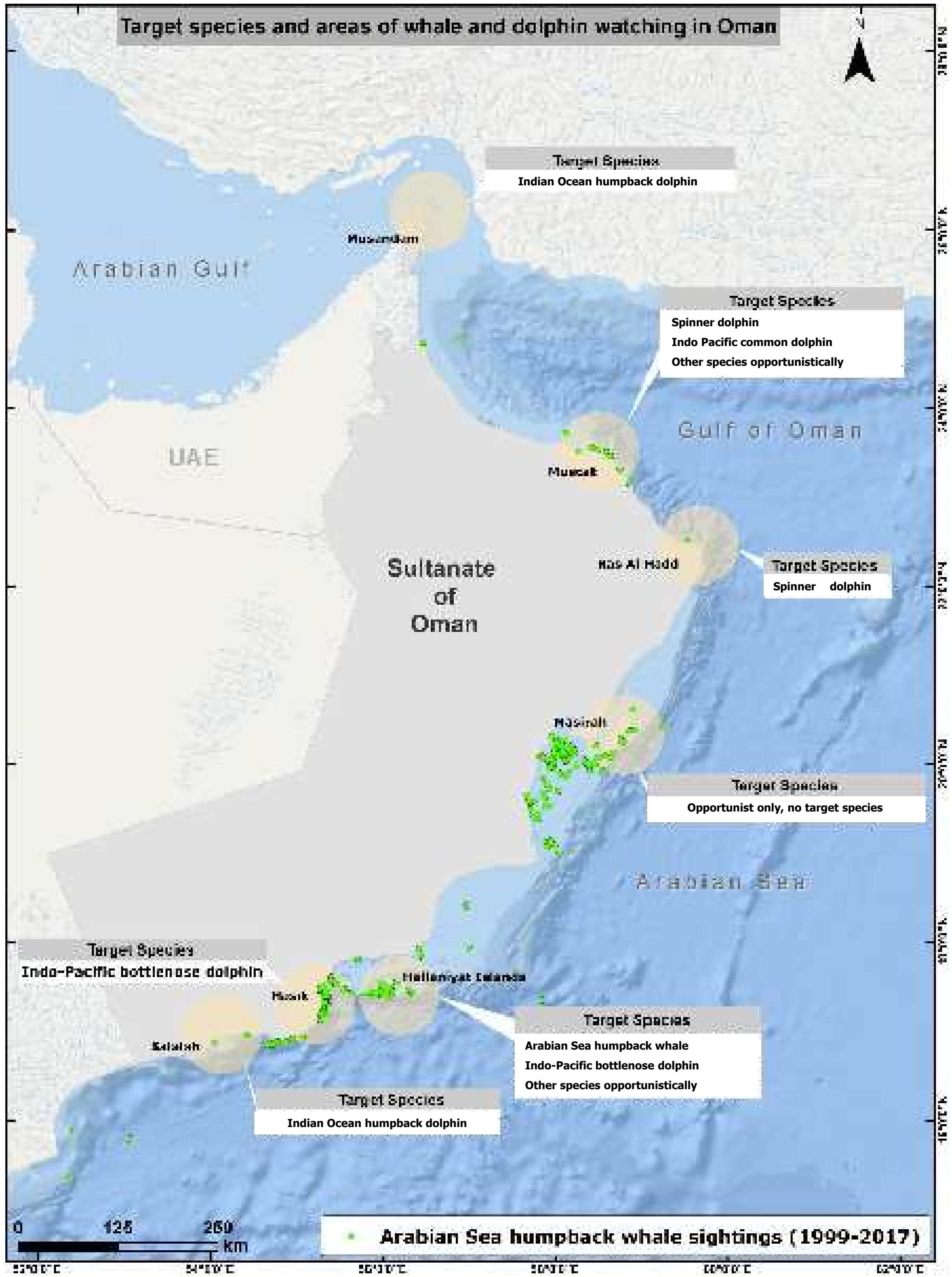


Figure 9) Target species and key areas of whale watching operations in Oman together with the areas of concern for expansion of the industry as represented by Arabian Sea Humpback Whale sightings records.

Figure 10) Swimming with whales presents dangers to both people and whales. Here an Arabian Sea Humpback Whale is using its flipper to swim backwards and avoid a snorkeller at close quarters. This image was taken in an area where no regulations are in place.

Figure 11) Unsustainable whale watching practices can emerge even in countries with regulations and restrictions in place. This scene from Egypt shows multiple vessels and divers with dolphins at a popular swim-with site which contravene codes of conduct.

ALONGSIDE UNREGULATED WHALE AND DOLPHIN WATCHING AND POOR VESSEL SAFETY, 'swim-with' programmes are also contentious, particularly when unregulated. Even in areas that apply regulations (such as licensing of operations and time area closures) operations may still present safety concerns for people and conservation and welfare issues for cetaceans [32]. Small resident populations are particularly at risk, especially where targeted in discrete habitats that may be critical for resting, socializing or foraging. Behavioural studies of Humpback Whales in areas of tourist vessel movements in Australia [33] have revealed that whales display a higher frequency of avoidance behaviour when vessels are within 100m of whales, as well as increased avoidance whilst vessels positioned themselves to place divers in the water. Behavioural responses included increased swimming speeds, decreased duration of dives, and increased turning angles away from vessel headings. Aside from the welfare and conservation of cetaceans, it has been recommended that for Oman, swim-with programmes may be inappropriate [31]. Swimming with whales and dolphins is considered a potentially dangerous activity and previous surveys have noted safety procedures in whale and dolphin tour operations in Oman to be limited [30]. This may be exacerbated where the profile of tourists includes non-swimmers. Allowing swimming with whales or dolphins may also send a contradictory message about the responsible and sustainable direction of this sector of the tourism industry in Oman.

TO CONSIDER FURTHER ENHANCEMENT OF THE TOURISM INDUSTRY IN OMAN A 2017 [31] review recommended following a well-established blueprint [34] for achieving sustainable and responsible whale watching operations.

This blueprint contains eight key elements:

These elements have been applied to create a roadmap for sustainable whale and dolphin watching in Oman [31], summarised below.

INITIAL PLANNING AND ASSESSMENT

(Researchers, NGOs, and government representatives take the lead; other stakeholders assist)

Identify and form a planning group to refine and approve a draft working plan.

Devise and implement stakeholder involvement strategies.

Organize baseline research on whales and dolphins.

Complete a socioeconomic assessment and establish carrying capacity.

MARKETING AND TOUR DESIGN

(Tourism agencies, operators, and supporting businesses take the lead; other stakeholders assist)

Commission a tourism scoping/feasibility study for current and possible future local attractions.

Commission a tourism marketing analysis (including visitor background and expectations).

Design the whale watching/marine ecotourism tours or "tour products."

Shape the brand and overall marketing plan for the community/region.

FOCUS ON BUSINESS

(Operators, supporting businesses, and tourism agencies take the lead; other stakeholders assist)

Set up business development, training, and assistance programs and workshops.

Develop business plans for sustainable whale watching, including value-adding techniques and impact-lowering strategies.

MANAGEMENT OF THE RESOURCE

(Government as well as NGOs and researchers take the lead; other stakeholders assist)

Set the overall policies for managing the industry (licensing of operators and boats; devising and establishing regulations). Set the upper limits for whale watching.

Examine the legal tools for managing the industry and implement them.

Embed education and research, as well as monitoring of the development of whale watching (to determine the impact on the animals being watched).

Develop a sustainability evaluation mechanism, both self-evaluation and periodic outside evaluation (including consideration of a big picture sustainability analysis).

To date no capacity has been available to implement this plan and it remains a priority to ensure that the rewards of a well regulated industry are realised.

[whale and dolphin watching]

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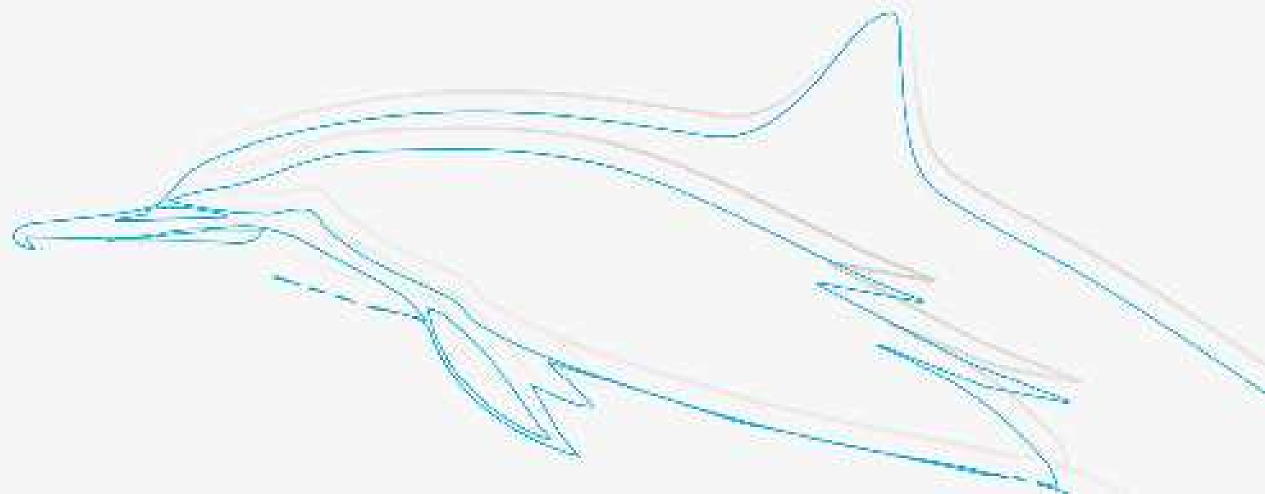

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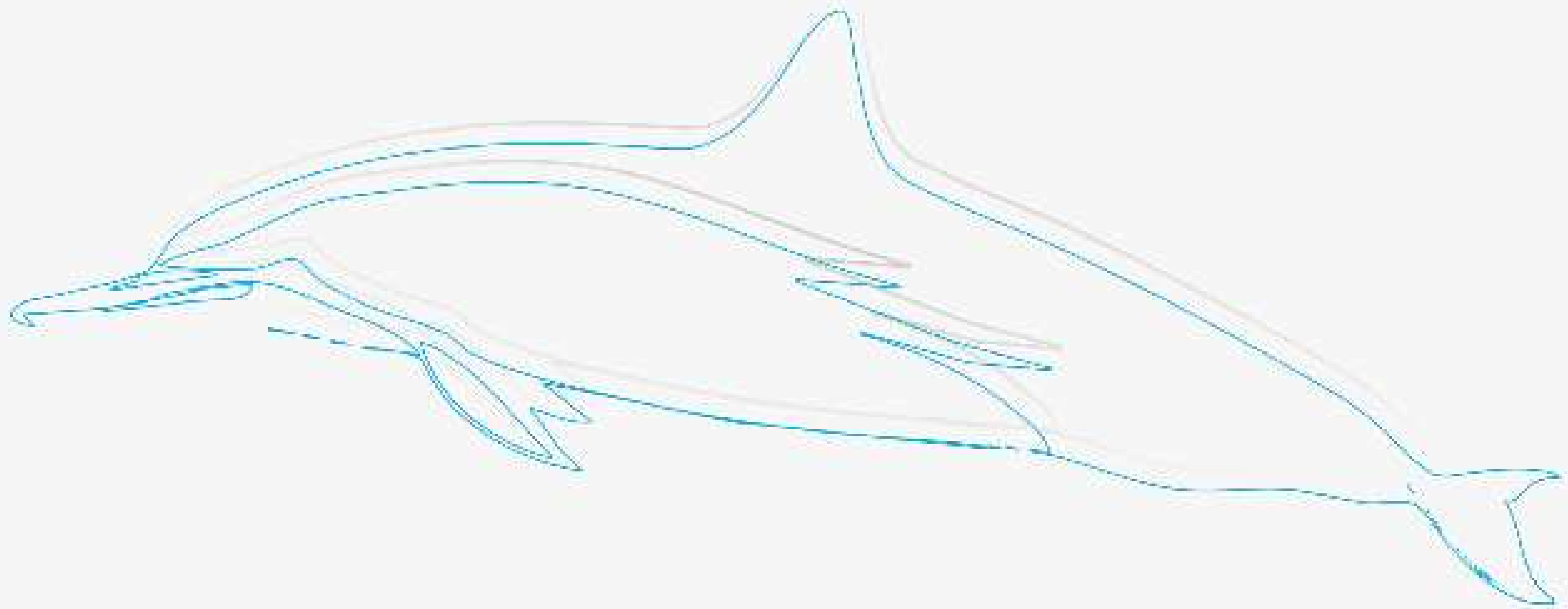


ORGANISATIONS AND 5 CONSERVATION FRAMEWORKS

MULTILATERAL ORGANISATIONS AND CONSERVATION FRAMEWORKS

THE INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN)

is the global authority on the status of the natural world and the measures needed to safeguard it. It is a membership Union, comprising States, government agencies, NGOs, Indigenous Peoples' organisations, scientific and academic institutions and business associations. There are currently more than 1,300 member organizations from over 170 countries, and the network has access to over 15,000 international expert members.

1

IUCN

https://www.iucn.org/

RED LIST OF THREATENED SPECIES

THE IUCN RED LIST OF THREATENED SPECIES IS A CRITICAL INDICATOR OF THE HEALTH of the world's biodiversity, and represents the world's most comprehensive information source of the global extinction risk status of plant, animal and fungus species. It is also a powerful tool to drive action for biodiversity conservation and policy change, providing information about species range, population size, habitat and ecology, use and/or trade, threats, and conservation actions.

To date, more than 116,000 species have been assessed for the IUCN Red List. The majority of these assessments are carried out by invited members of the IUCN Species Survival Commission (SSC), appointed Red List Authorities (RLAs), specialists working on IUCN-led assessment projects, or Red List Partners. Assessments are based on data which is currently available for the entire global range of the taxon in question, with full consideration of past and present published literature. Supporting information is also included, such as text summarizing the reason for the listed category, provision of a distribution map and completion of Classification Schemes (describing habitats, threats, etc.). Regional assessments are also included in the Red List, in addition to subspecies, subpopulations and (plant) varieties assessments, providing that a species level assessment has already been conducted. Submitted species assessments are reviewed by the IUCN Red List Unit staff (in addition to the Standards and Petitions Sub-Committee of the IUCN SSC Steering Committee on occasion) to ensure all criteria and supporting documentation requirements have been met.

The extinction risk of species is defined by one of nine categories, ranging from NE (Not Evaluated) to EX (Extinct). A full list of the Red List Categories can be seen in Figure 1 below.

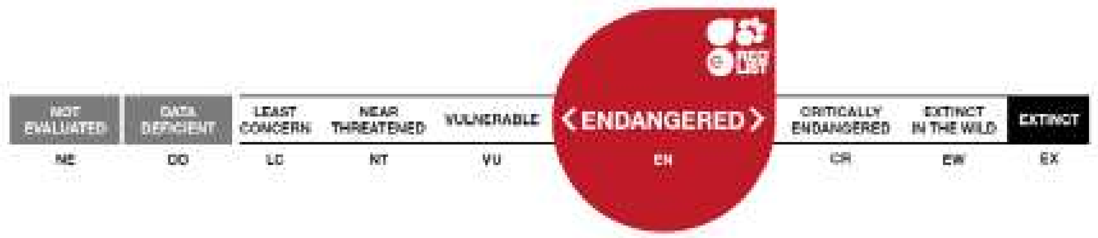


Figure 1) IUCN Red List Categories. Source: https://www.iucnredlist.org/

Species defined as Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) are considered to be threatened with extinction. These IUCN Red List statuses are used throughout this atlas.

Periodic reassessment of species in the Red List is important in order to monitor the status of biodiversity; reassessment may result in species moving into a different Red List Category. The IUCN relies on research work from around the world to inform the relevance of the category determination for each species. The reason for any changes in category is listed in the Red List, enabling quick recognition of species that have genuinely improved or deteriorated in status.

https://www.iucnredlist.org/

IUCN CETACEAN SPECIALIST GROUP

THE IUCN CETACEAN SPECIALIST GROUP (CSG) is one of the 100+ Specialist Groups and Task Forces that constitute the IUCN Species Survival Commission (SSC). The SSC is a scientific network of more than 7,500 invited volunteer experts from around the world, with specialist groups, such as the CSG, addressing conservation issues facing certain groups, populations or species, or focusing on topical issues such as wildlife health or reintroduction of species. The CSG has 130 members worldwide, all of whom are invited to membership based on technical expertise and experience which they provide to discussions and assessments on the status of the world's cetaceans.

The CSG has a few special Conservation Projects, including the Arabian Sea Humpback Whale; a population that is genetically isolated and endangered. The main threats to the Arabian Sea Humpback Whale population identified by the CSG include entanglement in fishing gear, shipping (including ship strikes and vessel noise), and oil and gas exploration and production.

The CSG supports regional collaborations for conservation and research purposes. These include working closely with the Arabian Sea Whale Network (ASWN), in which several CSG members have been involved since its inception, and in which collaborates with a range of regional organisations and individuals for the development and management of an online regional data platform aiding identification and regional analysis, as well as working with government and industry stakeholders to address a range of threats.

MARINE MAMMAL PROTECTED AREA TASK FORCE

THE MARINE MAMMAL PROTECTED AREAS TASK FORCE (MMPATF) was formed in 2013 by the International Committee on Marine Mammal Protected Areas (ICMMPA), IUCN's World Commission on Protected Areas (WCPA) Marine Vice Chair, and members of the IUCN SSC. The MMPATF encourages collaborations that promote the sharing of information and experience, and facilitates the use of knowledge and tools for MMPA establishment, monitoring and management. One of the MMPATF's key activities is to undertake Important Marine Mammal Areas (IMMA) assessments: those relevant to Oman are referenced in Chapter 2 of the Atlas.

https://www.marinemammalhabitat.org/

IWC

2

THE INTERNATIONAL WHALING COMMISSION (IWC) is an international body that was established under the International Convention for the Regulation of Whaling, signed in December 1946 in Washington DC. The legally binding "Schedule" of the Convention sets out specific measures that the IWC deems necessary in order to "provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry". The definition of 'whales' covers both mysticetes and odontocetes, and therefore includes all dolphins and porpoises, as well as the larger whales which formed the original focus of the Commission.

The IWC reviews and revises the measures laid down in the Schedule, which amongst other things, provide for the complete protection of certain species, including: designation of specified areas as 'whale sanctuaries'; imposing catch limits (zero in the case of commercial whaling); and protecting calves and females accompanied by calves. The reasons that review and revisions of the schedule may be necessary include variations in the requirements of aboriginal subsistence whalers and the provision of new whale research information from the scientific community.

The IWC also encourages, co-ordinates, and in some cases funds whale research and conservation work; this includes the development of an international entanglement response capacity and establishment of Conservation Management Plans (CMPs) for key species and populations. One such CMP has been proposed for the Arabian Sea (see below). The work of the IWC is divided among 6 committees, each of which are comprised of a series of sub-groups; some long-term, standing committees, others established for specific short-term requirements. Groups are chaired by Commissioners, members of national delegations or scientific experts from the wider IWC community (see Figure 2 on the following page for an organisational chart explaining the IWC structure).

Membership of the IWC is open to any country that formally adheres to the 1946 Conventions. However, as the IWC is a voluntary international organization, not backed by formal treaty, there are substantial practical limitations on the IWC's authority. As such, the IWC has no ability to enforce any of its decisions through penalty imposition. The Sultanate of Oman became a member of the IWC in 1980.

https://iwc.int/home

INTERNATIONAL WHALING COMMISSION

IWC

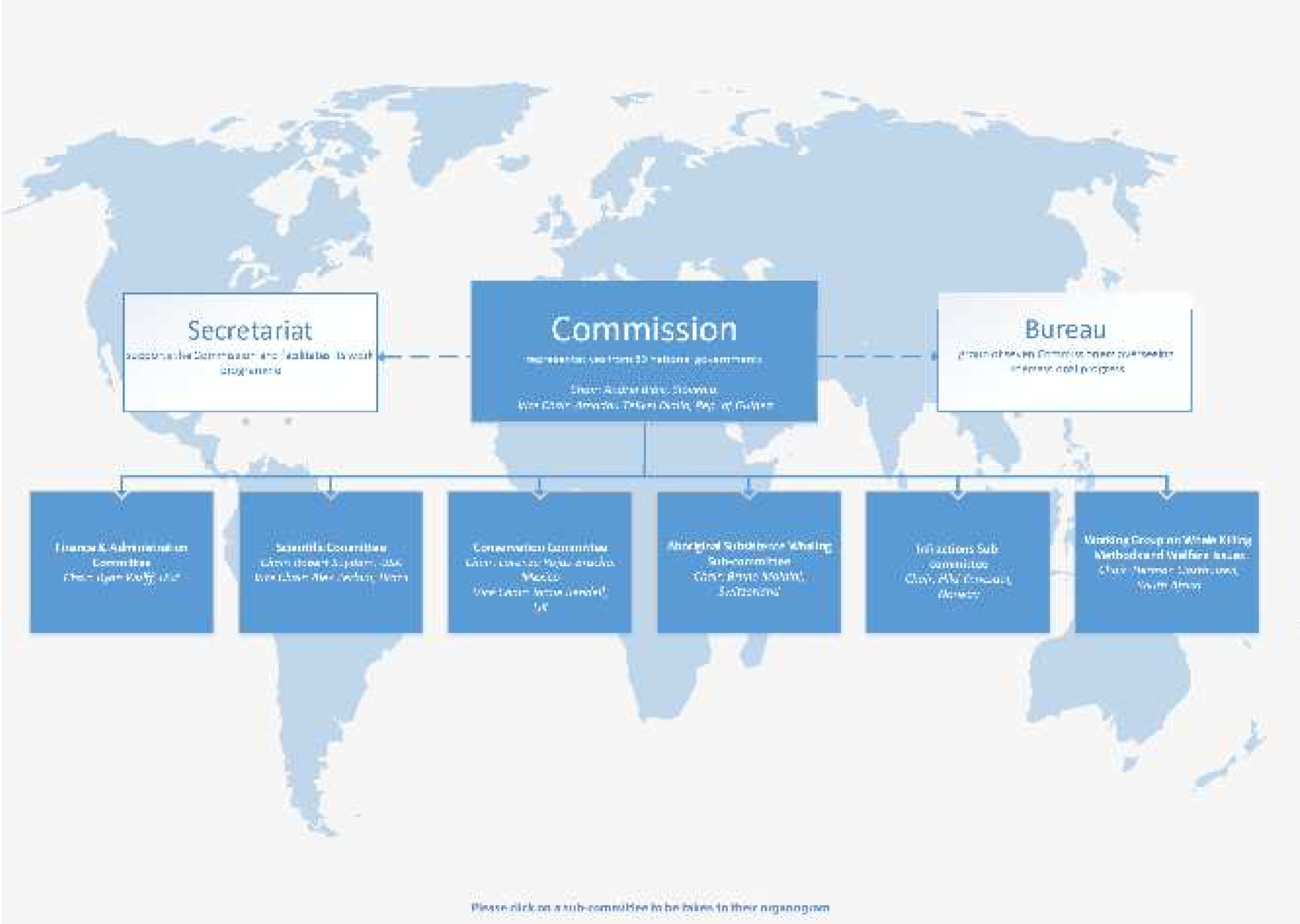


Figure 2) Organizational chart of the IWC structure. Source: https://iwc.int/organisational-structure

INTERNATIONAL WHALING COMMISSION

INDIAN OCEAN SANCTUARY

THE IWC HAS TWO DESIGNATED SANCTUARIES, BOTH OF WHICH PROHIBIT COMMERCIAL WHALING. The first of these to come into existence was the Indian Ocean Sanctuary (IOS), established in 1979. It covers Northern Hemisphere Indian Ocean waters from the coast of Africa to 100°E (including the Red Sea, Arabian Sea, Sea of Oman and Arabian Gulf) and Southern Hemisphere waters between 20°E and 130°E from the equator to 55°S. The IOS was proposed by the Republic of the Seychelles, and adopted at the 1979 meeting of the IWC. Representatives from Oman, even before it became an official IWC member, were actively involved in supporting this process. The second designated sanctuary of IWC, the Southern Ocean Sanctuary was formed in 1994 and surrounds the continent of Antarctica with a northern boundary line along 40°S.

INTERNATIONAL MORATORIUM ON WHALING

WAS DECLARED AS PART OF MEASURES IMPLEMENTED BY THE IWC to regulate whaling and conserve whale stocks. The IWC adopted the moratorium in 1982, effective from the 1985/86 whaling season onwards. Oman is a signatory to this moratorium, and has a commissioner who represents Oman at the IWC to this day.

INTERNATIONAL WHALING COMMISSION

IWC CONSERVATION MANAGEMENT PLANS

ONE OF THE SIX COMMITTEES OF THE IWC is the Conservation Committee, to which the Standing Working Group on Conservation Management Plans (CMPs) reports. CMPs are one of the important conservation initiatives of the IWC, providing a framework for collaboration of countries within the habitat range (range states) of vulnerable cetacean populations in order to help protect and recover identified populations. CMPs are flexible management tools which provide help for range states to address the threats facing populations, such as bycatch, entanglement, ship strike, habitat loss, etc. As part of the flexible nature of CMPs, they can be tailored to meet individual circumstances and draw on best available science and management expertise from the international scientific community. CMPs have so far been developed for four vulnerable cetacean populations, with the Arabian Sea Humpback Whale listed as a priority species for future CMP development.

ARABIAN SEA HUMPBACK WHALES

The Arabian Sea population of Humpback Whales was first suggested as a possible candidate for the development of a CMP in 2010. The population is listed as endangered by IUCN and is believed to comprise less than 100 individuals in Oman.

Expansion of fisheries, coastal infrastructure developments, offshore hydrocarbon exploration, the potential for unregulated whale-watching, and the planned commencement of new shipping routes and increased shipping traffic through known whale habitat are concerning, and provide persuasive argument for the advancement of a CMP.

Consistent with advice from the Scientific Committee, research on the Arabian Sea Humpback Whale population has continued, along with efforts amongst scientists and non-government organisations to establish a regional initiative to co-ordinate conservation efforts for the population.

In October 2017, the Conference of the Parties of the Convention on Migratory Species agreed a Concerted Action for the Arabian Sea Humpback Whale population, which included consideration of the IWC proposal for development of a CMP. Supporting statements were made by Oman, India, Pakistan, United Arab Emirates, Ecuador, Iran, Saudi Arabia, and the IWC's Secretariat.

The IWC will build on these developments and continue to engage with relevant range states to encourage and support the development of a CMP for the Arabian Sea Humpback Whale population.

Priority Species for future CMPs. Source: https://iwc.int/conservation-management-plans

INTERNATIONAL WHALING COMMISSION

IWC BYCATCH MANAGEMENT INITIATIVE

AT THE 2016 IWC MEETING, a new work programme, the Bycatch Mitigation Initiative (BMI), was agreed by the Conservation Committee, and is formed of a multi-disciplinary Expert Panel and Standing Working Group, with an appointed Bycatch coordinator to lead the work programme. The BMI has identified four inter-related areas of work which address improving the assessment of bycatch, as well as mitigation and management methods, transfer of knowledge and expertise, and engagement with other relevant international organisations.

The most recent meeting of the BMI was held in May 2019, in Nairobi, Kenya. The meeting was attended by 50 participants, including 24 from 9 countries within the Indian Ocean region. The primary objectives of the meeting were to "develop a broad-scale picture of cetacean bycatch across the North and Western Indian Ocean region (gaps, priorities, challenges and opportunities), to introduce the BMI to Indian Ocean stakeholders, and to assess how the BMI can be of use". Amongst the conclusions of the workshop was an identified, urgent requirement for a more systematic assessment of bycatch information, including further work to develop and trial low-cost and low-tech solutions for mitigation and monitoring.

More details from the meeting can be found here: https://iwc.int/bycatch-mitigation-in-the-indian-ocean-iwc.

Details from the report relating directly to Oman [1] are presented in the following pages.

INTERNATIONAL WHALING COMMISSION

IWC BMI WORKSHOP SUMMARY, *SECTION 3.4* OMAN.

3.4.1

BYCAUGHT CETACEAN SPECIES AND MAIN FISHING GEARS INVOLVED

CURRENTLY FISHING IN OMAN IS >95% ARTISANAL [2,3] and employs a range of artisanal and small-scale gears including traps, pole lines, trolling lines, gillnets, driftnets, beach seines, and longlines. As elsewhere in the region, cetacean bycatch is most likely to be associated with gillnets in both drifting and set-net configurations. These nets are operated from both small vessels less than 8m in length, and those up to and greater than 15m. There is scarce information on cetacean distribution, and most available information is on the Arabian Sea Humpback Whale [4]. Potential high-risk areas for cetacean bycatch (based on knowledge of fisheries and cetacean co-occurrence) are presented in Figure 3.

INTERNATIONAL WHALING COMMISSION

3.4.2

RELEVANT WORK ON BYCATCH

VESSEL-BASED CETACEAN SURVEYS IN OMAN have generated a sighting and encounters-based photographic database of Arabian Sea Humpback Whales. This database has been used to evaluate the incidence of exposure to fisheries interactions [5,4] and other anthropogenic threats [6]. This latest evaluation [6], which was funded by the IWC, examined all available images of Arabian Sea Humpback Whales obtained between 2000 and 2018 for evidence of disease, predation, epizoites and human-induced scarring or injury to individuals. Tattoo-like skin disease, first reported in Arabian Sea Humpback Whales in 2014 [7] was detected in 43.4% of 83 adult whales, with a roughly equal distribution between males and females. The prevalence of the disease was significantly higher in 2012-2018 (51.7%) than in 2000-2011 (24.1%). Killer whale tooth rakes were detected in 12% (95% CI 4.5-18%) of individuals based on examination of photographs showing the ventral surface of tail flukes (n=77), but no cookie cutter shark wounds were detected on any body parts of any of the whales examined. Roughly two thirds (66.6%: 95% CI 52-80%) of individuals represented by good quality photos of the caudal peduncle region (n=42) bore scarring patterns considered likely to be associated with entanglement in fishing gear, with no significant differences in entanglement scarring rates between males and females. Four individuals bore injuries consistent with vessel strikes, and at least two individuals showed severe injuries and deformations likely to have been caused by interactions with vessels and/or fishing gear [6]. Documented entanglement events from Oman and Pakistan [8] involved large-mesh nylon gillnets, which are known to be used extensively throughout the Arabian Sea.

Dedicated and ad-hoc beach stranding surveys have been undertaken in Oman since the late 70's [9]. Protocols include assessing stranded specimens for external signs of entanglement or interaction with fisheries. Data is stored in the Oman Stranding Database which is managed by the National Stranding Committee (NSC) chaired by Oman's Environment Authority (formerly the Ministry of Environment and Climate Affairs). In 2015, the NSC hosted a training programme in stranding and entanglement response delivered by IFAW and IWC experts [10]. The NSC also hosts a social media group that posts stranding and entanglement-related events in Oman.

Localised work on bycatch has been undertaken on Masirah Island as part of an evaluation of significant decline in Masirah's nesting loggerhead turtle (*Caretta caretta*) population [11]. Preliminary work began in 2010 and included high level interviews with leading fishermen and authorities on the island and was followed by a detailed community-based questionnaire survey undertaken in 2012 to both characterise the fishery (seasonal effort, distribution, gear types used and species encountered) and account for turtle bycatch. In 2016, a study was launched to refine the method for logging of fishing effort and bycatch, using vessel captains and crew as reporters. This programme evolved into a remote electronic monitoring observer system using time-lapse cameras and GPS equipment to capture data on vessel effort and bycatch events around the island. This more recent data includes opportunistic reporting on the bycatch of small cetaceans (including spinner dolphins) captured to the south of Masirah Island within a high density fishing area [12]. However due to the method employed, it was not possible to establish the bycatch rate. GIS analysis has also been completed to show the co-occurrence of fishing effort and turtle distribution around the island [12]. The Masirah project is led by a partnership formed by the Environment Society Oman, Five Oceans Environmental Services LLC, US Fish and Wildlife Service, US Southwest Fisheries Science Centre and Oman's Environment Authority (formerly the Ministry of Environment and Climate Affairs) and is permitted by the Ministry of Agriculture and Fisheries Wealth. Most recently on the island, a project led by the Environment Society of Oman has been using a conservation psychology 'behaviour change' approach to address the disposal and loss of fishing nets by the artisanal fishing fleet. The study engages with fisher contacts established during the previous projects at Masirah.

INTERNATIONAL WHALING COMMISSION

3.4.3

CHALLENGES AND BARRIERS - POLITICAL, TECHNICAL, CULTURAL ETC.

THE MASIRAH STUDY IDENTIFIED A NUMBER OF CHALLENGES TO TACKLING BYCATCH [12]. In relation to data collection this included a perceived lack of incentives for fishers to change behaviour or report bycatch, and that improving data collection through observer programmes or Remote Electronic Monitoring (REM) would have financial implications. The study also reported that there could be cultural challenges involved, including the interplay between vessel owners (mainly Omani nationals), fishing crews (predominantly expatriates such as those from India and Bangladesh) and bycatch researchers (predominantly western expatriates). It was reported that the expatriate fishing crews may have few incentives to collaborate on bycatch work. Furthermore, there are many different fisheries operating in Omani waters and this changes seasonally. This makes the process of identifying fisheries that are potentially a high risk for bycatch time consuming and complex. The group also reported that there could be potential political barriers to tackling the issue as bycatch reduction measures could be viewed by the industry as potentially restrictive, leading to potential reduction in fisheries productivity. This could result in a reluctance to raise the profile of the bycatch issue and address it. Meanwhile management authorities are placed in a difficult situation where they are positioned between the aspirations of fishing communities and obligations of international agreements regarding bycatch reporting and reduction, such as those associated with the Indian Ocean Tuna Commission and US Marine Mammal Protection Act. In addition, such agreements have obligations that might work well for industrial fisheries but may not be suited to small scale artisanal fisheries, where it is difficult to find methods and resources to evaluate bycatch and find solutions to problems that may be specific to the type of fishery, boat, gear and competency of crew. There may also be a lack of capacity to address the requirements of these obligations.

3.4.4

OPPORTUNITIES AND NEEDS FOR TACKLING BYCATCH

THE MASIRAH ISLAND STUDY [12] NEVERTHELESS REVEALED that there may be opportunities to tackle bycatch through fisheries community programmes. The study was endorsed by Oman's Ministry of Agriculture and Fisheries Wealth revealing political will to address the issue, and there is the potential for the programme to expand to a more cross taxa approach. Data collection using REM was low-cost and archived results present an opportunity for assessment of multiple taxa. This could include assessment of catch per unit (CPU) effort of cetaceans and comparison of fishing effort data with species distribution data to assess co-occurrence, as has already been undertaken for turtles. There is also opportunity to develop computational models to further evaluate fishing effort based on the existing GIS data.

Ultimately, the results of this study, and the valuable community participation and that was achieved, could lead to development of mitigation measures to address bycatch, such as use of alterative fishing gears, in tandem with development of behaviour change methods using a conservation psychology approach.

BYCATCH HOTSPOTS AND POTENTIAL HIGH RISK AREAS IDENTIFIED FOR THE INDIAN OCEAN, INCLUDING AREAS ALONG THE ARABIAN SEA COAST OF OMAN

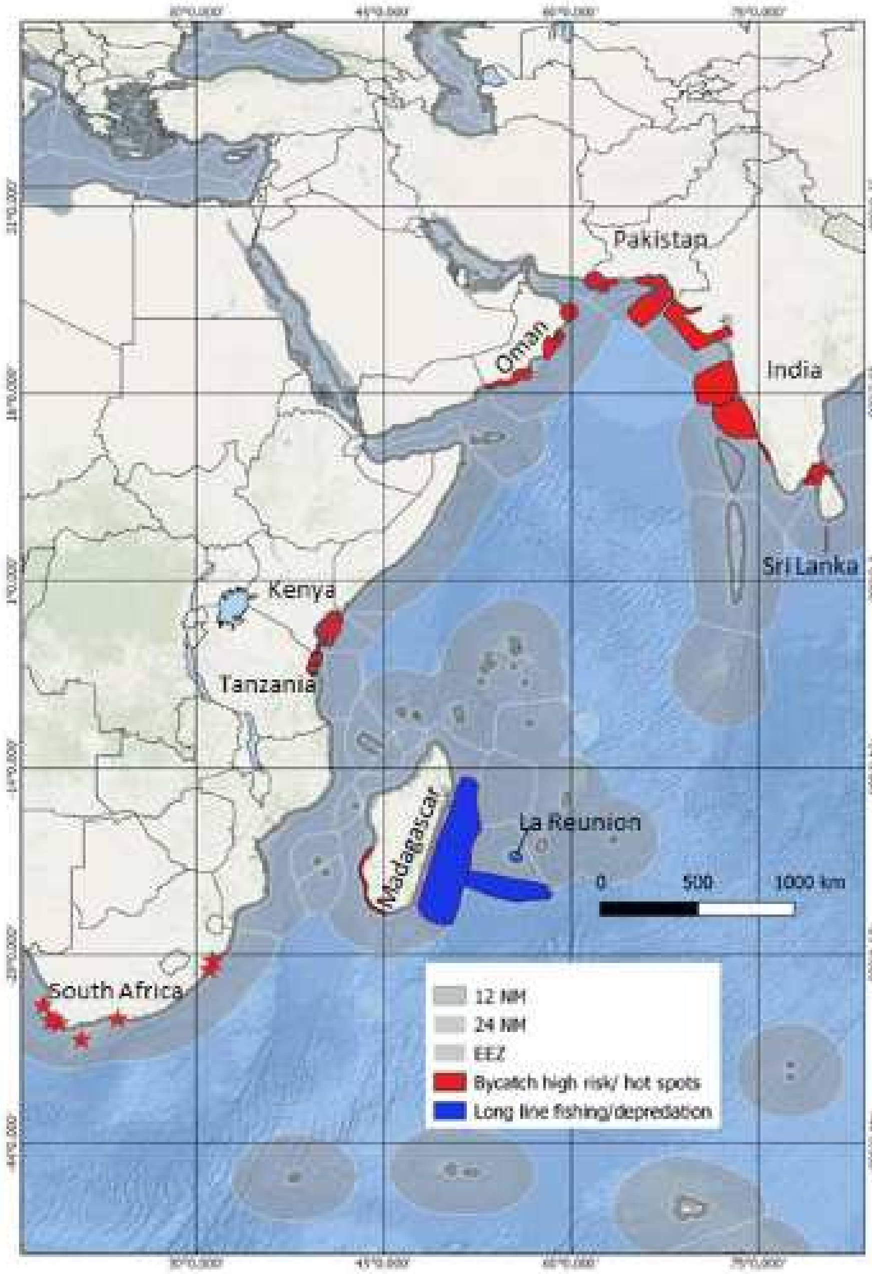


Figure 3) Bycatch hotspots, and potential high-risk areas for bycatch or depredation (La Réunion) in the Indian Ocean and Arabian Sea region identified during the 2019 IWC BMI workshop. *Source: Report of the IWC Workshop on Bycatch Mitigation Opportunities in the Western Indian Ocean and Arabian Sea. IWC, 2019.*

IWC SHIP STRIKE COMMITTEE

BOTH THE CONSERVATION AND THE SCIENTIFIC COMMITTEES of the IWC are working to better understand the threat posed by ship strikes and how to reduce this threat globally. To this end, a Strategic Plan to Mitigate the Impacts of Ship Strikes [13] has been prepared. The Arabian Sea Humpback Whale population is identified by this plan as a population of concern owing to high levels of shipping traffic within its home range [13].

WITHIN THE STRATEGIC PLAN, THE SHIP STRIKE COMMITTEE HAS A REMIT TO:

1. define and identify areas in which ships and large whales frequently co-occur ("High Risk Areas")
2. identify large whale populations vulnerable to decline in part due to mortalities associated with ship strikes
3. discuss the possible attributes of some ship strike avoidance technologies
4. identify the need for collaboration among key constituent sectors
5. discuss the importance of inter-organization communication and the streamlining of data

INTERNATIONAL WHALING COMMISSION

IWC SHIP STRIKE COMMITTEE

The various stages included in the identification of high risk areas and development of appropriate mitigation strategies are presented below. The Arabian Sea Humpback Whale population assessment is among those being assessed by the IWC and is currently at *Stage 2* of this process.

STAGE ONE

High risk area of potential concern identified based on overlap of shipping and whale distribution or a high number of reported incidents.

STAGE TWO

Use scientific survey data for whales and vessel Automatic Identification System (AIS) data for shipping to inform risk analysis and local vs international jurisdiction.

STAGE THREE

Consideration of possible practical options based on risk analysis. Recommendations from IWC Scientific Committee provide basis for IWC to approach relevant states to offer information and advice.

STAGE FOUR

Stakeholder workshops to discuss possible mitigation measures and optimize risk reduction in the interests of stakeholder and whales.

STAGE FIVE

Relevant states consider proposals to IMO (International Marine Organisation) supported by information from IWC.

STAGE SIX

Measures implemented through IMO.

STAGE SEVEN

Continued monitoring to evaluate ongoing effectiveness of measures.

INTERNATIONAL WHALING COMMISSION

A VISUAL REPRESENTATION OF THE SHIP STRIKE WORKING GROUP STRATEGIC PLAN 2017 – 2020 CAN BE SEEN IN FIGURE 4 BELOW.

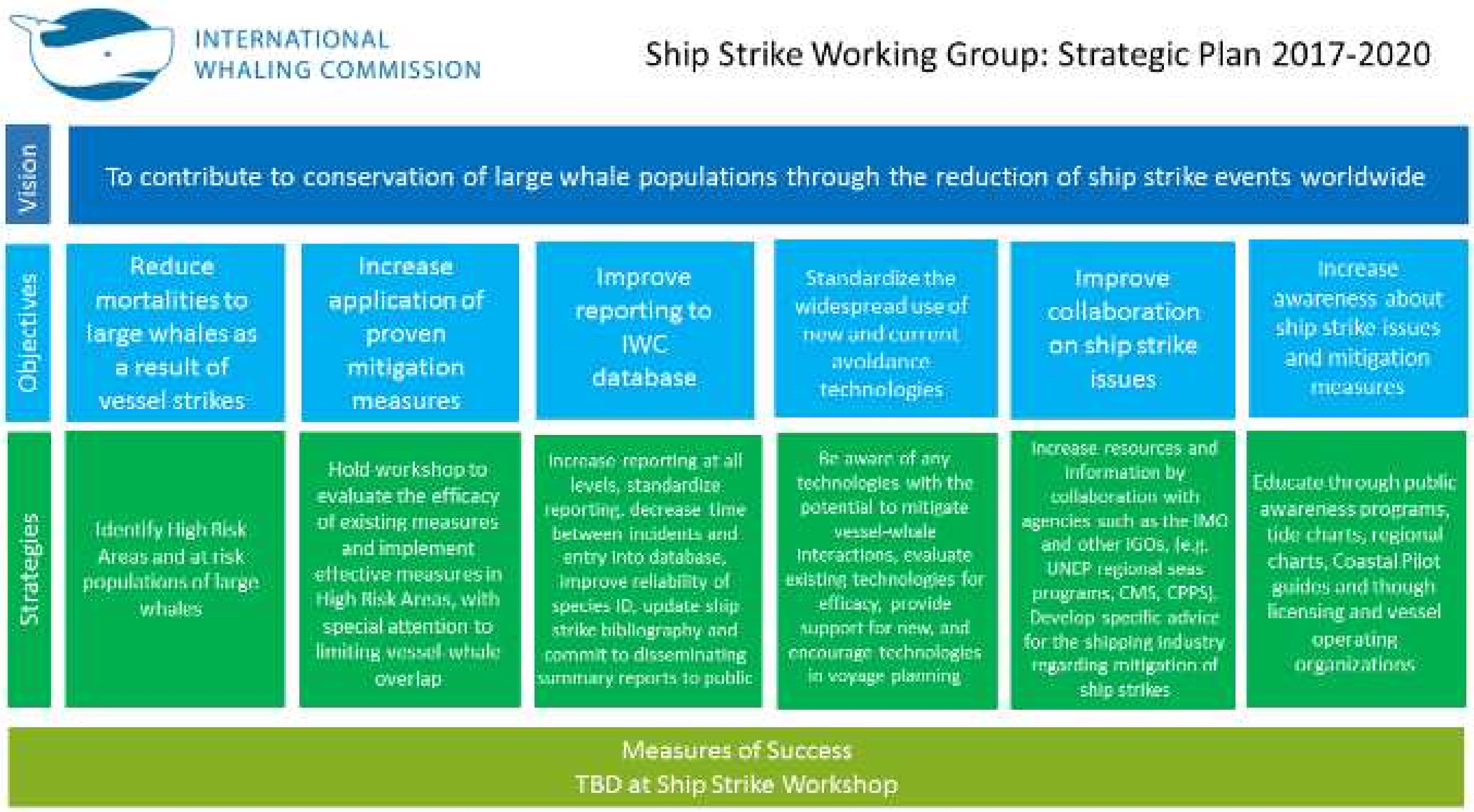


Figure 4) Flow Chart for the Strategic Plan. Source: Cates et al., 2017 [13].

INTERNATIONAL WHALING COMMISSION

IWC SCIENTIFIC COMMITTEE

THE IWC SCIENTIFIC COMMITTEE IS ONE OF THE 6 COMMITTEES REPORTING TO THE IWC COMMISSION. The Convention requires that revisions and amendments to the Schedule "shall be based on scientific findings" and the Scientific Committee was established to meet this purpose. It is the oldest and most established of the IWC committees, and is involved in the majority of the work undertaken by the IWC.

https://iwc.int/scmain

INTERNATIONAL WHALING COMMISSION

IWC CONSERVATION COMMITTEE

THE IWC CONSERVATION COMMITTEE IS ANOTHER OF THE 6 COMMITTEES REPORTING TO THE COMMISSION. It collaborates closely with the IWC Scientific Committee, and acts to consider a wide range of cetacean conservation issues. The 2016 Strategic Plan adopted by the Conservation Committee identifies priority threats to cetaceans, priority actions, measures of success, key partnerships and resourcing.

https://iwc.int/conservation-committee

INTERNATIONAL WHALING COMMISSION

CMS

3

THE CONVENTION ON THE CONSERVATION OF MIGRATORY SPECIES OF WILD ANIMALS (CMS OR BONN CONVENTION), was adopted in Bonn, Germany in 1979 and came into force in 1983. It is an environmental treaty of the United Nations (UN), bringing together the States through which migratory species pass (Range States) and lays down the legal foundation for internationally coordinated conservation measures throughout the migratory range of a species. Agreements of the Convention range from legally binding treaties (Agreements) to less formal instruments (e.g. Memorandums of Understanding (MOUs)), and can be tailored to the specific requirements of particular regions.

CMS provides a global platform for the sustainable use and conservation of migratory species and their habitats. It is the only global convention which specializes in the conservation of migratory species, and as such, cooperates with, and complements other international organisations, NGOs and partners in the corporate sector and the media. The CMS promotes concerted action among the Range States of many of the species listed in the Appendices of the convention. Appendix I of the Convention lists migratory species which are currently threatened with extinction, with a focus on strictly protecting these animals, mitigating obstacles to migration, conserving or restoring their habitats and controlling endangering factors. Appendix II lists migratory species that need, or would significantly benefit from, international cooperation.

The Humpback Whale *Megaptera novaeangliae* has been listed in Appendix I of the convention since 1979 and was designated for Concerted Action by the CMS Conference of Parties in 2002. The CMS Concerted Action plan for Humpback Whales of the Arabian Sea was proposed in 2014, given that its conservation status (Endangered) makes it of far greater concern than that of the global population as a whole (which is classified as Least Concern).

The Arabian Sea Humpback Whale Concerted Action [14] includes a list of priority activities within three main categories:

ADDRESSING KNOWLEDGE GAPS RELATING TO THE CONSERVATION OF ASHW	CAPACITY/BUILDING AND DEVELOPMENT AND IMPLEMENTATION OF MITIGATION STRATEGIES	INFORMATION SHARING AND AWARENESS RAISING

ARABIAN SEA HUMPBACK WHALE CONCERTED ACTION: PRIORITY ACTIVITIES AND OUTCOMES

Increased number of geographical range of Arabian Sea Humpback Whale sightings in regional database

The development of a marine mammal reporting **smartphone app** and citizen science tools, to allow the crews of fishing, coast guard and whale-watch vessels and ferries to record and report whale and dolphin observations

Improved data and models of current Humpback Whale distribution throughout the Arabian Sea

Improved understanding of whale distribution in Eastern Arabian Sea (e.g. Gujarat and Rann of Kutch)

Use of **passive acoustic recorders** to detect the presence of whales and monitor anthropogenic noise in areas that are logistically difficult or dangerous to survey

Recordings that indicate year-round presence/absence of Humpback Whales in areas where boat surveys not conducted

Genetic analysis of samples collected from strandings and during dedicated whale surveys to determine whether Arabian Sea Humpback Whales comprise a new sub-species

Likely designation of ASHW as new species or subspecies, understanding of kinship and relatedness of sampled whales

Publications in peer-reviewed journals and likely designation of new species/subspecies. May impact status listings and understanding of connectivity range-wide eventually

Collaborative **boat-based research** to continue photo-identification studies, collect tissue samples for genetic analysis, and identify critical habitat. The involvement of local scientists in this research will build capacity for future conservation in the region.

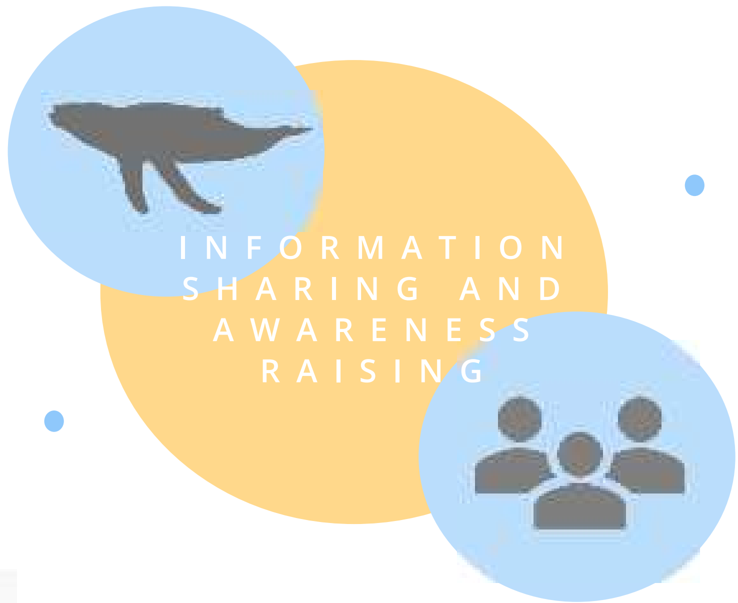
Increased number and wider geographical range of Arabian Sea Humpback Whale genetic samples, photos suitable for individual identification, and distribution data. At least two new trained local scientists.

Improved data on whale distribution, habitat use, population identity and connectivity between regions, and increased number of qualified cetacean researchers in the region

expected outcome

indicators

ARABIAN SEA HUMPBACK WHALE CONCERTED ACTION: PRIORITY ACTIVITIES AND OUTCOMES



Increased awareness of Arabian Sea Humpback Whale conservation needs among stakeholders

An improved **website** that provides a portal to the shared database, informs the general public of whale conservation needs, and provides members with a range of **outreach tools** to engage governments and other stakeholders in their region and involve them in whale conservation efforts

Number of visits to website, increased participation of stakeholders in mitigation and management plans

Improved understanding of Arabian Sea Humpback Whale distribution and connectivity between study areas

The development of a **regional shared online data platform** to promote standardization, comparability and timely analyses of data collected throughout the region. This will be used to facilitate the creation of sensitivity maps and assist stakeholders in the design of local, national and regional conservation strategies, including protected areas

Regional maps of Arabian Sea Humpback Whale sightings and strandings with improved and integrated input from Arabian Sea Humpback Whale Range States

Within the proposal for Concerted Action, it is highlighted that the Sultanate of Oman (although not a Contracting Party of CMS) "provides one example of the process through which government participation and support can be achieved through collaboration over time" with a multi-pronged approach from all sectors resulting in "impressive progress toward understanding Arabian Sea Humpback Whale distribution and conservation needs and increasing government support for conservation and mitigation of threats".

Further details of the Arabian Sea Humpback Whale Concerted Action can be found below:

https://www.cms.int/en/document/proposal-concerted-action-arabian-sea-humpback-whale-megaptera-novaeangliae

https://www.cms.int/sites/default/files/document/cms_cop13_doc.28.1.4_ca-report-arabian-humpback-whales_e_0.pdf

CMS

expected outcome

indicators

CITES

4

THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES) is a multilateral treaty that aims to ensure that the survival of wild animals and plants is not threatened by their trade. The Convention was drafted as a result of a resolution adopted at an IUCN members meeting in 1963 and came into force on 1 July 1975. CITES is legally binding for member Parties (States agreeing to be bound by the Convention), but it does not take the place of national laws; it provides a framework for each party to adopt domestic legislation to ensure that CITES is implemented at a national level.

The trade of species covered by CITES is subject to certain controls; all import, export, re-export and introduction from the sea of target species has to be authorized through a licensing system. Species listed in Appendix I include those threatened with extinction, trade of which is permitted only in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction, but those for which trade must be controlled to avoid threatening their survival. Species included in Appendix II are those which are protected in at least one country that has asked other CITES Parties for assistance in controlling their trade.
https://www.cites.org/eng

These conditions cover the transportation of specimens, including live capture or even biological samples, where the State of introduction is the same as the State of the registered vessel if the specimen has been taken from the high seas. Under other circumstances (relating to the State of export and State of import, area of capture etc.), general Appendix I and Appendix II species regulations apply.

Oman is an official signatory of CITES, with all species of marine mammals in Oman listed under Appendix II, apart from the Sperm Whale (*Physeter macrocephalus*), Blue Whale (*Balaenoptera musculus*), Humpback Whale (*Megaptera novaeangliae*) and Bryde's Whale (*Balaenoptera edeni*) which are listed under Appendix I.

https://www.cites.org/eng/app/appendices.php

THE INTRODUCTION FROM THE SEA OF ANY **APPENDIX I** SPECIES REQUIRES A CERTIFICATE, GRANTED ONLY WHEN THE FOLLOWING CONDITIONS ARE MET

- A Management Authority of the State of introduction is satisfied that the proposed recipient of a living specimen is suitably equipped to house and care for it
- A Scientific Authority of the State of introduction advises that the introduction will not be detrimental to the survival of the species involved
- A Management Authority of the State of introduction is satisfied that the specimen is not to be used for primarily commercial purposes

THE FOLLOWING CONDITIONS MUST BE MET FOR THE PROVISION OF A CERTIFICATE FOR **APPENDIX II** SPECIES

- A Scientific Authority of the State of introduction advises that the introduction will not be detrimental to the survival of the species involved
- A Management Authority of the State of introduction is satisfied that any living specimen will be so handled as to minimize the risk of injury, damage to health or cruel treatment

5

IMO

THE INTERNATIONAL MARITIME ORGANISATION (IMO) is the UN specialised agency concerned with the safety and security of shipping, and the prevention of marine and atmospheric pollution by ships. The main role of the IMO is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented. This includes developing vessel operation conventions, protocols, codes and recommendations for addressing safety, environmental protection, legal matters, technical cooperation and efficiency of shipping.

Together with government authorities in Oman, the IMO is considered one of the primary stakeholders through which adoption and dissemination of information related to mitigation of ship/whale interactions should be pursued. The IMO consists of an Assembly, a Council and five main committees, one of which is the Marine Environment Protection Committee (MEPC). The MEPC addresses environmental issues under IMO's remit, including the control and prevention of ship-source pollution, ballast water management, anti-fouling systems, ship recycling, pollution preparedness and response, and identification of special areas and particularly sensitive sea areas.

One of the key treaties adopted by the IMO to prevent and minimise pollution from shipping is the International Convention for the Prevention of Pollution from Ships (MARPOL), whilst work is also being carried out on other topics such as protecting marine biodiversity, mitigating underwater noise and protecting marine mammals against ship strikes. To this effect, the IMO published a guidance document in 2009 [15] for minimizing the risk of ship strikes on cetaceans. The document set forth important general principles to be taken into account, as well as possible risk-reduction actions to be taken. The possible actions are generally divided into those which might be taken at a national level, and those which require coordination with other States at an international level. More information on IMO activities in relation to addressing ship strikes can be found in Chapter 4.

INTERNATIONAL MARITIME ORGANIZATION

http://www.imo.org/

PARTICULARLY SENSITIVE SEA AREAS AND SPECIAL AREAS

ONE OF IMOs MARINE ENVIRONMENT MANAGEMENT MECHANISMS is the identification and designation of Particularly Sensitive Sea Areas (PSSAs), defined as areas requiring special protection through IMO action due to recognized ecological, socio-economic or scientific features which may otherwise be vulnerable to damage by international maritime activities. When an area is approved as a PSSA, specific measures can be implemented to help control and manage maritime activities in that area, such as vessel routeing measures, strict application of MARPOL discharge and equipment requirements and the installation of Vessel Traffic Services (VTS). To date, 14 PSSAs have been approved, although none are located in Omani waters.

Special Areas are designated under the MARPOL convention for technical reasons relating to oceanographic and ecological conditions, as well as sea traffic and provide for special mandatory measures for the prevention of sea pollution such as oil, noxious liquids, sewage and garbage from ships. The whole coastline of Oman is identified as a Special Area (SA) under MARPOL Annex I: Prevention of pollution by oil, which was adopted in October 2004 and came into force in January 2007 [16]. The coastline north of Ras Al Hadd is designated as an SA under Annex V: Prevention of pollution by garbage from ships as part of the "Gulfs" area. A PSSA may be identified within an SA and vice versa.

INTERNATIONAL MARITIME ORGANIZATION

http://www.imo.org/

FAO

6

THE FOOD AND AGRICULTURE ORGANIZATION (FAO) is a specialized agency of the UN leading on international efforts to defeat hunger.

FISHERIES

ECONOMIC

CONSUMER PROTECTION

FAO IS COMPOSED OF 6 DEPARTMENTS

AQUACULTURE

AGRICULTURE

SOCIAL DEVELOPMENT

Within its framework the Fisheries and Aquaculture Department is framed under the Deputy Director General for Climate and Natural Resources. Oman is a member state under the Deputy Director for General Operations and has enjoyed country representation since 2012 [17]. FAO's assistance to Oman is shaped by a Country Programming Framework which works to improve economic competitiveness of fisheries and agriculture, including enhancing sustainable management and consideration of resources with respect to climate change (see http://www.fao.org/3/az576en/AZ576EN.pdf).

All international dialogue relating to cetaceans is directed through the International Whaling Commission. However, the FAO are directly engaged with the IWC on issues relating to marine mammals through the FAO Committee for Fisheries (see http://www.fao.org/3/ca5184en/CA5184EN.pdf).

The FAO has also convened and hosted meetings on marine mammal bycatch, with the most recent being the 'Expert workshop on means and methods for reducing marine mammal mortality in fishing and aquaculture operations', held in 2018 (see http://www.fao.org/3/I9993EN/i9993en.pdf).

http://www.fao.org/home/en/

The FAO addresses taxa-specific issues related to fisheries bycatch through the 'International Plans of Action' mechanism. Currently this addresses seabirds and sharks, although in the 2018 expert workshop, the inclusion of marine mammals was also discussed.

Bycatch and fisheries interactions are covered under two FAO notices as described below:

1) INTERNATIONAL GUIDELINES FOR BYCATCH MANAGEMENT AND REDUCTION OF DISCARDS

These guidelines were produced to direct fisheries management data collection and regulatory frameworks that help to ensure conservation of target and non-target species. The guidelines are voluntary and intended to support States and Regional Fisheries Management Organisations (RFMOs) in preparing and implementing measures for bycatch management and reduction of discards.

(see http://www.fao.org/3/a-ba0022t.pdf)

2) CODE OF CONDUCT ON RESPONSIBLE FISHERIES (1995)

This is a voluntary instrument related to the United Nations Convention on the Law of the Sea (1982) and related binding legal instruments among FAO parties including the International Conservation and Management Measures by Fishing Vessels on the High Seas, (1993). **The objectives of this instrument relevant to marine mammal resource management include:**

"promote protection of living aquatic resources and their environments and coastal areas"

"promote research on fisheries as well as on associated ecosystems and relevant environmental factors"

"provide standards of conduct for all persons involved in the fisheries sector"

In relation to the fisheries research guidance the code states:

"States should collect reliable and accurate data which are required to assess the status of fisheries and ecosystems, including data on bycatch, discards and waste. Where appropriate, this data should be provided, at an appropriate time and level of aggregation, to relevant States and subregional, regional and global fisheries organizations".

(see http://www.fao.org/3/v9878e/V9878E.pdf)

FAO REGIONAL FRAMEWORKS

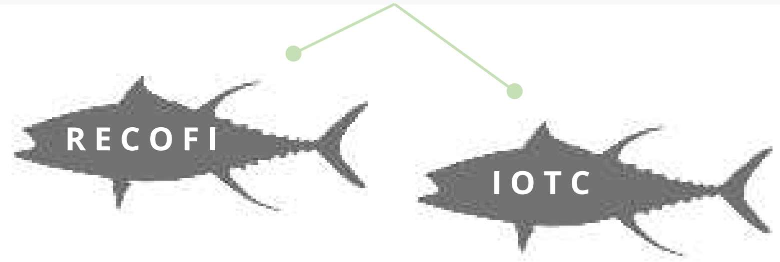
A NUMBER OF FRAMEWORKS EXISTS FOR GUIDING THE MANAGEMENT OF ACTIVITIES IN REGIONAL AREAS.

REGIONAL FISHERIES MANAGEMENT ORGANISATIONS

In many parts of the world, the high seas are covered by Regional Fisheries Management Organisations (RFMOs). However, there is no RFMO covering high seas areas in the Northern Indian Ocean.

REGIONAL FISHERIES BODIES

Regional fisheries bodies promote international cooperation for long-term sustainable fisheries and include two key organisations relevant to Oman:



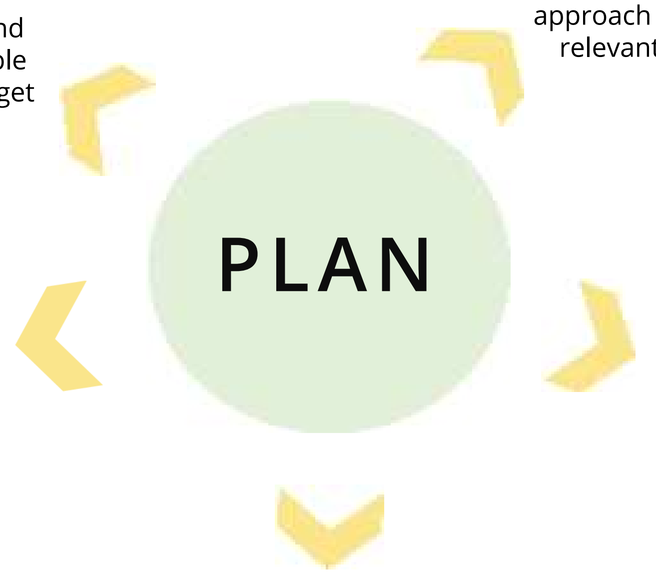
[FAO regional frameworks]

http://www.fao.org/home/en/

RECOFI

THE REGIONAL COMMISSION FOR FISHERIES (RECOFI) includes Bahrain, Iraq, Iran (Islamic Rep. of), Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates as member states and has an area of competence that covers all marine living resources. RECOFI has in place a Regional Action Plan for Managing the Environmental Impacts of Fishing (see http://www.fao.org/3/i3260e/i3260e.pdf).

Plan objectives include [18]:



- Prioritization of responsible fishing through embedding the ecosystem approach to fisheries (EAF) in relevant national policies
- Adoption of a comprehensive approach to recognize the differing environmental, economic and social conditions of the various fisheries within the region
- Raising awareness, training and incentivizing stakeholders about sustainable fishing.
- Provision of a rational approach to fleets for reducing bycatch, discards and lost gear
- Minimization of the impact of trawling on sensitive habitats and reduction of impact on vulnerable species, both target and non-target

Information contained within this atlas could help to address components of this plan.

http://www.fao.org/home/en/

IOTC

THE INDIAN OCEAN TUNA COMMISSION (IOTC) formed under FAO council and came into operation in 1996. It is an intergovernmental organization coordinating regulation and management of stocks of tuna and tuna-like species in the Indian Ocean (see https://iotc.org/).

Membership of the IOTC is open to all Indian Ocean coastal countries and to those countries or regional organisations fishing for tuna in the Indian Ocean that are members of the UN or one of its specialised agencies. It has an area of competence that includes territorial waters, the EEZs of most member states surrounding the Indian Ocean and the high seas. There are currently 31 Contracting Parties (Members), including Oman, who were accepted as members in April 2000.

The Commission has four key functions and responsibilities enabling it to achieve its objectives, drawn from the United Nations Convention on the Law of the Sea (UNCLOS):

1. To keep under review the conditions and trends of the stocks, and to gather, analyse and disseminate scientific information, catch and effort statistics and other data relevant to the conservation and management of the stocks and to fisheries based on the stocks.

2. To encourage, recommend, and coordinate research and development activities in respect of the stocks and fisheries covered by the IOTC, and such other activities as the Commission may decide appropriate, such as transfer of technology, training and enhancement, having due regard to the need to ensure the equitable participation of Members of the Commission in the fisheries and the special interests and needs of Members in the region that are developing countries.

3. To adopt – on the basis of scientific evidence – Conservation and Management Measures (CMM) to ensure the conservation of the stocks covered by the Agreement and to promote the objective of their optimum utilisation throughout the Area.

4. To keep under review the economic and social aspects of the fisheries based on the stocks covered by the Agreement bearing in mind, in particular, the interests of developing coastal States.

iotc ctoi

FAO FIAT PANIS

http://www.fao.org/home/en/

IOTC

THE SCIENTIFIC COMMITTEE (SC) OF THE IOTC MEETS ANNUALLY, providing advice to the Commission on the status of stocks and the management actions necessary to ensure sustainability of the fishery. Working parties operate through the IOTC SC with their primary function to analyse technical problems relating to the specific management goals of the IOTC. The IOTC SC also includes a working party on Ecosystems and Bycatch. This working party reviews and analyses matters relating to non-target species and although not yet included as a focal taxon, future collaboration with the IWC Bycatch Management Initiative is expected to better help the understanding of cetacean bycatch in the Western Indian Ocean https://iotc.org/documents/WPEB/15/RE.

The commission works to adopt Conservation Management Measures with resolutions being binding and recommendations non-binding (relying on voluntary input). A compendium of these measures can be found via the following link: https://iotc.org/cmms.

RESOLUTION 13/04 | ON THE CONSERVATION OF CETACEANS

refers to the requirement for reporting of cetacean bycatch related to purse seine or other methods for fishing of tuna or tuna-like species.

Workshops have been held and resources made available to assist member states in the identification of marine mammals. Further information is available at:

https://www.iotc.org/news/cetacean-identification-guide-indian-ocean

RESOLUTION 15/02 | MANDATORY STATISTICAL REPORTING REQUIREMENTS

for IOTC contracting parties and cooperating non-contracting parties - a management need for the collection and reporting of catch and effort data from surface, longline and coastal fisheries. This also refers to the requirements of other resolutions that cover bycatch (including resolution 13/04).

RESOLUTION 17/07 | ON THE PROHIBITION OF LARGE SCALE DRIFTNETS IN THE IOTC AREA

recognises that there are a large number of vessels operating in the area with nets in excess of 4km, both within EEZs and in the high seas, which have negative ecological impacts on marine mammals (as well as turtles and other marine wildlife). The binding resolution states that nets in excess of 2.5km will be prohibited from the IOTC area of competence from 1st January 2021.

iotc ctoi

FAO FIAT PANIS

http://www.fao.org/home/en/

ASWN

7

ESTABLISHED AT A WORKSHOP IN DUBAI IN JANUARY 2015, THE ARABIAN SEA WHALE NETWORK (ASWN) is an informal group of researchers and stakeholders concerned with the conservation of the genetically distinct Arabian Sea Humpback Whale population and other cetaceans in the Arabian Sea. While members of this group collaborate on a regional level with academics and independent scientists, the issues addressed have also received support from an international audience, including the Environment Society of Oman, Plan4theland (Iran based), World Wildlife Fund (WWF), International Union for Conservation of Nature (IUCN), Wildlife Conservation Society (WCS), and the International Whaling Commission (IWC). Since its formation, ASWN has led various initiatives including (1) the drafting of a Convention on Migratory Species (CMS) Concerted Action plan for Arabian Sea Humpback Whales which was presented in the 2017 CMS Convention of parties in the Philippines, (2) development of web-based data sharing platform for data collected on cetaceans in the region, and including a function to help analyse Arabian Sea Humpback Whale distribution and identify individual whales, (3) identifying Important Marine Mammal Areas (IMMA) for the Western Indian Ocean and Arabian Seas as part of an IMMA workshop held in Salalah, Oman in 2018, (4) gathering genetic, acoustic and satellite tagging information on Arabian Sea Humpback Whales, and (5) raising awareness about regional cetaceans through community outreach and education programs, including development of an Arabian Sea Humpback Whale infographic distributed throughout the region. More information on current ASWN initiatives, updates, and available resources can be found at https://arabianseawhalenetwork.org/posts/.

Figure 5) Delegates of the inaugural meeting of the Arabian Sea Whale Network, Dubai, 2015, representing a range of regional and international organisations.

ARABIAN SEA WHALE NETWORK

https://arabianseawhalenetwork.org/

ARABIAN SEA WHALE NETWORK

https://arabianseawhalenetwork.org/

REGIONAL SCIENTIFIC CONSERVATION FORUMS AND INSTITUTIONS

OMAN NATURAL HISTORY MUSEUM

The Natural History Museum of Oman first opened its doors to the public on 30 December 1985, and soon afterwards in 1989, the Whale Hall in the Museum was opened, displaying the 14m skeleton of a male sperm whale which died in Barka in 1986.

From top) Skull of Killer Whale (*Orcinus orca),* Archival Cetacean collection

ONE OF THE MOST IMPORTANT COLLECTIONS at the Oman Natural History Museum is the National Collection of Animals and Skeletons which contains the cetacean collection. The cetacean collection includes 420 dry specimens of skeletons and skulls of whales and dolphins documented in an Access database. In addition, the Oman Natural History Museum has five scientific collections (National herbarium, National Collection of Seashell, National Collection of Insects and National Collection of Fossils) for preservation, archiving, and scientific research purposes.

The cetacean collection represents a well- developed scientific reference source of whales and dolphins of the Sultanate of Oman which has proven to be of value, including as follows:

1. It has allowed many scientists and researchers to conduct studies on whales and dolphins, using the materials at the ONHM for detailed scientific analyses.
2. The Museum contributes to the Scientific Committee of the Marine Genetic Resources for Oman Animal & Plant Genetic Resources Center and also contributes to the scientific committee to study the cause of death of marine mammals (and sea turtles) in Oman under supervision of the Environment Authority.
3. Collaboration with educational institutions to incorporate in their academic curriculum the opportunity for student appreciation of their environmental surroundings by providing specimens from the collection for display and study.

Whale hall

SCIENTIFIC RESEARCH ON CETACEANS:

THE CETACEAN COLLECTION also has attracted many scientists and researchers to conduct studies on whales and dolphins of Oman over the years, such as:

FEB 2020 — Mr. Matthew Burmati, University of Sheffield, UK, under the supervision of Dr. Elena Maini of the Ministry's Italian Archaeology Mission, conducted a study to compare cetacean remains found during archeological studies with extant species from Omani waters.

MAY 1996 — Dr. Koen Van Waerebeek, the Director of the Peruvian Centre for Cetacean Research (CEPEC) in Latin America, and Dr. Vassili Papastavrou of The University of Bristol, UK, and a representative from the International Whaling Commission visited the museum to conduct morphological studies of the common dolphin skulls as part of a global review of the taxonomy of the species.

MARCH 1990 — Dr. Van, a mammologist at the Dutch University of Amsterdam used the collection to study toothed whales' skeletons.

The collection has also been used to publish and update the Museum's 'Whales and Dolphins Guide'. The purpose of this guide is to help identify whales and dolphins found in Omani waters (including all 20 species of whales and dolphin known from Oman).

Visitors can also identify many other whale and dolphin species from displays in the Whale Hall, which provides an interesting explanation of the lives of many species and breeding. Some displays are interactive enabling visitors to identify the sounds of some species.

متحف التاريخ الطبيعي
وزارة التراث والثقافة
NATURAL HISTORY MUSEUM

ENVIRONMENT SOCIETY OF OMAN

THE ENVIRONMENT SOCIETY OF OMAN (ESO) is a non-profit organisation founded by a representative group of Omanis in March 2004, to help protect and conserve Oman's natural heritage by implementing collaborative, sustainable initiatives. One of the many ongoing projects includes the Renaissance Whale & Dolphin Project, which was established in March 2011 with the aim to further the understanding of the distribution and ecology of Oman's whales and dolphins. With a focus on the Endangered Arabian Sea Humpback Whales, the project has been successful in producing guidelines for whale and dolphin watching in Oman, conducting detailed field research on Arabian Sea Humpback Whales, including photo-identification studies, genetic research, satellite tagging (nine individuals) and deployment of passive acoustic monitoring devices to record, analyse, and detect whale song. As a result, a better understanding of whale behaviour, movement patterns and critical habitats has been gained. This information is made available to help develop new policy guidelines and to continue to reveal important ways for maximizing conservation efforts for Oman's whales and dolphins. The continued partnership with local and international stakeholders emphasizes the value of collective action and stewardship for Oman's whales and dolphins.



Figure 6) (L-R) Municipal beach clean-up organised on Masirah Island, Fishermen awareness campaign on marine wildlife entanglement in fishing nets, Members of ESO and 5OES working together in Hasik for acoustic deployment and whale & dolphin surveying.

STAFF OF FIVE OCEANS ENVIRONMENTAL SERVICES LLC (5OES) have been central to the collection of marine mammal data in Oman since the early 1990's. Strandings and incidental sightings records were initially recorded in a database established as part of IUCN's Coastal Zone Management Programme in Oman which 5OES staff further developed in collaboration with other organisations, including the Oman Natural History Museum. With a revival of dedicated research in 1999, the budding 5OES team consolidated the database as the Oman Cetacean Database (OMCD) and developed standardized survey and recording protocols for all cetacean strandings and sightings. 5OES has worked in collaboration with ESO since its inception and has led all scientific field research and subsequent analyses of data.

- Above) Collecting coral recruitment tiles in collaboration with NYUAD

  Top Left) Collecting water quality samples using a Niskin water sampler

  Top Right) Pantropical Spotted Dolphins (*Stenella attenuate)* spotted during a MMO survey

  Bottom Left) Conducting underwater transects at a coral survey site

  Bottom Right) A team on board a cetacean survey vessel off Dhofar, with purpose-designed platform at the bow for tagging whales

- Top) Walking back towards field camp after a day at sea, searching for cetaceans

  Bottom) Arabian Sea Humpback Whale (*Megaptera novaeangliae)* breeching during a field survey

5OES also works in association with local government agencies and external scientists to provide additional support in specialised areas of scientific research. Key staff are members of the IUCN Species Survival Commission Cetacean Specialist Group and regularly attend IWC Scientific Committee meetings to present and discuss research results. As a principle-led company with a regional outlook, 5OES is actively engaged in marine mammal and other research and consultancy projects throughout much of the Arabian Peninsula. The organisation occupies a unique space in which it interfaces with commercial clients as well as academic institutions, government agencies and NGO's to share and apply knowledge related to policy, conservation management, environmental impact assessments, scientific research and monitoring.

Five Oceans
Environmental Services LLC

FIVE OCEANS ENVIRONMENTAL SERVICES

ENVIRONMENT AUTHORITY

THE ENVIRONMENT AUTHORITY (EA) IS ONE OF THE MAIN GOVERNMENT AGENCIES IN OMAN responsible for regulating development to ensure compliance with environmental legislation, developing environment protection plans, preserving Oman's natural resources and spreading environmental awareness. The EA also plays an important role in scientific research, and has established the Oman National Stranding Committee (ONSC) responsible for coordinating responses to the stranding and entanglement of marine mammals and collection of associated data. The EA is also involved in the production of environmental law and legislation, including that which aims to protect marine mammals from harmful fishing practices and overexploitation, including enforcing strict penalties for violators. In addition, the EA has been collaborating with other government sectors and universities, including the Ministry of Agriculture and Fisheries Wealth and Water Resources, Ministry of Heritage and Tourism, Ministry of Transport, Communications and Information Technology and Sultan Qaboos University, in the development of marine conservation planning. EA continues to be involved in marine mammal research and is responsible for reviewing and providing permits for research activities as well as monitoring results that may be used to help progress of the country's marine conservation agenda.

سلطنة عمان
SULTANATE OF OMAN
هيئة البيئة
ENVIRONMENT AUTHORITY

MINISTRY OF AGRICULTURE, FISHERIES AND WATER RESOURCES

A message from Saud Bin Hamood Bin Ahmed Al-Habsi

THE SULTANATE OF OMAN is characterized by a strategic geographical location in the Arabian Peninsula. It overlooks three bodies of water in the Indian Ocean; the Arabian Gulf, the Sea of Oman, and the Arabian Sea. The Sultanate's location is considered as one of the main reasons for the country's unique biological diversity, including its marine biodiversity. As this Atlas portrays, off the 3,165 kms of Omani coastline, live about 20 different species of marine mammals, including whales, and dolphins of all sizes. However, recent information has revealed that some of them are at risk of extinction. The list of dangers facing these marine creatures that cause their numbers to decrease include the remnants of fishing nets and equipment, noise pollution, collision with boats and ships and the loss of the natural environment due to the continuous human development activities.

The Ministry of Agricultural, Fisheries and Water Resources seeks to conserve these important creatures by enacting laws and legislation that work to minimize the dangers they face. Among the most prominent of these are the Living Aquatic Resources Law and its regulatory provisions issued by Royal Decree No. (20/2019), some of which stipulate the need to protect marine mammals and prohibit any means of fishing or activities that may negatively affect marine organisms or pollute the environment. The Ministry is also working in cooperation with other authorities such as the Environment Agency and the Environment Society of Oman, including a number of projects with a focus on marine mammal species and related biological data, in addition to awareness programs aimed at furthering conservation.

This Atlas is a culmination of efforts implemented by the concerned authorities and researchers in order to improve awareness and knowledge of marine mammals present in Omani waters, including information on their distribution, abundance, threats and impacts, and other topics, as well as presenting a general framework for conservation.

We hope that this Atlas contains useful information on marine mammals that can serve to help develop future plans for the preservation of these marine creatures, and we acknowledge all the efforts made to produce this valuable Atlas on Oman's marine mammals.

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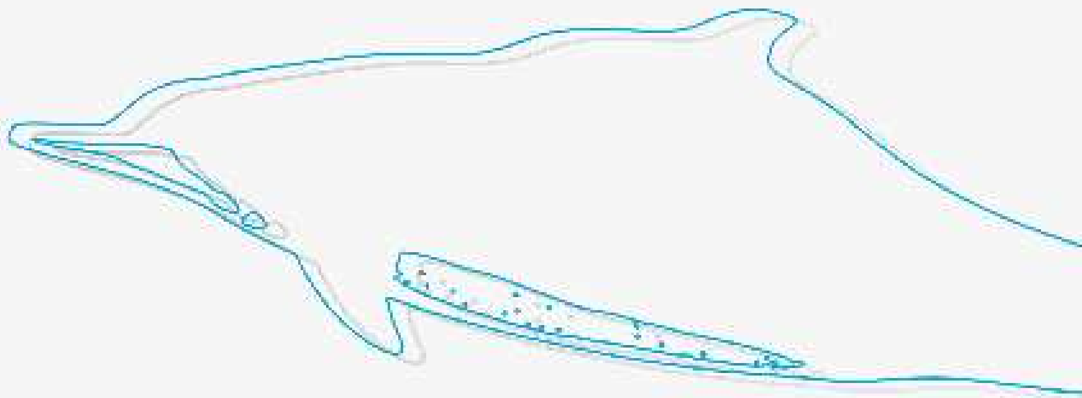

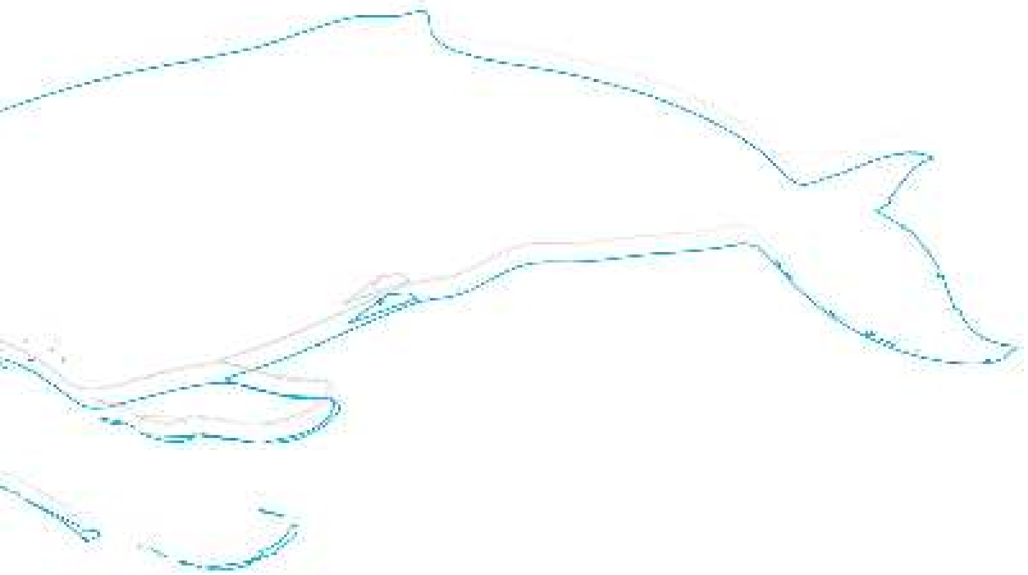

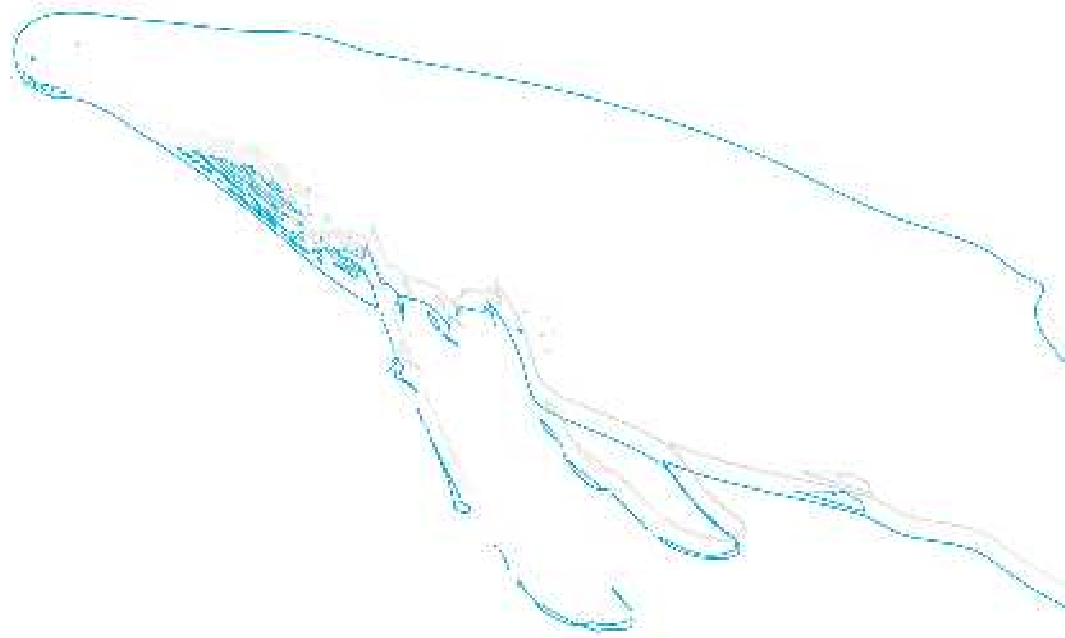

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