

Mapping cetacean distribution using citizen science in the Western Cape, South Africa

by

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“The sea, once it casts its spell, holds one in its net of wonder forever”

- Jacques Cousteau



Dusky dolphin, 2016, Tevya Lotriet



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SUMMARY

The Western Cape is a unique area to undertake research, due to the varying oceanographic conditions along the coast. These diverse environments create a hotspot for cetacean presence and diversity. This study aimed to collate and map distribution information of local whale and dolphin species in the Western Cape using citizen science. The first data chapter focused on obtaining opportunistic sightings from water users from scientific, platform of opportunity and sporadic sighting platforms including social media. The second data chapter focussed on obtaining local knowledge on cetacean species by interviewing experienced water users such as fisherman, divers and conservationists on local cetacean presence. Both of these methods were aimed at trying to answer the same question which is to understand where the species range boundaries are and what the potential drivers are. Results between the two chapters yielded congruent information which validated the use of citizen science in this context. Most of the results obtained supported existing knowledge of the species' distribution range in South Africa. Results identified a seasonal pattern whereby common dolphin presence peaked during autumn in False Bay and is probably linked to bait fish availability. False Bay was highlighted as an important habitat area for dolphins and whales, but most notably for common dolphins and Bryde's whales. Possible range shifts of humpback dolphins and bottlenose dolphins are also suggested. It is important to monitor these local cetacean populations and any current or potential anthropogenic threats. The abundance and distribution of prey species was also suggested as an important factor for cetacean distribution. The limited knowledge and research of cetaceans in South Africa clearly highlights the need for the on-going collection of opportunistic sightings data. Future research could focus on comparing cetacean distribution data to accurate environmental data to identify any potential patterns as well as investigate distribution patterns in data scarce areas.



DECLARATION

I declare that the dissertation/thesis, which I hereby submit for the degree Master of Science in Zoology at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

ETHICS STATEMENT

The author, whose name appears on the title page of this dissertation/thesis, has obtained, for the research described in this work, the applicable research ethics approval.

The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for Researchers and the Policy guidelines for responsible research

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RESEARCH OUTPUTS

Conference presentations

Oral presentations

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Print media

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National Sea Rescue Institute Magazine, winter issue 2016

Oceana Power Boat Club newsletter, October 2016

Hout Bay Sentinel Newspaper, June 2017

Television

SABC 2 Hectic 9 TV programme appearance, August 2016



LIST OF FIGURES

Chapter 1:

Figure 1.1: Monthly satellite SST climatology from 2000 to 2010 for the south western Cape, South Africa.....	15
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Chapter 2:

Figure 2.1: Map of the study area in the Western Cape, South Africa.....	63
--	----

Figure 2.2: Map of Shark Spotter locations in the Western Cape, South Africa.....	64
---	----

Figure 2.3: The distribution of Heaviside's dolphin <i>Cephalorhynchus heavisidii</i> sightings collated from different sources in the Western Cape, South Africa.....	65
--	----

Figure 2.4: The total number of dolphin sightings during each month in different regions in the Western Cape, South Africa.....	66
---	----

Figure 2.5: The total number of dolphin sightings during each month in different regions within the south western Cape, South Africa.....	67
---	----

Figure 2.6: The distribution of dusky dolphin <i>Lagenorhynchus obscurus</i> sightings collated from different sources in the Western Cape, South Africa.....	68
---	----

Figure 2.7: The distribution of humpback dolphin <i>Sousa plumbea</i> sightings collated from different sources in the Western Cape, South Africa.....	69
--	----

Figure 2.8: The distribution of bottlenose dolphin <i>Tursiops aduncus</i> sightings collated from different sources in the Western Cape, South Africa.....	70
---	----

Figure 2.9: The distribution of common dolphin <i>Delphinus delphis</i> sightings collated from different sources in the Western Cape, South Africa.....	71
--	----

Figure 2.10: The distribution of killer whale *Orcinus orca* sightings collated from different sources in the Western Cape, South Africa.....72

Figure 2.11: The distribution of southern right whale *Eubalaena australis* sightings collated from different sources in the Western Cape, South Africa.....73

Figure 2.12: The total number of whale sightings during each month by different regions in the Western Cape, South Africa.....74

Figure 2.13: The total number of whale sightings during each month in different regions within the south western Cape, South Africa.....75

Figure 2.14: The distribution of Bryde's whale *Balaenoptera brydei* sightings collated from different sources in the Western Cape, South Africa.....76

Figure 2.15: The distribution of humpback whale *Megaptera novaeangliae* sightings collated from different sources in the Western Cape, South Africa.....77

Chapter 3:

Figure 3.1: Map of the study area where interviews were conducted in the Western Cape, South Africa..... 114

Figure 3.2: The geographic distribution of cumulative effort hours at sea for 55 interviewees in the Western Cape, South Africa..... 115

Figure 3.3: The geographic distribution of the cumulative number of observers as a measure of effort coverage in the Western Cape, South Africa.....116

Figure 3.4: The reported occurrence of Heaviside's dolphins *Cephalorhynchus heavisidii* in the Western Cape, South Africa.....116

Figure 3.5: Sighting probabilities of dolphin species reported by interviewees.....117

Figure 3.6: The reported occurrence of dusky dolphins *Lagenorhynchus obscurus* in the Western Cape, South Africa..... 118

Figure 3.7: The reported occurrence of humpback dolphins *Sousa plumbea* in the Western Cape, South Africa.....118

Figure 3.8: The reported occurrence of bottlenose dolphins *Tursiops aduncus* the Western Cape, South Africa.....119

Figure 3.9: The reported occurrence of common dolphins *Delphinus delphis* the Western Cape, South Africa.....119

Figure 3.10: The reported occurrence of killer whales *Orcinus orca* the Western Cape, South Africa..... 120

Figure 3.11: The reported occurrence of southern right whales *Eubalaena australis* the Western Cape, South Africa..... 120

Figure 3.12: Sighting probabilities of whale species reported by interviewees..... 121

Figure 3.13: The reported occurrence of Bryde's whales *Balaenoptera brydei* the Western Cape, South Africa.....121

Figure 3.14: The reported occurrence of humpback whales *Megaptera novaeangliae* the Western Cape, South Africa..... 122



LIST OF APPENDICES

Appendix 1: Cetacean species identification flyer.....	128
Appendix 2: Cetacean sightings submission flyer.....	129
Appendix 3: NSRI newsletter.....	130
Appendix 4: Hout Bay Sentinel Newspaper article.....	131
Appendix 5: Interview consent form.....	132
Appendix 6: Interview questionnaire	133
Appendix 7: Interview maps.....	135



TABLE OF CONTENTS

Summary	i
Declaration	ii
Acknowledgements	iii
Research outputs	v
List of figures	vi
List of appendices	ix
Chapter 1: Introduction	1
1.1 General introduction	1
1.2 Aims and objectives	7
1.3 References	8
1.4 Figures	15
Chapter 2: Spatial and temporal patterns of cetaceans using opportunistic data in the Western Cape, South Africa.	16
2.1 Abstract	16
2.2 Introduction	17
2.3 Methods	22
2.3.1 Study area	22
2.3.2 Data collection	22
2.3.3 Data analyses	31
2.4 Results	32
2.5 Discussion	40
2.6 References	52



2.7 Figures	63
Chapter 3: Spatio-temporal patterns of cetaceans using Local Ecological Knowledge in the Western Cape, South Africa.....	78
3.1 Abstract.....	78
3.2 Introduction.....	79
3.3 Methods.....	82
3.3.1 Study area.....	82
3.3.2 Ethical considerations	82
3.3.3 Interview procedure	82
3.3.4 Interview data processing.....	84
3.3.5 Data analyses	85
3.4 Results.....	86
3.5 Discussion.....	94
3.6 LEK method review	103
3.6.1 Limitations and concerns	103
3.6.2 Advantages.....	104
3.6.3 Recommendations.....	105
3.7 References.....	106
3.8 Figure	114
Chapter 4: Conclusion.....	123
4.1 Overall conclusion	123
4.2 References.....	127
5. Appendices.....	128

Chapter 1: Introduction

1.1 General introduction

Global biodiversity is under increasing pressure due to environmental change and anthropogenic stressors both in marine and terrestrial environments (Wernberg et al. 2011; Voerman et al. 2013; Wernberg et al. 2013; Blamey et al. 2015). There is convincing evidence on the effect of climate change on marine systems (Hoegh-Guldberg and Bruno 2010; Poloczanska et al. 2013; Blamey et al. 2015) with fishing and human-induced climate change acting as the primary influencing factors. The impacts of global climate change are likely to have significant ecological impacts affecting species distribution, abundance, prey availability, migration, competition and extinction (Perry et al. 2005; Klausmeyer and Shaw 2009; Thomas 2010; Lloyd et al. 2012). Temperatures are rising worldwide, mainly due to an increase in CO₂ emissions (Peters et al. 2013; IPCC 2014). This subsequent increase has caused an alteration to all functional units of the Earth, especially the oceans (Barnett et al. 2005; Harley et al. 2006). A global redistribution of species is occurring as a result of climate change, with species tracking environmental warming, most often by moving towards the poles (Chen et al. 2011; Sunday et al. 2012). The increasing rise in temperature will lead to greater re-shuffling of species assemblages, and greater challenges for sustainable natural resource management (Williams et al. 2008; Doney et al. 2011; Hobday and Pecl 2014).

Species distribution information forms the basis of understanding biodiversity and planning for future conservation (Lamoureux et al. 2006). Effective conservation of wild populations requires an understanding of the relationship between populations and their habitats and one of the first steps towards this is to determine which habitats are used most frequently (Cañadas et al. 2005; Kaschner et al. 2011). Understanding where important habitat areas are can be used to determine the environmental and biological conditions a species prefers and essentially aid in maintaining a favourable conservation status (Cañadas et al. 2005).

Furthermore, predictable habitat areas and times of concentration can be used to focus conservation measures in relation to human activities such as by-catch reduction, shipping and tourism (Evans and Hammond 2004). It could also highlight times and areas that are important for calving and mating (Evans and Hammond 2004). There is an increasing need for species distribution information for research and conservation planning.

Detailed geographic information is required to understand spatial and temporal distributions of species. Advances in geographic information systems (GIS) and computer software have enabled researchers to efficiently map and model species distribution. Mapping and modelling species distribution is increasingly important for several decision making and management purposes such as biodiversity management, species protection, species re-introduction, alien species control, prediction of possible climate change impacts; all of which contributes to sustainable natural resource management (Aspinall et al. 1998).

Increasing evidence suggests that changing environmental conditions is affecting distributions of many taxa, including cetaceans (Lambert et al. 2014). The importance of monitoring cetacean distributions is critical for their survival, especially since at least one quarter of cetacean species in the world have been classified as endangered, and this figure may worsen as the status of many more remains unknown (IUCN 2008). Cetaceans are apex predators in the ocean and changes in their distribution are likely to cause cascading impacts on other trophic levels, potentially causing an imbalance in the ecosystem. The impacts of shifting distributions are of particular importance for the management and conservation of cetaceans (Simmonds and Isaac 2007; Macleod 2009; Lambert et al. 2011). A study by Macleod (2009) showed that 88% of cetaceans may experience range shifts as a result of changing temperatures. Furthermore, 47% of these species would experience a negative impact on their conservation due to the changes, and for 21% there is a risk of extinction if the species is geographically isolated (Macleod 2009). Cetacean communities with ranges

that are restricted to certain areas such as those defined by upwelling or downwelling may be at a higher risk than those in other regions. If climate change destroys their habitat they have no corridors to move to colder waters, as opposed to oceanic species which would likely shift more poleward (Macleod 2009). Climate change could have implications for South African cetaceans, since a number of species lies within upwelling regions.

The southern African coastline (including South African and Namibian waters), is home to around 36 different cetacean species (Findlay et al. 1992; Best 2007), which is more than occurs in the entire North Pacific (27 species) or North Atlantic (28 species). Much of this diversity is a result of the South African coast straddling two oceans and two major ecosystems. The west coast of South Africa is characterised by the cool northward flowing Benguela Current system in the Atlantic Ocean, which is largely characterised by wind-driven coastal upwelling of cool sub-thermocline water (Shannon 1985; Mucina and Rutherford 2006; Ansorge and Lutjeharms 2007). In the southern Benguela, the south-east trade winds are responsible for the offshore transport of near-surface layers, resulting in a belt of coastal upwelling (Ansorge and Lutjeharms 2007). Upwelling, the process of surface water being moved offshore by wind action and cold nutrient rich water drawn to the surface, plays a crucial role in the oceanography and fisheries of the Benguela region and subsequently the west coast of southern Africa (Blamey et al. 2015). As a result of this cool nutrient rich water, the west coast is known for its high biomass productivity, which supports a diverse range of organisms, from extensive kelp beds to marine mammals such as dusky (*Lagenorhynchus obscurus*) and Heaviside's (*Cephalorhynchus heavisidii*) dolphins. Organisms occurring in this oceanic region are all adapted to inhabit the cool temperate waters of the Atlantic Ocean. In contrast to this, the east coast is characterised by the warm western boundary Agulhas Current in the Indian Ocean, which flows strongly southward from the equatorial region of the western Indian Ocean (van Leeuwen et al. 2000). In contrast, the east coast waters are

generally poor in nutrients and are associated with high marine diversity (Lutjeharms 1998; Schumann 1998; Mucina and Rutherford 2006). Species occurring in these waters are adapted to warm and low nutrient conditions with diversities ranging from tropical fish to marine mammals such as bottlenose (*Tursiops aduncus*) and humpback (*Sousa plumbea*) dolphins. When the Agulhas current passes the southern tip of the African continental shelf, it turns back in a tight loop which is called the Agulhas retroflexion and this configuration has shown to be unstable and at irregular intervals forms independent Agulhas rings that move off into the South Atlantic (van Leeuwen et al. 2000; Ansorge and Lutjeharms 2007). This process results in the occasional intrusion of warm water from the Agulhas breaking off to slowly spin into the South Atlantic carrying heat, salt and organisms characteristic of the Agulhas Current (Olson and Evans 1986). The movement of surface waters from the Indian Ocean to the Atlantic Ocean is an important component of the global circulation of water (Hastenrath 1982; Olson and Evans 1986). On the south coast of South Africa, upwelling occurs along the shelf break and at headlands, which causes a dynamic and intensive mixing region along the broad Agulhas Bank region. The conditions along the south coast are intermediate in terms of temperature and productivity between the Agulhas and Benguela ecosystems (Hutchings et al. 2002). The south coast is an exceptionally important region for pelagic fish spawning, as eggs and larvae are swept westwards and northwards onto the west coast shelf, which the juvenile fish use as a productive nursery area before returning to spawn on the Agulhas Bank (Hutchings et al. 2002). A range of endemic species occurs on both the south and west coasts while many species on the east coast are often extensions from the diverse Indian Ocean assemblages (Hutchings et al. 2002). The strong variability in oceanographic conditions along the South African coastline, in particular the differences in temperature, productivity, and dissolved oxygen create a mosaic of habitats and biogeographic boundaries and are reflected in the diversity of marine fauna and flora

(Cockcroft et al. 1990). The area between the Cape Peninsula and Cape Agulhas (~ 150 km of coast) acts as a transition zone between the warmer Agulhas and cooler Benguela currents with recognised biogeographic transition zones at both Cape Point and Cape Agulhas (Hutchings et al. 2002) (Figure 1.1). The warm shallow waters of False Bay, to the east of Cape Point act as something of a microcosm of this changeover at a smaller scale with significant changes in the species assemblages in the ~100 km around the Cape Peninsula from Table Bay to False Bay (Hutchings et al. 2002; Ansorge and Lutjeharms 2007), including coastal dolphins species presence (Findlay et al. 1992).

There is evidence of distribution shifts of other species in the Western Cape region (Bolton et al. 2012; Blamey et al. 2015). It is important to investigate whether cetacean distributions may have potentially shifted too. While the number of peer-reviewed publications investigating cetacean distributions using citizen science is increasing globally, no studies are available from South Africa (Whitehead et al. 2008; Macleod 2009; Simmonds and Elliott 2009; Elwen et al. 2011), despite the high diversity of species in the region (Best 2007) and the paucity of data on cetacean distribution in the region.

This study generated data on the distribution and timing of cetaceans in the Western Cape region of South Africa since 2000, using a number of sources ranging from existing scientific survey data to opportunistic sightings from ‘citizen scientists’ as well as through collation of “local ecological knowledge” of cetacean distribution from water users. “Citizen science” refers to cases when non-specialists assist scientists by voluntarily contributing to science and research (Cigliano et al. 2015). Citizen science projects can positively impact marine conservation by informing management and policies and strengthen community capacities in addressing environmental issues (Cigliano et al. 2015). The broad study area ranged from Cape Columbine on the west coast to Cape Agulhas on the east coast with a special focus on the area between False Bay and Table Bay. This area presents a unique model ecosystem

wherein four dolphin species all occur at the southernmost extremes of their distributional range. Two of the delphinid species for this study occur on the west coast and are associated with the cooler Benguela ecosystem, namely the dusky dolphin (*Lagenorhynchus obscurus*) and Heaviside's dolphin (*Cephalorhynchus heavisidii*), with their southern range limits given as False Bay and Cape Point respectively (Best 2007). Two other dolphin species are associated with the warmer waters of the Agulhas current and Indo-Pacific region, namely the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and Indian Ocean humpback dolphin (*Sousa plumbea*), the latter being classified as endangered (Plön et al. 2016). The common dolphin (*Delphinus delphis*) occurs predominantly over the continental shelf in the warmer Agulhas current region east of Cape Point, but is known to range regularly as far north as St Helena Bay (~ 200 km north of Cape Point). There are two species of bottlenose dolphins which occur in South African waters; *Tursiops aduncus* is the inshore species with sightings generally recorded in less than 30 metre water depth (Ross et al. 1987) and *Tursiops truncatus* which has an oceanic habitat associated with the shelf edge and pelagic zone and is very rarely sighted in nearshore waters of the Western Cape, with the exception of some sightings in the deep water off Cape Point (Best 2007). As the vast majority of bottlenose dolphin sightings in this thesis occurred close to shore (within 2km), it is assumed that all bottlenose dolphins throughout this thesis refers to the inshore *T. aduncus* species, unless otherwise stated. Also of increasing interest and included in this study is the killer whale (*Orcinus orca*). Finally the three whale species occurring in the study region and also included in this study are the Bryde's whale (*Balaenoptera brydei*), southern right whale (*Eubalaena australis*) and humpback whale (*Megaptera novaeangliae*).

1.2 Aims and objectives

The overarching aim of this project is to understand the environmental factors limiting the distribution of cetacean species which occur in the Western Cape region of South Africa, as a precursor to predicting climate change impacts in the future.

The specific objectives of this study are as follows:

- 1) Investigate spatial and temporal distribution of dolphins using opportunistic data gathered from citizen scientists.
- 2) Compare and evaluate patterns of two data sets i.e. opportunistic data and dedicated boat survey data.
- 3) Investigate spatial and temporal patterns in cetaceans using local ecological knowledge (LEK).
- 4) Evaluate LEK as a rapid conservation assessment tool for the region.

This study forms part of a larger project which additionally uses Passive Acoustic Monitoring and dedicated boat surveys to address the same aim, which is to investigate the distributional boundaries/limiting factors of cetacean species near the end of the species ranges. Once this has been investigated and understood, the three methods will be used in combination with climate models to try and predict changes. This MSc will focus specifically on how data from citizen scientists can be used to investigate cetacean distributional boundaries/limiting factors and will comprise the use of opportunistic data and local ecological knowledge (LEK).

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1.4 Figures

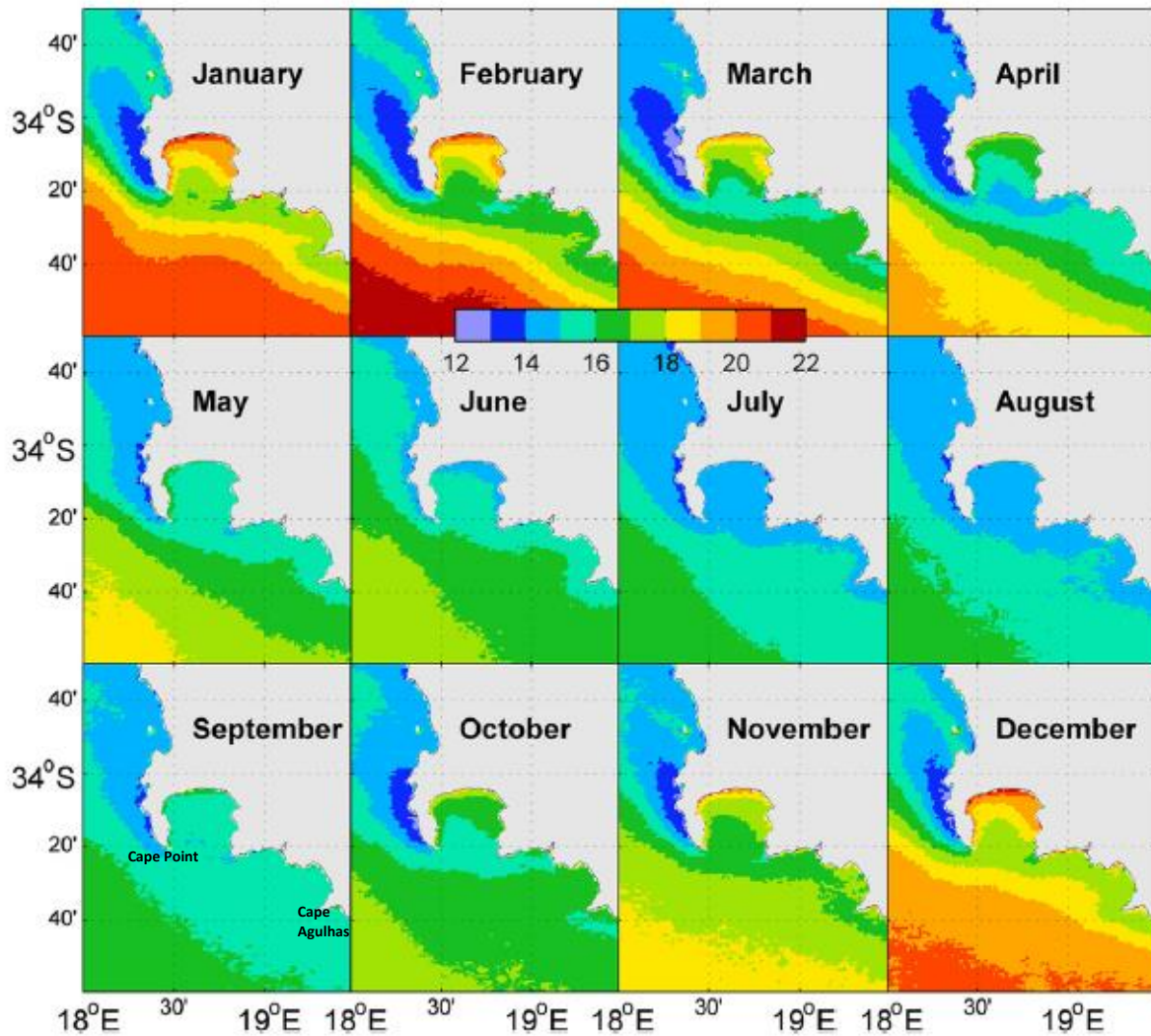


Figure 1.1: Monthly SST climatology from 2000 to 2010 computed with satellite for the south western Cape, South Africa, showing the coast from approximately Yzerfontein in the north to Quoin Point in the east (Dufois and Rouault 2012).

Chapter 2: Spatial and temporal patterns of cetaceans using opportunistic data in the Western Cape, South Africa.

2.1 Abstract

Conducting research on cetacean distribution is often logistically and financially challenging, especially in developing countries. Data derived from opportunistic sources can provide a cost efficient way to gain insight into cetacean movements especially in poorly studied oceanic regions. There is a high diversity of cetaceans in the Western Cape region of South Africa and the majority of them are poorly studied. This study collated sightings of cetaceans in the Western Cape from multiple opportunistic sources in order to map and describe spatial and temporal trends in their presence. The study focused on the five main dolphin species which occur in the region which included the dusky dolphin (*Lagenorhynchus obscurus*), Heaviside's dolphin (*Cephalorhynchus heavisidii*), common dolphin (*Delphinus delphis*), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and Indian Ocean humpback dolphin (*Sousa plumbea*). Whale species investigated included the Bryde's whale (*Balaenoptera brydei*), southern right whale (*Eubalaena australis*) and humpback whale (*Megaptera novaeangliae*). Results supported existing knowledge for most species and highlighted False Bay as an important area for cetaceans, especially for common dolphins and Bryde's whales. It is suggested that future research locally is focused in areas where a gap in distribution knowledge exists i.e. between Hout Bay and Cape Point and the eastern side of False Bay. This study highlights the value of opportunistic data for studies on cetacean distribution.

Key words: citizen science, distribution, dolphin, habitat use, seasonality, whale

2.2 Introduction

South Africa is a global hotspot for cetacean diversity, yet most species remain poorly studied (Elwen et al. 2011). The distribution of small odontocetes (toothed whales) species in South Africa was last formally described by Findlay et al. (1992) and updated by Best (2007) for all cetacean species. The data which exists is mostly broad scale, except for a few papers on localised distribution (Elwen et al. 2010; Barendse et al. 2011; Barendse and Best 2014; Vinding et al. 2015; Melly et al. 2017), none of which focused on the area around the city of Cape Town and the Cape Peninsula. The area around the Cape Peninsula is notable as it encompasses the southern range limit of four dolphin species. This makes the area potentially very informative to understanding habitat choice and change at the range boundaries of cetacean species. Understanding range limiting factors could provide insight on potential range shifts in light of predicted climate change impacts.

The Western Cape is surrounded by two oceans and characterised by two major ecosystems. The west coast is characterised by the cool northward flowing Benguela Current system in the Atlantic Ocean, which is largely characterised by wind-driven coastal upwelling of cool sub-thermocline water (Shannon 1985; Mucina and Rutherford 2006; Ansorge and Lutjeharms 2007). In contrast, the east coast of South Africa is characterised by the warm southward flowing Agulhas Current in the Indian Ocean, which brings equatorial water and is associated with lower biomass but higher species diversity (Lutjeharms 1998; Schumann 1998; Mucina and Rutherford 2006). South of Africa the continental shelf becomes wider to form the Agulhas Bank (Lutjeharms et al. 2000). The Agulhas Current continues along the shelf edge and subsequently moves offshore as it moves southwards and follows the wider shelf (Lutjeharms et al. 2000). Its movement is characterised by constant downstream circulation until it reaches a point south of Africa at which the current is basically reversed, known as the Agulhas retroflexion (Lutjeharms and Van Ballegooyen 1988). The south

coast, ranging from Cape Point off the Cape Peninsula to Cape Agulhas the southern tip of Africa, is characterised as a transition zone in terms of oceanography of the Benguela and Agulhas regions since it is influenced by elements of both currents. The contrasting oceanographic conditions along the entire coastline create an extremely diverse range of habitats and are reflected in the diversity of organisms occurring in different geographic regions. Local studies have demonstrated distribution changes for a range of organisms in the region, including prey species that are important for cetaceans (Cockcroft et al. 2008; Bolton et al. 2012; Blamey et al. 2015) as well as changes in environmental parameters (Blamey et al. 2015). It is possible that there may have been range shifts for some cetacean species, especially since they are known to respond to shifting environmental and biological conditions (MacLeod 2009).

Effective conservation management requires detailed information on the spatial and temporal distribution of species, and could potentially be used to predict effects of climate change (Margules and Pressey 2000; Kaschner et al. 2011). Conducting research to obtain detailed distribution data is often challenging and logistically costly especially for highly mobile animals such as cetaceans (Hauser et al. 2006; Williams et al. 2006). Cetaceans are able to move over vast areas in a relatively short space of time, making it difficult for researchers to accurately track their movements. Citizen science is a field of study in which volunteers/members of the public help scientists answer research questions, usually by assisting with data collection over broad geographic scales (Cooper et al. 2007). Cetacean distribution data derived from citizen science opportunistic sources such as tourist boats, ferries, research vessels and even from shore present an effective and cost-efficient option for researchers to study areas which would be otherwise costly or difficult to access (Williams et al. 2006; Compton et al. 2007; Luque et al. 2006). Citizen science has become an increasingly popular approach in cetacean research. There has been an increase in cetacean

data collected from platforms of opportunity which are conducted by observers with some level of effort and track route collected and relatively consistently in space and time (Evans and Hammond 2004). Platforms of opportunity which have provided cetacean data for research include seismic survey vessels (Stone and Tasker 2006; de Boer 2010; Weir 2011; Wang et al. 2016), commercial ferries (Brereton et al. 2000; Kiszka et al. 2007), cruise ships (Compton et al. 2007), whale watching vessels (Ingram et al. 2007; Bruce et al. 2014; Vinding et al. 2015), shore based sightings (Cheney et al. 2013; McClellan et al. 2014; Melly et al. 2017) and whaling records (Clapham et al. 2004; Best 2006) among others.

Opportunistic data in the form of incidental sightings, which refer to sightings not associated with any dedicated search effort, have also provided valuable information for studies on cetacean distribution (Jeewonarain et al. 1999; Weir 2011; Cheney et al. 2013). These ‘presence only’ sightings are generally inconsistent in space and time but still provide useful information for researchers, particularly in remote areas or areas where there is a paucity of scientific data. Incidental sightings can be hard to interpret as they lack associated research effort and detailed information and species identification can be suspect. In the absence of scientific or effort-corrected data, incidental sightings can be valuable in delineating species hotspot areas and in some instances may even be the primary source of information for rare species (Evans and Hammond 2004). Incidental sightings have been collated from a wide range of sources for use in cetacean studies including the public, naturalists, fishermen and from different organisations which often comprise observer networks (Evans 1980; Jeewonarain et al. 1999; Luque et al. 2006; Mandleberg 2006; Weir 2011).

Data derived from citizen scientists need to be interpreted carefully, especially due to the spatial or temporal biases in effort and variation in the ability of observers to correctly identify species, which is usually due to lack of experience and training (Evans and Hammond 2004; Hauser et al. 2006). Studies suggest that observer skill and inter-observer

variation varies widely with species and problems can be lessened using good sample design and analysis (de Solla et al. 2005; Dickinson et al. 2010). Age of observer and years of experience have been shown to be important factors in data quality with increased accuracy from observers with more years of experience (Delaney et al. 2008). Photographs are useful in validating observer records. Professional scientists can validate photographs of observations against reported occurrences to establish if there were any identification errors. Training citizen scientists on species identification is another technique to greatly reduce misidentification errors. Variation in sampling effort of platform of opportunity data can create sampling biases (Sauer et al. 1994; Dickinson et al. 2010) which are usually caused by the limited control over the route taken and the speed of the vessel (Evans and Hammond 2004). In these cases, it is usually not possible to divert from the route or move closer if the observation is from shore to confirm the group size and species identification (Evans and Hammond 2004). Temporal variation in sampling effort could result in over-reporting of rare species, under reporting of common species, as well as failure to report repeated sightings, due to lack of interest by observers (Dickinson et al. 2010).

In response to the aforementioned biases, researchers have adopted methods to standardise sampling effort, ranging from regular interval repeated-visits protocols to flexible guidelines and benchmarks that participants are encouraged to reach (Dickinson et al. 2010).

Furthermore, studies often use other species presence data to represent effort as ‘pseudo absences’ of target species and employ careful standardisation of sightings information (El-Gabbas and Dormann 2017). These data basically indicates where the study animal was not present and is particularly useful in poorly surveyed regions and when monitoring a broad range of a species (Dickinson et al. 2010). Although opportunistic data have its challenges, the benefits are powerful, particularly the ability to provide useful data on cetacean communities in South Africa.

There have been a number of organisations and projects which have successfully collated cetacean sightings from multiple opportunistic sources for research purposes. One such example was a joint initiative by The Hebridean Whale and Dolphin Trust and the Sea Watch Foundation who gathered cetacean sightings using an observer network from ferries, private yachts, wildlife and whale watching vessels, fishing vessels and the general public in Northwest Scotland (Jeewoonarain et al. 1999). Another successful project by the Cetacean Group in the British Isles began in 1973 and comprised a large observer network including observers such as zoologists, navy personnel, ornithologists, life guards and yachtsmen who recorded cetacean sightings. These sightings which were collated from multiple sources were able to yield valuable cetacean presence data at a low cost, emphasizing the importance of using opportunistic sources. Collating sightings from multiple sources enables the amount of occurrence data to be maximised and allows the monitoring capacity to be increased (Mandleberg 2006). Where it has been done, the results of studies which used data from opportunistic platforms compared well with studies using data from structured scientific surveys (Mandleberg 2006; Williams et al. 2006; Bissell 2013; Cheney et al. 2013).

This study aimed to investigate the spatial and temporal distribution of cetaceans in the Western Cape region of South Africa using opportunistic data collated from multiple sources, essentially to understand distribution range limits as a basis for predicting future changes under climate change. Furthermore, data derived opportunistically was compared to scientific data to establish whether results were similar. Dolphin species in this study included the west coast species dusky dolphin (*Lagenorhynchus obscurus*) and Heaviside's dolphin (*Cephalorhynchus heavisidii*) and south coast species common dolphin (*Delphinus delphis*), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and Indian Ocean humpback dolphin (*Sousa plumbea*), all of which occur at the southernmost extremes of their distributional range. Bottlenose dolphin throughout this chapter refers to the nearshore species (*Tursiops*

aduncus and not the common bottlenose *Tursiops truncatus* which has an exclusively offshore distribution in South Africa. The killer whale (*Orcinus orca*) is the most infrequent species but was also included in the study. Whale species investigated included the Bryde's whale (*Balaenoptera brydei*), southern right whale (*Eubalaena australis*) and humpback whale (*Megaptera novaeangliae*).

2.3 Methods

2.3.1 Study area

The study area ranged from Cape Columbine to Cape Agulhas (the southern tip of Africa), encompassing roughly 450km of coastline (Figure 2.1). The west coast is characterised by the cold Benguela Current fuelled by wind-driven upwelling close inshore at active upwelling sites (Shannon 1985). The region between Cape Point and Cape Agulhas lies on the south coast, where upwelling of nutrient-rich sub-photoc water occurs along the shelf break and at promontories along the southern coastline, creating an intensive, dynamic mixing region on the broad Agulhas Bank of the south coast, intermediate in terms of temperature and productivity between the Benguela and Agulhas regimes and therefore can be considered a transition zone (Hutchings et al. 2002). This diverse range of oceanographic conditions, particularly the contrasts in productivity, temperature and dissolved oxygen is reflected in the corresponding differences in marine diversity at different biogeographic regions along the coast (Anderson et al. 2016). A full description of the background of the environment is in Chapter 1.

2.3.2 Data collection

Cetacean species occurrence records were obtained from various sources and were divided into three categories; scientific, platform of opportunity and opportunistic, described below. Permission was obtained from all data contributors for use of their data in this study. Where large datasets were contributed, a memorandum of understanding was compiled and signed

by data contributors and all researchers involved in the study. In cases where the species could not be identified, the category unidentified dolphin (UD) or unidentified whale (UW) was assigned to the respective sighting and were not included in the analyses.

Scientific data

In the context of this study, scientific refers to data collection of cetacean sightings where there was a measure for effort. Some of the data used have already been reported on in other studies (Elwen et al. 2010; Vinding et al. 2015; Vermeulen et al. 2018). In this study I use these data within a broader spatial coverage to investigate wider trends in habitat use and temporal trends in cetacean presence in the Western Cape.

Scientific surveys by the University of Pretoria, Mammal Research Institute: Dedicated cetacean scientific surveys were conducted by cetacean researchers from the University of Pretoria's (UP) Mammal Research Institute (MRI) from three main projects. A study focussed on Heaviside's dolphins in nearshore waters, conducted from 1999-2001, working from several harbours between Granger Bay and Lamberts Bay which only had effort during summer (Elwen et al. 2010); a study which focussed on humpback dolphin data collection in Walker Bay, Kleinbaai, Struisbaai and St Sebastian Bay (Vermeulen et al. 2018); and data from surveys forming a parallel part of this project conducted around the Cape Peninsula (Laubscher unpublished data). All surveys focussed primarily on dolphins and the vast majority of survey effort was within 5km from shore. All scientific surveys followed the same basic protocol of weather dependence whereby surveys were conducted when weather conditions were favourable for sighting cetaceans. Group data collected included species name, GPS location, group size, presence of juveniles or calves and behaviour. Weather data collected included wind speed and direction, cloud cover, Beaufort Sea state, swell height and sightability. Photo identification information was collected and occasionally other data such as acoustic recordings or biopsy were collected (not reported on here). As all crew were

experienced and cetaceans were photographed, all species identifications are regarded as correct. For the purposes of this study only presence data were used.

Dedicated aerial surveys: Cetacean occurrences were derived from aerial surveys conducted by a UP MRI team. Three aerial surveys were conducted in total, with effort recorded on all surveys. The first survey, conducted 27/10/2015 in a gyrocopter, departed near Table Bay in Cape Town and followed a route along the coastline around Cape Point and back. The two other surveys were conducted in a small aircraft. The aerial survey on 02/03/2016 was conducted between Hawston and Cape Agulhas on the Cape south coast. The aerial survey on the 09/08/2016 surveyed the region between Bot River near Hermanus and Cape Infanta, an area located east of Cape Agulhas. Both trips included cetacean surveys to and from destinations. Data collected on the trip included trip start and end time, total trip distance, elevation and the track of the trip. When cetaceans were encountered the GPS coordinates, species, group size, presence of calves or juveniles and weather conditions (cloud cover, wind speed and direction, Beaufort Sea state and sightability) were recorded. Photographic documentation was also collected on all surveys. There were 50 cetacean encounters recorded in total. As all crew were experience and cetaceans were photographed, all species identifications are regarded as correct. For the purposes of this study only presence data were used.

Platform of opportunity data

In the context of this study, cetacean presence reports derived from platforms of opportunity refers to those platforms/sources that are consistent in the area covered and have at least some level of ‘search effort’ available through consistency in routes and/or trip times. These sources can be looked at with some level of effort since they are not random sightings. There is variation among observers regarding years of experience and although species identification guides were provided, there are potentially misidentification errors.

Whale watching trips: Cetacean occurrences were recorded on board a Whale Watching Vessel (WWV) by the BBWW (boat-based whale watching) company “Dyer Island Cruises” (DIC) throughout the year from 2003-2012 in the Dyer Island region, South Africa. These data were used as part of K. Vinding-Petersons PhD work and a subset published as Vinding et al. (2015). The study area ranged from Danger Point to Quoin Point just to the west of Cape Agulhas. Data were collected by skippers and/or biologists on board the vessel. A total of 3914 trips were conducted of which cetaceans were sighted on 3390 trips with 7492 encounters documented in total. Data collected on each trip included date, time of departure/return and weather conditions such as wind speed and direction and Beaufort Sea state. If whales or dolphins were sighted, the GPS location, species name, group size, presence of calves, behaviour and photographic documentation was recorded. For detailed description of data validation, refer to Vinding et al. (2015).

Shark Spotters sightings: Shark Spotters is an organisation which focuses on improving bather safety by reducing the risk of shark attacks and has been in operation since 2004. They also conduct scientific research on white sharks (*Carcharodon carcharias*) in False Bay, South Africa. Observers located at strategic elevated locations at popular beaches visually search for sharks. Spotters were located at seven beaches in False Bay at Kogelbay, Monwabisi, Muizenberg, St James, Clovelly, Fish Hoek and Glencairn and one location on the western side of the Cape Peninsula at Noordhoek beach (Figure 2.2). Spotters were located on the mountain on a daily basis for eight hours. While scanning for sharks, cetacean presence was also recorded. Information recorded included date and presence of dolphins and/or whales within a morning or afternoon watch period. Cetacean occurrences were derived from shark spotters data from 2004-2017. There were 4533 cetacean occurrences recorded in total. Due to a combination of distance from sightings, poor observer training (especially in the early part of the project) and the lesser focus on cetaceans in the

programme, the majority of sightings were only identified as ‘dolphin’ or ‘whale’, but are still useful for investigating broad trends in presence in the area.

Shark diving operator trips: A White Shark Cage Diving (WSCD) operator, “Apex Shark Expeditions”, conducted commercial shark diving trips from Simon’s Town harbour to Seal Island in False Bay from 1996-2015. Cetacean occurrences were recorded on all trips by experienced guides. Information collected on each trip included trip number, date, sea surface temperature at the island and weather conditions (wind direction and speed, cloud cover, swell height and water visibility). When cetaceans were encountered, the species, group size, and a description of the location were recorded in a log book. A total of 2311 trips were conducted over the 20 year period, predominantly from February to September, when most shark viewing trips were run. Cetaceans were encountered on 856 of the trips with 1211 encounters recorded in total. Trips where wind speed exceeded 12 knots were excluded from the analyses to reduce the effect of rough conditions on the ability to see cetaceans. After filtering the data and removing trips with bad weather, 1939 trips remained for analyses. Cetaceans were encountered on 744 of these trips with 1066 encounters in total.

Pelagic birding trips: Cetacean occurrence records were derived from offshore pelagic bird trip reports from 2005-2017. A not-for-profit organisation, “Cape Town Pelagics”, conducted offshore bird trips which were led by experienced sea bird guides. Trips generally departed from Hout Bay or Simon’s Town early in the morning and headed ~ 20 nautical miles south or south-west of Cape Point to the commercial fishing grounds. Trips were eight hours long on average and were conducted throughout the year, with two trips per month on average. Cetacean sightings were recorded by guides on all trips and information regarding the sightings was included in a trip report following each trip. The type of information collected included species name, group size and a descriptive location. There were 265 cetacean encounters described out of a total of 314 trips.

Kayak tour operated trips: Cetacean occurrence records were derived from a kayak tour operating company “Kaskazi Kayaks” from 2015-2017. Kayak trips launched from Three Anchor Bay, on the southern side of Table Bay in the Western Cape. Trips were conducted on a daily basis, weather permitting, and were on average two hours long and conducted between one and three times per day. Photographs were collected by kayak guides on all trips and uploaded to Facebook with a description of the trip, usually stating if cetaceans were encountered. Cetacean occurrences were derived from the kayak companies Facebook page with permission (Rauch pers. comm.). Cetacean sightings were validated with the photographs uploaded after each trip when available.

Opportunistic data

Cetacean occurrences were derived from a range of opportunistic sources. In the context of this study, opportunistic sources were those that were inconsistent in terms of area covered and time and had no measure of associated search effort. Opportunistic sightings were submitted by “citizen scientists” who included the general public, naturalists, conservationists, scientists and any other people who were willing to contribute records of observed cetaceans to the study. A number of platforms and contact routes were set up to allow the submission of sightings through the observer’s route of choice. These included paper sighting log sheets, email, telephone contact and several social media platforms. Each method had instructions on how to submit sightings and the type of information to include. Printed flyers were created to promote the project and the submission of sightings (Appendix 1 and 2) and articles were featured in a number of media including local newspapers and newsletters (Appendix 3 and 4). The flyers included pictures of the common cetacean species found in the Western Cape, as well as contact information of the available reporting platforms. Printed flyers were disseminated in public places such as beaches and surf shops and electronically through social media platforms. I aimed to provide a variety of platforms

to suit a range of contributors and included both digital and manual options. Where possible reported data were validated against photographs provided in order to confirm correct species identification. All sightings where observers could not accurately confirm species identification were labelled as unidentified whale or dolphin and were not included in the final analyses.

Facebook: Facebook is a social media web-platform on which information can spread in a matter of seconds and reach an exceptionally large audience. It provides an easy and quick way for observers to contribute sightings to this study. A Facebook ‘personal’ profile, named ‘Seasearch Sightings’, was created for citizen scientists to easily submit sightings to this study by simply ‘tagging’ this profile in the image(s) to draw our attention to it. People often did not want to submit sightings to a specific site and instead uploaded it to their own profile and simply tagged the Seasearch Sightings profile in order to notify and alert me to the sighting. Observers were also able to upload a picture and/or description directly to the Seasearch Sightings profile.

iSpot: A citizen science initiative called iSpot was established by the Open University to enable nature enthusiasts to share, identify and discuss wildlife observations. Observers were able to upload pictures of the cetacean species they encountered to the iSpot website (www.ispotnature.org) and choose the location of their observation via an interactive map of the study area. Users were then able to add all the necessary information such as species, estimated number of individuals, date, time, behaviour and any other details of importance. iSpot is a good platform for observers who are unsure about the identification of a certain species, because it allows experts in the field to identify the species based on the pictures and information the observer uploaded. [Note iSpot has been replaced by iNaturalist in South Africa since 2018].

Twitter: Twitter is a social media platform that enables communication and connectivity to large audiences, often in the form of real-time and frequent short messages. A twitter account named @SeaSearchAfrica was created to allow for the tagging of cetacean sighting reports by citizen scientists. Cetacean occurrence records were derived from Twitter in two ways. The first is by observers tagging the Sea Search profile in their observation/tweet to alert me to their sighting and the second is to acquire sightings from other profiles with the permission of the observer/Twitter account holder. Twitter sightings were mainly sourced from an organisation called “Whale Heritage”. Whale Heritage is a network of spotters who regularly submit cetacean sightings which are then posted on the Whale Heritage Twitter account. Sighting information obtained from their profile provided information such as species name, group size and a vague description of the sighting location.

Email: Some observers preferred to submit sightings via email. Cetacean sightings were submitted to this study via a dedicated sightings email address as well as the researchers email address and generally included species name, date and time, group size, location, behaviour and sometimes photographs.

WhatsApp: Cetacean occurrences were obtained from citizen scientists via the instant messaging application WhatsApp. Sightings were mainly obtained from WhatsApp groups such as the “Cape Town Boating group” which consisted of 117 participants (10/12/2017) who were either involved with boating related activities for leisure or for business.

Participants in the group shared cetacean sightings in the group on a regular basis. Sighting information provided included species name and location. GPS coordinates were often provided, as well as video and photographic footage.

Seafari cetacean sightings app: A software application was launched in March 2017 with the primary aim of enabling people to submit sightings of marine mammals. The app allows

users to add information such as species name, group size, presence of calves, behaviour and a geographic coordinate. The app allows the user to select the location using an interactive map which then obtains a coordinate for the sighting. The app was designed and funded by Alexander Vogel in consultation with cetacean specialist Dr Victor Cockcroft and other local cetacean biologists including Dr Simon Elwen, and built by Dreamweavedigital. Later improvements to the app were made in consultation with other cetacean specialists including Sea Search Africa. The goal of the app was for the data to be available for research purposes as needed. After contacting the above people, they were happy to have the data included in this study and sent me data summaries directly from the apps 'backend' on a monthly basis. Cetacean occurrences were derived from this app and 405 records were obtained from March to September 2017.

Sightings sheets: Paper sightings sheets were distributed to water users who preferred recording sightings on a hard copy while at sea as this was found to be simplest and least interfering with their work.

The following text was displayed on all sightings submission platforms as far as possible including Facebook and iSpot: "Disclaimer: By "tagging" Sea Search in sightings (comments, status updates or video) or submitting sightings via any of the other aforementioned platforms, it is specified by the submitter that he/she agrees to donate the information to the project and databases of Sea Search. The sightings will then be visible to all "Friends" of this profile, in the case of Facebook, and be added to a database. Sea Search and its associated staff and students undertake to not use any photos or videos donated to the project in their raw form in any form of media (talks, print, digital or scientific) without prior consent from the donator and owner of those data. In cases where submissions of content are used in a summarised or processed form (e.g. maps, graphs), all data contributors will be acknowledged as far as possible. If a contributor is likely to submit a lot of data to the project,

a more detailed Memorandum of Understanding will be drawn up and signed with the contributor.”

2.3.3 Data analyses

Spatial: All sightings data were entered and stored in a Microsoft Access© database.

Sightings were categorised by source as either scientific, platform of opportunity or opportunistic. In many cases the location of sightings submitted was descriptive (e.g. “five nautical miles west of Seal Island”) and coordinates were then estimated using Google Earth to allow for spatial projection of the data. The distribution of sightings for each species was mapped by source using ArcMap 10.5.1 (ESRI), projection WGS 1985.

Temporal: Cetacean occurrences were divided into three biogeographic regions to investigate temporal trends in these areas separately. All sightings east of False Bay (-34.39° , 18.83°) were grouped together and labelled WB (Walker Bay and surrounding areas). Sightings north of Table Bay (33.69° , 18.42°) were grouped together and labelled WC (West Coast). All sightings between WB and WC (Table Bay to False Bay) (33.69° , 18.42° - 34.39° , 18.83°) were grouped together and labelled as SWC (south-western Cape including the Cape Peninsula and surrounding areas). The SWC region was further broken down to compare differences within the area. It included False Bay, Cape Point-Hout Bay and Hout Bay-Table Bay based on the distribution of effort and the shift in environmental conditions around Hout Bay associated with the Cape Peninsula upwelling cell (it usually being substantially windier to the south, than north of this point)(Andrews and Hutchings 1980; Dufois and Rouault 2012). Summer was considered as December, January and February; autumn as March, April and May; winter as June, July and August; and spring as September, October and November. R software was used to plot the total number of monthly occurrences for all species at different regions. As no index of search effort was used, these data report on trends in presence only and are strongly affected by the distribution of the (often unknown) observer

effort. However, it is commonly assumed that the report of the presence of one species at a specific time and place can be interpreted as the absence of all others. Thus it is essential to interpret all species trends relative to the overall pattern of reports and the presence of other species.

2.4 Results

There were 19 166 cetacean sightings obtained in total from 1996-2017. Scientific sources accounted for 2185 (11.4%) records and all sighting coordinates were measured. Platform of opportunity sources accounted for 11 710 (61.1%) records of which 39.8% of the locations were measured and 61.2% of coordinates were estimated. Opportunistic sources accounted for 5 271 of the records (27.5%) of which 32.4% of coordinates were measured and 67.7% were estimated. There were 7141 sightings (50.2%) obtained from the region between Table Bay and False Bay (SWC) (Figure 2.1), 5 668 sightings (39.9%) were obtained from the region east of False Bay to Cape Agulhas (Figure 2.1), and 1 412 sightings (9.9%) were obtained on the west coast of Cape Town, north of Table Bay as far as Cape Columbine (WC) (Figure 2.1). Common dolphin, killer whale, southern right, humpback and Bryde's were found on both western and eastern regions within the study area. Heaviside's and dusky dolphins were predominantly western bound whereas humpback and bottlenose dolphins were more common on the south east coast. In the below results, n indicates the number of animals in a group.

Heaviside's dolphin

Heaviside's dolphins were reported 2006 times in total. Most sightings were derived from scientific data sources (1575 sightings) on the Cape west coast. The southern limit of regular sightings was around the Hout Bay area. There was one sighting recorded near Dyer Island on 23/11/2007 (n=4) and one sighting recorded at Cape Point on 02/11/2007 (n=2) (Figure 2.3). The sighting at Dyer Island was confirmed photographically (Vinding et al. 2015),

whereas the sighting at Cape Point was not. The most recent southernmost confirmed sighting of Heaviside's dolphins was recorded on 31/10/2017 (n=4) at a location close to shore about halfway between Hout Bay and Cape Point. In the context of this study, close to shore refers to within 2km from shore. There were only 14 Heaviside's dolphin sightings between Cape Point and Hout Bay, most of which were in Hout Bay and all of them towards the northern part of the Cape Peninsula. In contrast, there were 486 Heaviside's dolphin sightings recorded from the north of Hout Bay to Table Bay. Sightings derived from all sources overlapped in Hout Bay and on the western side of Table Bay. Heaviside's dolphins were recorded throughout the year from platform of opportunity sightings in the SWC region between Hout Bay and Table Bay (Figure 2.1, 2.4 and 2.5). The highest occurrence of sightings was in April (51 sightings) and the lowest in June and August (13 sightings). Heaviside's dolphins in the SWC were recorded throughout the year between Hout Bay and Table Bay from opportunistic sources. The highest occurrence was in September (12 sightings) and the lowest in January (one sighting). Heaviside's dolphin sightings from scientific sources were not recorded throughout the year for any of the regions as available data were collected during a series of trips that occurred during a short space of time in three consecutive summers. There were sightings of Heaviside's dolphins in all months except July, August, September and November from scientific sources in the SWC region. The highest occurrences were in February (43 sightings). Scientific sightings on the west coast indicated high numbers of occurrences between February (330 sightings) and April (103 sightings), due to survey effort limited to those months.

Dusky dolphin

Dusky dolphins were sighted 358 times in total, mainly by scientific data sources (241 sightings) (Figure 2.6). The southern limit of regular sightings was in False Bay. Sightings in False Bay occurred predominantly in the western side of the bay (three sightings) except for

one record in the eastern side near Gordon's Bay on 28/10/2017. Only two confirmed sightings of dusky dolphins occurred to the east of False Bay, both in Walker Bay on 18/11/2011 (n=3) and 18/11/2017 (n= ~200). The latter represents the most recent confirmed southernmost sighting of dusky dolphins. Most sightings occurred in areas less than 100m deep except for six sightings at 200m depth off Cape Point. Dusky dolphin sightings from scientific sources occurred only on the western side of the peninsula, south of Hout Bay, with only two sightings recorded between Hout Bay and Cape Point. Dusky dolphin sightings in False Bay and around Cape Point were recorded only by opportunistic and platform of opportunity sources. Within the SWC region (Figure 2.1), the highest concentration of occurrences was between Hout Bay and Table Bay (81 sightings) whereas 48 sightings were recorded in False Bay. Sightings derived from all sources overlapped on the western side of Table Bay. Dusky dolphins were recorded throughout the year in the SWC region between False Bay and Table Bay (Figure 2.4 and 2.5). The highest occurrence of sightings was in January (31 sightings) and the lowest in March (four sightings). Within the SWC region between Hout Bay and Table Bay, there were generally a lower number of sightings in the winter months compared to summer months. Dusky dolphins on the west coast were recorded by scientific sources in January (four sightings), February (41 sightings), March (47 sightings) and April (36 sightings) and by opportunistic sources in March (two sightings), August (one sighting) and October (one sighting).

Humpback dolphin

Humpback dolphins were sighted 406 times in total, mainly from platform of opportunity sources (340 sightings). Humpback dolphin sightings ranged from False Bay to Cape Agulhas with the majority of sightings located close to shore and around Dyer Island (Figure 2.7). The most western confirmed sighting in False Bay was recorded 23/09/2017 (n=3). There were no humpback dolphin sightings recorded to the west of False Bay or in the WC

area. Only 15 sightings occurred in False Bay and four in Walker Bay whereas 336 were recorded around Dyer Island. All sightings in False Bay occurred close to shore along the northern coast, with sightings from all data sources overlapping in this region. Humpback dolphins in False Bay were only recorded in March, April, September, October and November with the highest occurrence in April (three sightings, two from scientific and one from opportunistic sources) and in Dyer Island recorded throughout the year from platform of opportunity sources with the lowest number of sightings in May (six sightings) and highest in December (59 sightings) (Figure 2.4 and 2.5). Humpback dolphins were recorded between Walker Bay and Cape Agulhas by scientific sources only in March, due to field trips conducted at that time (17 sightings) and opportunistic sources recorded sightings in March (one sighting), April (three sightings), May (one sighting), August (one sighting) and November (one sighting).

Bottlenose dolphin

Bottlenose dolphins were sighted 309 times in total, mainly from platform of opportunity sources (210 sightings). The westernmost confirmed sighting was on the western side of the Cape Peninsula between Cape Point and Hout Bay (18/02/2013). All other sightings occurred between False Bay and Cape Agulhas with the highest concentration of sightings between Walker Bay and Dyer Island (Figure 2.8). Only 34 of the 309 sightings occurred in False Bay. There were no sightings recorded in the WC region (Figure 2.1). Sightings from all data sources overlapped in Walker Bay and there was no temporal trend within False Bay by any of the data sources (Figure 2.4 and 2.5). In the Walker Bay region, sightings from platform of opportunity sources recorded bottlenose dolphins throughout the year with the lowest total number of sightings recorded in May (one sighting) and highest in December (31 sightings). No clear seasonal trends were observed. Most of the platform of opportunity source data were derived from the BBWW vessel operating in the area.

Common dolphin

Common dolphins were recorded 880 times in total, mainly from platform of opportunity sources (722 sightings). Common dolphin sightings generally ranged from Table Bay to the Dyer Island region (Figure 2.9) with the northern most sighting between Robben Island and Koeberg. There were no recorded sightings further north on the west coast (WC). All common dolphin sightings occurred in the WB and SWC region, most notably in the SWC. The majority of sightings occurred in False Bay, mainly in the western side of the bay. Sightings derived from all sources overlapped in this region. False Bay accounted for 722 sightings whereas only 68 sightings occurred between Hout Bay and Table Bay. Only 29 of 880 sightings occurred east of False Bay. Common dolphin sightings were recorded throughout the year in the SWC region (Figure 2.4). In False Bay the highest number of sightings was in April (175 sightings) and lowest in November (two sightings) (Figure 2.5). Common dolphin sightings between Cape Point and Table Bay were most frequent in May (40 sightings) and least frequent in December (one sighting). There was a general trend in peak occurrence from March-May. There was no clear temporal trend in the Walker Bay region.

Killer whale

Killer whales were recorded 47 times in total. Sightings occurred in all regions from Cape Columbine in the west to the Dyer Island region on the south east coast (Figure 2.10). There were no sightings derived from scientific sources, only from opportunistic and platform of opportunity sources. Most sightings occurred in the SWC region (Figure 2.1) between False Bay and Table Bay (37 sightings, 10 from opportunistic and 27 from platform of opportunity sources). There were eight killer whale sightings off Cape Point near the 500m depth isobath. Only eight killer whale records were reported east of False Bay around the Walker Bay region and only two sightings were recorded on the west coast at Saldanha Bay and Cape

Columbine. Killer whales were recorded during all months in the SWC region with the highest total occurrence of eight sightings recorded in April and May and the lowest from November-January (one sighting) (Figure 2.4). There was a clear spike of killer whale occurrences during April and May, compared to other months. In the Walker Bay region, the highest number of sightings was in April (three sightings) and one sighting was recorded in February, June, July, August and October. On the west coast, one sighting was recorded in January and one in April.

Southern right whale

Southern right whales were recorded 5081 times in total, mainly by platform of opportunity sources (4612 sightings). The bulk of these sightings were derived from the boat based whale watching company operating in Walker Bay. Sightings were distributed throughout the study area from Cape Columbine to Cape Agulhas (WC, SWC and WB) with the majority of sightings located close to shore (Figure 2.11). The highest concentration of southern right whales was between Walker Bay and the Dyer Island region, accounting for 4491 sightings. Only 55 southern right whale sightings were recorded north of Table Bay on the west coast whereas 535 sightings were recorded between Table Bay and False Bay. Sightings from all data sources overlapped in most parts of the SWC and in Walker Bay. Southern right whales were recorded in all months in the SWC region between False Bay and Table Bay with most sightings in September (156 sightings) and the least in December (three sightings) and January (three sightings) (Figure 2.12 and 2.13). There was a seasonal trend observed with records generally increasing from June to September. Southern right whales were recorded in all months in the Walker Bay-Dyer Island region with most sightings recorded in October (1277 sightings) and the least in February (one sighting) and April (one sighting). There was a clear seasonal trend with occurrences increasing from June to October. Southern right whale sightings on the west coast were recorded in February, March, April, July, August,

September, October and December with highest occurrences in February (13 sightings) and lowest in July (one sighting). No seasonal trend was observed on the west coast.

Bryde's whale

Bryde's whales were recorded 562 times in total, mainly from platform of opportunity sources (405 sightings). Sightings were distributed from Table Bay in the west to near Cape Agulhas in the south east, with the highest concentration in False Bay (Figure 2.14). The northern most sighting was one sighting between Robben Island and Koeberg on the west coast. There were no sightings of Bryde's whales recorded further north on the west coast. The eastern most sighting was a single occurrence between Quoin Point and Cape Agulhas. There were three offshore sightings of Bryde's whales recorded between 100 and 200m depths. There were 135 Bryde's whale sightings between Walker Bay and the Dyer Island region. The region between Table Bay and False Bay accounted for 427 Bryde's whale sightings however there were low sightings numbers between Table Bay and Cape Point (37 sightings), in comparison to the high concentration within False Bay (360 sightings). The most overlap of sightings from different sources occurred in False Bay. Bryde's whales were generally not as coastal as southern right whales. Bryde's whales were recorded during all months in False Bay within the SWC region with the highest occurrence in July (69 sightings) and least in December (four sightings) and January (four sightings) (Figure 2.12 and 2.13). Occurrences generally increased from February to July in False Bay. Bryde's whale occurrences between Cape Point and Hout Bay were recorded in February, March, April, May, June, July, August, September and November with the highest total occurrences recorded in September (eight sightings). No seasonal trend was observed. There were relatively low occurrences of Bryde's whales between Hout Bay and Table Bay with no recorded sightings from December to February. The maximum number of sightings was recorded in April (nine sightings). In the Walker Bay-Dyer Island area, Bryde's whales were

recorded during all months with the maximum sightings recorded in May (33 sightings) and lowest in September (one sighting). Bryde's whale occurrences in the Walker Bay region peaked between March and May and were much lower during other times of the year.

Humpback whale

Humpback whales were sighted 567 times in total, mainly from platform of opportunity sources (297 sightings). Sightings were generally recorded throughout the study area from Cape Columbine to east of the Dyer Island area (Figure 2.15). Most sightings occurred around the Cape Peninsula (412 sightings) with the least number of sightings recorded north of Table Bay in the WC region (46 sightings). There were 109 humpback whale sightings east of False Bay between Walker Bay and Dyer Island. Humpback whale sightings were distributed both in nearshore and offshore waters with at least 15 sightings recorded at or near the 200m isobath. Sightings from all sources overlapped at most areas around the Cape Peninsula, especially in the northern side of False Bay and the area between Hout Bay and Table Bay. Humpback whales were recorded during all months of the year in False Bay within the SWC region except during April and December with the highest total occurrences recorded in August (47 sightings) and lowest in January (one sighting) and February (one sighting) (Figure 2.12 and 2.13). Humpback whale sightings increased from June to October. Sightings between Cape Point and Hout Bay were recorded in all months except May with the highest occurrences in July (38 sightings) and lowest in January (one sighting) and April (one sighting). There was a clear spike in humpback whale occurrences from June to September. Humpback whale sightings between Hout Bay and Table Bay were recorded in all months except January and May with the highest number of records in July (21 sightings) and least in September (one sighting). There were peaks in occurrence in July and August (12 sightings), as well as in November (17 sightings) and December (10 sightings). Humpback whales on the west coast were recorded in all months except May and December with the

highest occurrences recorded in July (nine sightings) and November (nine sightings) and lowest in January (one sighting) and June (one sighting). Humpback whale occurrences fluctuated through the year with peaks in February, July and November. In the Walker Bay-Dyer Island area, humpback whales were only recorded from May-January, due to the BBWW company operating during those months, with highest occurrences recorded in August (30 sightings). Sightings increased from June to August.

2.5 Discussion

Most of the gaps in sightings within the study area, most notably between Hout Bay and Cape Point and between Cape Hangklip and Walker Bay were due to low observer effort and therefore do not represent a true absence of species within the region. The area in question forms part of the Cape Point Nature Reserve and MPA, it is significantly exposed to the elements, it is far from the nearest harbour, no fishing is allowed and access from shore is restricted as road access is limited. It is important to bear this low observer effort in mind when interpreting the results.

There was a consensus among all data sources in that Heaviside's dolphins only occurred on the west coast of South Africa, generally in nearshore waters. The distribution of sightings obtained supports existing descriptions of the species distribution range in South Africa (Findlay et al. 1992; Elwen et al. 2010) and knowledge of their general movement patterns (Elwen et al. 2006; Elwen et al. 2010). Best (2007) describes the southern limit of the range as Cape Point, based on an unconfirmed incidental sighting one mile east of Cape Point (Findlay et al. 1992) and one other sighting on the east coast (Cockcroft pers. comm. as cited by Best 2007). However, due to the absence of confirmed sightings east of Cape Point and at Cape Point, data from this study suggests that the effective southern limit of the species range lies between Cape Point and Hout Bay with any sightings further south and east considered exploratory or vagrant. Heaviside's dolphins are endemic to the cool waters of the

Benguela Ecosystem and temperature appears to play a significant role in their choice of habitat and movement patterns. These dolphins feed offshore primarily on shallow-water hake (Sekiguchi et al. 1992) and previous work has shown that Heaviside's dolphins were more common in areas where juvenile hake was more readily available, usually to the north of upwelling cells (Elwen et al. 2010). They also have an apparent preference for sandy beaches and exposed headlands (Elwen et al. 2010). All of the above factors limit the attractiveness of areas south of Hout Bay, where strong upwelling occurs and hake densities are low (Andrews and Hutchings 1980). The strong and rapid changes of temperature south of Hout Bay may act as cues to limit further dispersion. Heaviside's dolphins sighted south of Hout Bay were recorded mainly in summer months, which might be due to the presence of cooler upwelled waters present during this time, enabling the dolphins to venture further south within their thermal range or perhaps pursuing other prey. Heaviside's dolphins were present throughout the year, but displayed a drop in occurrence during winter, as shown by Findlay (1989). It is uncertain whether this is a true reflection of temporal presence or if it is due to lack of effort during winter months.

Previous knowledge of dusky dolphin distribution patterns in South Africa is limited. Findlay et al. (1992) proposed their distribution to range along the west coast of South Africa as far south as False Bay. Elwen et al. (2010) confirmed the regular presence of dusky dolphins between Table Bay and Lambert's Bay on the west coast. In this study all data sources confirmed regular dusky dolphin presence on the west coast of South Africa, which supports existing knowledge (Findlay et al. 1992; Elwen et al. 2010), and provides much greater detail of the presence of this species at the southern boundary of their range near Cape Point. No scientific observations of dusky dolphin were made in False Bay but a 19 year consistently collected time series in False Bay was available from a shark diving operator and provided some insight into long-term patterns within the bay. The majority of dusky dolphin sightings

in False Bay were recorded between 2000 and 2002 and only a few were reported after. Although some sightings south of Simon's Town have been reported in this period from other sources, these results do suggest that the presence of dusky dolphins in False Bay has reduced since the early 2000s. It is suggested here that the 'southern' limit of dusky dolphin distribution is probably False Bay, although sightings are much more frequent to the west of Cape Point. Any sightings east of False Bay are considered exploratory. Previous studies on dusky dolphins on the west coast were unable to identify any obvious patterns in their distribution but did highlight a preference for sandy shores (Elwen et al. 2010). Since dusky dolphins generally occur further from shore than Heaviside's dolphins, sightings close to shore are essentially at the edge of their range and probably do not represent their true choice of habitat (Elwen et al. 2010). Dusky dolphins are known to be generalist foragers feeding primarily on small pelagic fish (Sekiguchi et al. 1992). Several anecdotal reports from fisherman in False Bay reported a general decline of fish in the bay over the years (Author pers. comm.), which could potentially be a contributing factor as to why dusky dolphins are less frequently sighted in False Bay. Dusky dolphin sightings in False Bay occurred mainly on the western coast of the bay, an area which is cooler in temperature than the eastern side of the bay, and is exposed to upwelled water entering from Cape Point. Dusky dolphins could be entering the bay to move out of the cold upwelling cell at Cape Point but their general movement east of False Bay is probably limited by the presence of warm water temperatures. The overall seasonal trend observed in this study also agrees with existing knowledge (Elwen et al. 2010), and suggests that it may be linked to preferred water temperature or higher availability of prey during the summer upwelling periods.

The most western locality of humpback dolphins from all data sources was False Bay, all along the northern coast of the bay. Humpback dolphins were found to be predominantly nearshore, which supports existing knowledge about the species distribution (Best 2007;

Braulik et al. 2015). Humpback dolphins were the least sighted dolphin which was expected since it is South Africa's most endangered marine mammal (Plön et al. 2016). The low number of sightings in False Bay suggests that it is not common in this region. Humpback dolphins have been found to feed on inshore fish and cephalopod species in the Eastern Cape of South Africa (Barros and Cockcroft 1991). The availability of inshore prey species could be a driver limiting their distribution ranges close to shore. It is suggested that temperature may also play a role in limiting this species' distributional range as they occur frequently in the warmer waters of the south and east coasts of South Africa and globally in tropical and temperate waters (Best 2007). Humpback dolphins prefer sandy shores. The change from warm water and sandy shores to cold water and rocky cliffs south of Fish Hoek is likely an important factor limiting their range. The absence of any clear seasonal trends was not surprising since Best (2007) mentioned seasonal movements are not characteristic of humpback dolphins. It is obvious that humpback dolphin populations in the Western Cape require consistent monitoring and effective conservation interventions.

The western limit of bottlenose dolphins from all data sources was False Bay, with the exception of two sightings on the western side of the Cape Peninsula. Existing knowledge of the distribution suggested the western limit is False Bay, based solely on a stranding (Best 2007), and this study can officially confirm this with certainty. It is uncertain whether the sightings on the western side of the peninsula are of the form *Tursiops aduncus* or *Tursiops truncatus*. The limited number of scientific sightings in False Bay and general low number of sightings from other sources suggests this species is uncommon in the region. Bottlenose dolphins occur much more consistently further east where water temperatures are warmer in Walker Bay and the Dyer Island area, a mere ~100km east of False Bay (Vinding et al. 2015). There is a gradual cooling of sea surface temperature along the coast west of Cape Agulhas until a warm peak is hit in northern False Bay (Smit et al. 2013). The coldest

temperatures are between Walker Bay and False Bay (Smit et al. 2013). It is possible the cold temperatures west of Walker Bay may be limiting bottlenose dolphins from moving west to the False Bay region. The waters west of Walker Bay are the coldest occupied by this species in South Africa, and possibly even globally given that it only gets more tropical east of South Africa. Sightings and the distribution of sighting effort were too few to establish a temporal pattern in False Bay. But in the Dyer Island area, a year-round presence was observed (Vinding et al. 2015). More survey effort is required west of Walker Bay to investigate where the sighting rate drops off and if there are any obvious environmental changes triggering it.

The majority of common dolphin sightings from all data sources were recorded in False Bay. Existing knowledge suggests the western limit of the species range is St Helena Bay near Cape Columbine (Best 2007). Records of common dolphins to the west of Cape Point and in Table Bay were much less common than in False Bay and scientific survey sightings were only recorded as far south as Hout Bay on the western side of the Cape Peninsula. The absence of sightings between Table Bay and Cape Columbine in this study suggests that the western limit might be further south than previously proposed. However most of the data north of Table Bay arises from one data set, a scientific survey in 1999-2001 conducted in summer months. The absence of sightings could be due to low effort, coupled with low human densities inhabiting the relatively isolated section of coastline on the west coast. Based on the high frequency of sightings in False Bay, it is suggested this could be a 'hotspot' area for common dolphins, especially during March, April and May when there was a clear spike in occurrence. Sightings of common dolphins obtained from opportunistic sources were valuable and made it possible for me to identify a seasonal and spatial trend. The presence of common dolphins in the KwaZulu-Natal region of South Africa during winter has been linked to the annual sardine run and their occurrence was found to be the primary predictor of sardine presence, compared to other species also migrating to indulge in

the feast (Cockcroft and Peddemors 1990; O'Donoghue et al. 2010). Common dolphins are opportunistic feeders and have been known to feed on a wide range of prey species but primarily small pelagic shoaling fish species such as sardine and anchovy (Young and Cockcroft 1994). Previous studies show that common dolphins usually feed on the most locally abundant prey species and change their diets in relation to fluctuations of prey abundance and availability (Young and Cockcroft 1994; Ambrose et al. 2013). False Bay lies between the cool Benguela and warm Agulhas currents and is affected by both systems and associated upwelling (Dufois and Rouault 2012). False Bay thus provides favourable conditions for small pelagic fish species such as sardine and anchovy that pass by during their annual return migration from the west coast to the Agulhas Bank (Hutchings 1992). The seasonal spike of common dolphin occurrences in False Bay coincides with the timing of the migration of small pelagic fish species and is probably the main reason for their presence in the bay. Stomach content analyses of stranded common dolphins in the Western Cape region must be investigated in order to gain insight into their diets. Furthermore, the main common dolphin breeding season is in March and April with a second peak from September-October, according to a study based on strandings in KwaZulu-Natal (Cockcroft 1990). It is uncertain whether the peak in False Bay has any relation to reproductive timing.

The absence of killer whales from scientific surveys illustrates how valuable opportunistic data are, but also highlights the rarity of the species within the study area. Opportunistic sightings confirmed the presence of killer whales throughout the study area both nearshore and offshore, supporting existing knowledge of its range (Best 2007). Most sightings were recorded in False Bay and the seasonal peak in April and May corresponded to the seasonal peak of common dolphin presence. It is suggested that the presence of killer whales is strongly driven by the presence of common dolphins, which usually occur in large numbers and as such provide a relatively quick and easy meal for the killer whales. The seasonal

pattern of killer whale presence was consistent across regions. Predation on common dolphins by killer whales has been previously documented in South Africa (Best et al. 2010). Over recent years there have been several reports of killer whales preying on common dolphins in False Bay, witnessed by tour operators in the area and with photographic evidence to confirm. The seasonal correlation in timing between killer whale and common dolphins in False Bay observed in this study suggests that the killer whales may be following the common dolphins into the bay. More sightings of killer whales in the Western Cape region would help gain more insight into their biology and distribution. Effort focused during the autumn months (March, April and May) when the likelihood of encountering killer whales may be higher than other times of the year could be useful for future research.

Bryde's whales in southern Africa are either of the inshore form which occur over the continental shelf south of 30° S or the offshore form which occur on the west coast of southern Africa from equatorial regions to about 34° S (Best 2007). This study focused only on the inshore population. Sightings of Bryde's whales were distributed in most regions in the study area, except for the west coast north of Table Bay. Existing knowledge of this species in South Africa suggests its distribution is limited to the Agulhas Bank and the population is likely small (Best 2007). Previous studies have shown that Bryde's whale distribution is mainly related to changes in the distribution of their prey (Tershy 1992; Zerbini et al. 1997; Best 2001, Penry et al. 2011; Kerosky et al. 2012). Similar to common dolphins, Bryde's whales feed primarily on shoaling small pelagic fish such as sardine and anchovy (Best 1977) and are known to feed opportunistically throughout the year (Penry et al. 2011). Although not a migratory population, Bryde's whales from the Inshore population of South Africa likely move up the west coast in autumn and back again in spring, coinciding with the movement of anchovy and sardine (Best 2007). This could potentially explain the absence of west coast sightings, since survey effort was conducted only in summer 2001-2002 on the west coast for

the present study. This movement pattern is supported by the increase in Bryde's whale encounters in Plettenberg Bay during summer and autumn, coinciding with increased feeding activity and availability of prey in the region (Penry et al. 2011). Bryde's whales in Plettenberg Bay (~ 500km east of False Bay) were seen feeding most frequently in association with common dolphins and gannets (>55% of all associations) (Penry et al. 2011). Bryde's whales were the only whale species that were found to be linked to the sardine run on the east coast of South Africa (O'Donoghue et al. 2010). The similarity between Bryde's whale and common dolphin distribution in this study suggests that the presence of Bryde's whales in False Bay and other areas in the Western Cape is likely driven by the presence of prey availability. The peak occurrence of Bryde's whale sightings during winter in the False Bay region could be related to high effort since the majority of sightings was provided by a platform of opportunity source which conducted most trips during winter. Equal effort throughout the year is required to establish if a real temporal pattern exists in the region.

Southern right whales are seasonal visitors to the South African coastline during winter and spring to calve and mate (Best 2000). There has been a lot of research effort focused on right whales, from aerial surveys which had a western limit of Muizenberg, and more recently Vinding et al. (2015) which focused around the Dyer Island area. There is also data from the feeding grounds on the west coast (Barendse and Best 2014) at the northern limit of this study area where the general pattern is year-round presence with a peak during the winter breeding season and a general westward movement over the season showing an increase in sighting rate from winter to summer (Barendse and Best 2014). Our results indicated that southern right whales were present throughout the study area with the majority of sightings located close to shore, supporting existing knowledge of its distribution in South Africa (Elwen and Best 2004). Best (2000) stated that the entire coast of South Africa could be considered as one homogenous population of southern right whales during winter and early spring. Gaps in

sightings along the coast between Hout Bay and Cape Point and between Cape Hangklip and Walker Bay were mostly likely due to low observer effort in these fairly isolated areas. Most sightings were in bays, which seem to be the preferred habitat due to being sheltered from the open ocean, providing protection of calves and less energetic expenses for lactating cows and newborns (Elwen and Best 2004). In general there was a strong consensus between data sources in terms of both regions and timing of occurrence with peak occurrence from June-September/October. This seasonal occurrence is typical of that seen elsewhere on the South African coast in the main breeding and calving areas (Best 1990; Vinding et al. 2015). On the west coast between Hout Bay and Table Bay, the high occurrence of southern right whales during other seasons is probably due to animals feeding, which has been previously documented (Best and Mate 2007; Barendse et al. 2010). It is possible these whales do not take the annual migration to the feeding grounds if there is a food source on the west coast sufficient to sustain them. Future studies assessing the presence and abundance of southern right whale prey species on the west coast could provide useful insight into future movement patterns.

Humpback whales have relatively predictable migrations whereby they feed in the Antarctic Polar Regions during summer and migrate to warmer waters off South Africa during winter to reproduce (Barendse et al. 2010). Of the seven different breeding stocks recognized globally by the International Whaling Commission, breeding stock B migrates between breeding grounds off the west coast of Africa and the Southern Ocean (Findlay et al. 2017). It has been suggested that the majority of the humpback whale population migrates offshore along the Walvis Ridge to the west of the southern Benguela region (Rosenbaum et al. 2014). At the northern limit of southern hemisphere humpback whale migrations, Rasmussen et al. (2007) found a direct correlation between sea surface temperature and the location of wintering areas, indicative that warmer waters are essential in defining winter breeding

migration patterns. The prevailing cold temperate oceanographic conditions in the Benguela Upwelling System off the west coast of Southern Africa results in the breeding grounds on this coast being significantly further north than off the east coast. In this study, all sources indicated that the majority of humpback whale occurrences were in False Bay and on the west coast. Most data obtained supported the migration season, throughout the study area, which means the majority of whales were likely breeding. However there were humpback whale occurrences towards the west coast during summer, supporting the feeding season. Humpback whales appeared to be less seasonal than southern right whales with more presence throughout the year. This is likely due to feeding off the west coast during late spring and early summer, which has become a relatively common occurrence (Findlay et al. 2017). It is suggested that the occurrence of humpback whales in the Western Cape is due to the area acting as a migratory corridor, and also providing an adequate food source in some areas.

This study provided evidence which illustrated the power and effectiveness of citizen science. The results obtained highlight False Bay as an important habitat for most cetacean species. It is therefore important to monitor these cetacean populations and any current or potential anthropogenic threats. The abundance and distribution of prey species is also an important factor for cetacean distribution. The limited knowledge and research of cetaceans in South Africa clearly highlights the need for the on-going collection of opportunistic sightings data.

While there are potentially significant biases associated with opportunistically collected data from different sources, the information provided is still valuable and can be used to identify research areas requiring more attention. One of the primary challenges of this study was not always being able to validate whether a species was correctly identified, as many records did not include photographs. To address this, the sightings from opportunistic sources were compared to sightings collected by professional scientists and were used to validate the

opportunistic sightings results. I found that the online sighting submission platforms, particularly Facebook, was useful for guiding and informing citizen scientists on the correct species name. When a sighting with a species name and picture was submitted, all other citizen scientists were able to see, and this increased the ability for other citizen scientists to correctly identify a species. Furthermore, citizen scientists who submitted sightings without a photograph were often asked to describe the animal (colour, size, group size, location), and based on this I was able to determine which species they encountered. I would then forward a picture of the respective species and ask to confirm if it was what they saw. Training more observers to effectively identify and report cetaceans will be useful for future studies and increase the quality of the data. Citizen science can be used as a stepping stone for initiating more structured scientific research, potentially identifying issues that even scientists may have failed to notice.

It could be useful to incorporate artificial intelligence and machine learning in future cetacean monitoring within the study region. Artificial intelligence is increasingly being used to track and study wildlife populations (Di Minin et al. 2018; Nuñez et al. 2018). New developments in artificial intelligence use algorithms to analyse photographs provided by citizen scientists and identify individual whales using pictures of their fins or flukes (Lopez 2017; Harlow 2018; Winters 2018). This enables scientists to identify individual whales while also tracking their movement, population and trends (Lopez 2017; Harlow 2018; Winters 2018). This type of technology would be particularly valuable in the Western Cape and other regions in South Africa, where cetacean distribution information is limited.

It is suggested that in future studies, more effort is concentrated between the eastern region of False Bay and Walker Bay as well as between Cape Point and Hout Bay, where the least effort occurred. Future research could focus on comparing reliable and consistent



environmental data to cetacean occurrence in order to predict future changes in response to climate change.

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2.7 Figures

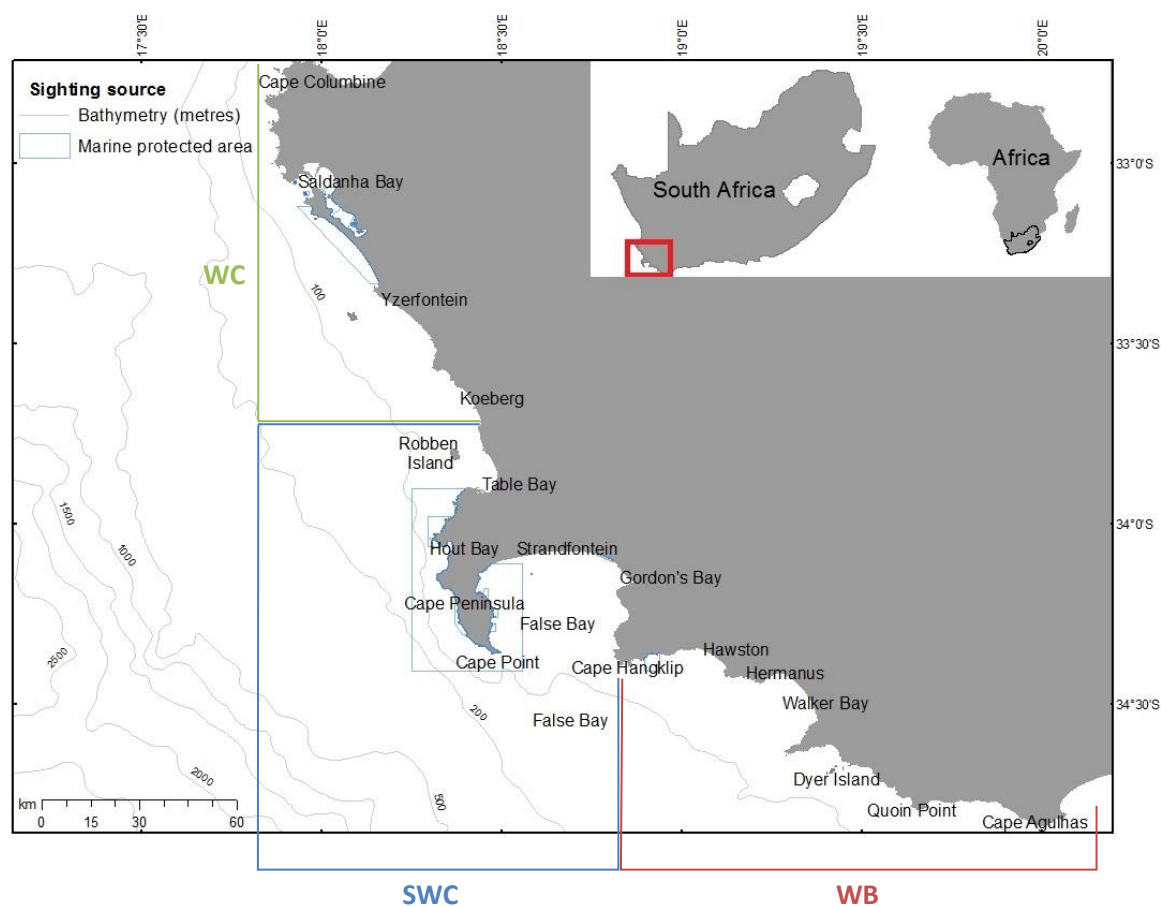


Figure 2.1: Map of the study area in the Western Cape, South Africa. The three area zones for temporal analysis in this study are shown: WB (Walker Bay and surrounding areas), WC (north of Table Bay) and SWC (the area between WB and WC).

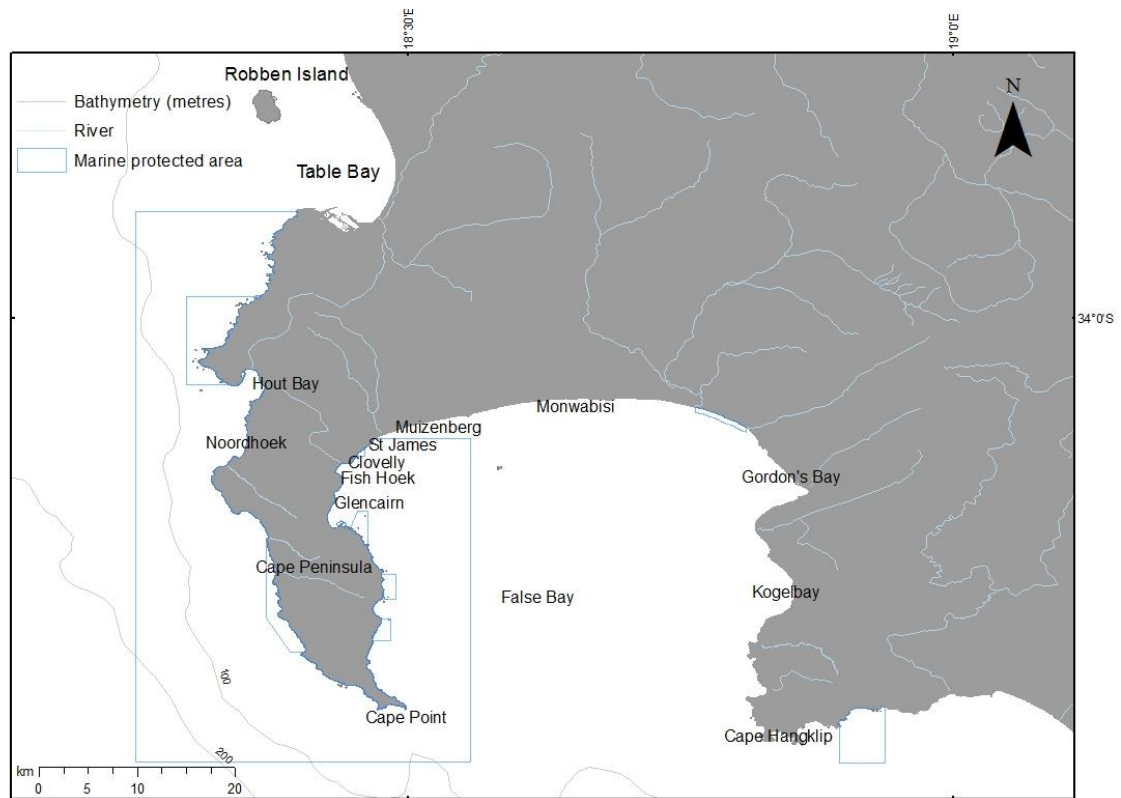


Figure 2.2: Map of Shark Spotter locations in the Western Cape, South Africa.

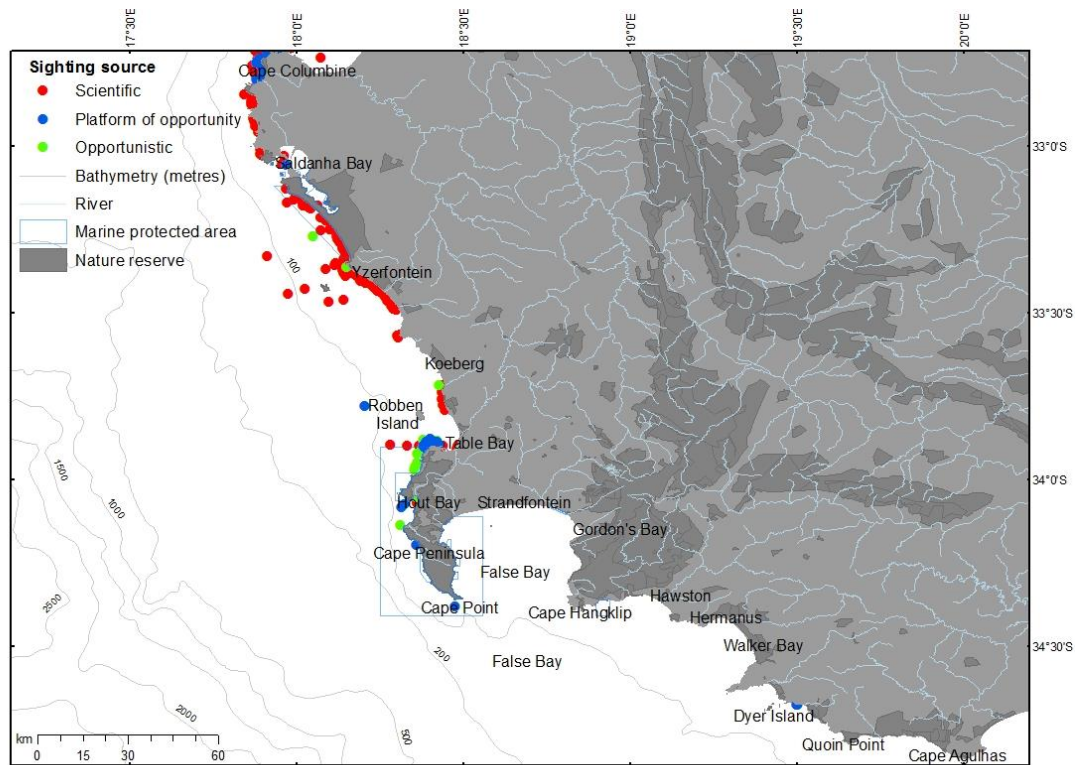


Figure 2.3: The distribution of Heaviside's dolphin *Cephalorhynchus heavisidii* sightings collated from different sources in the Western Cape, South Africa.

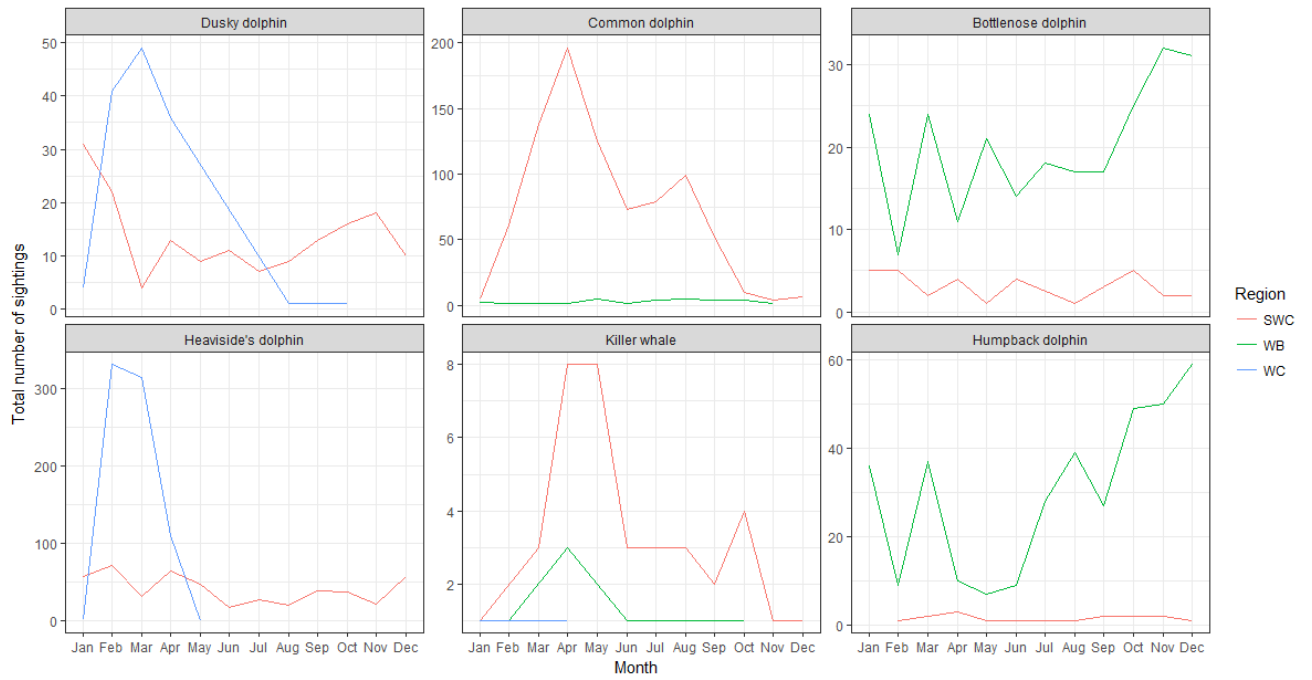


Figure 2.4: The total number of dolphin sightings during each month in different regions in the Western Cape, South Africa. SWC: Table Bay – False Bay, WB: Walker Bay – Cape Agulhas and WC: West Coast.

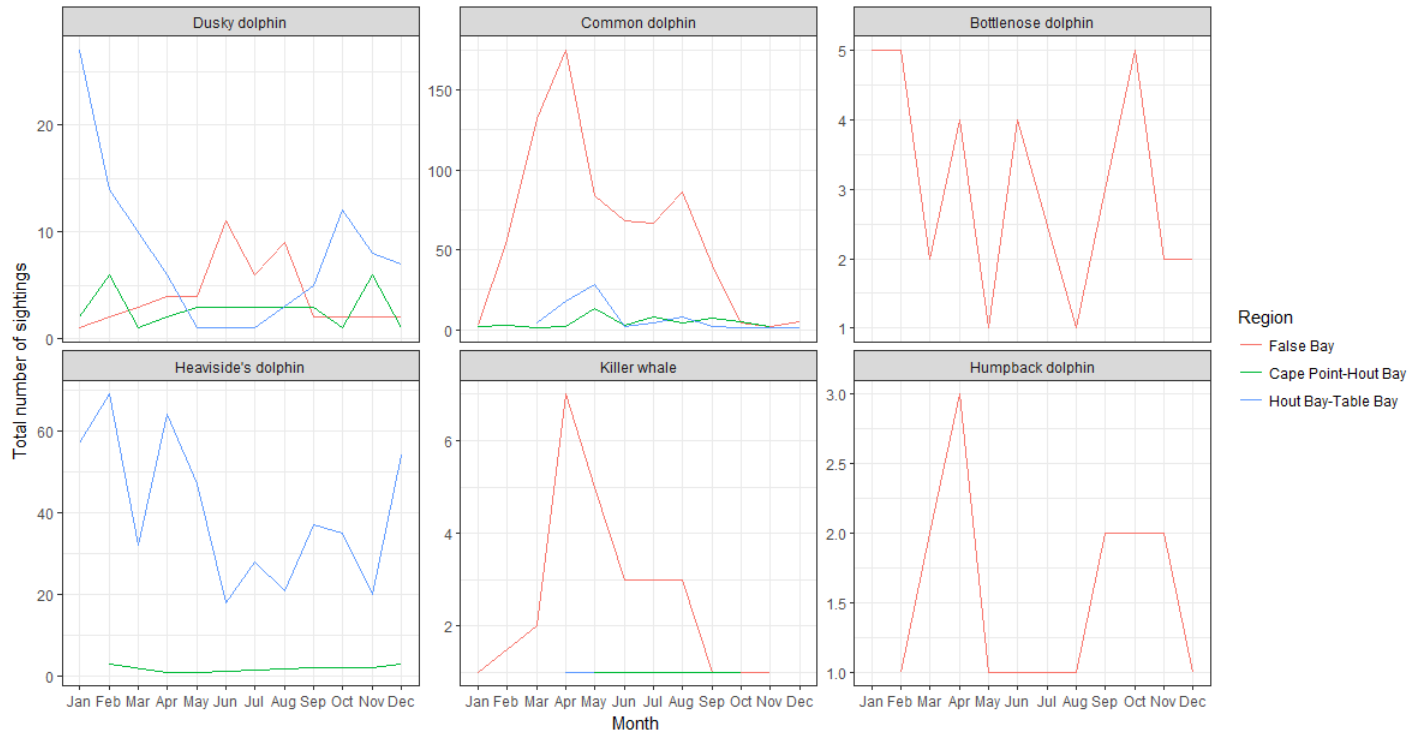


Figure 2.5: The total number of dolphin sightings during each month in different regions within the south western Cape (SWC), South Africa.

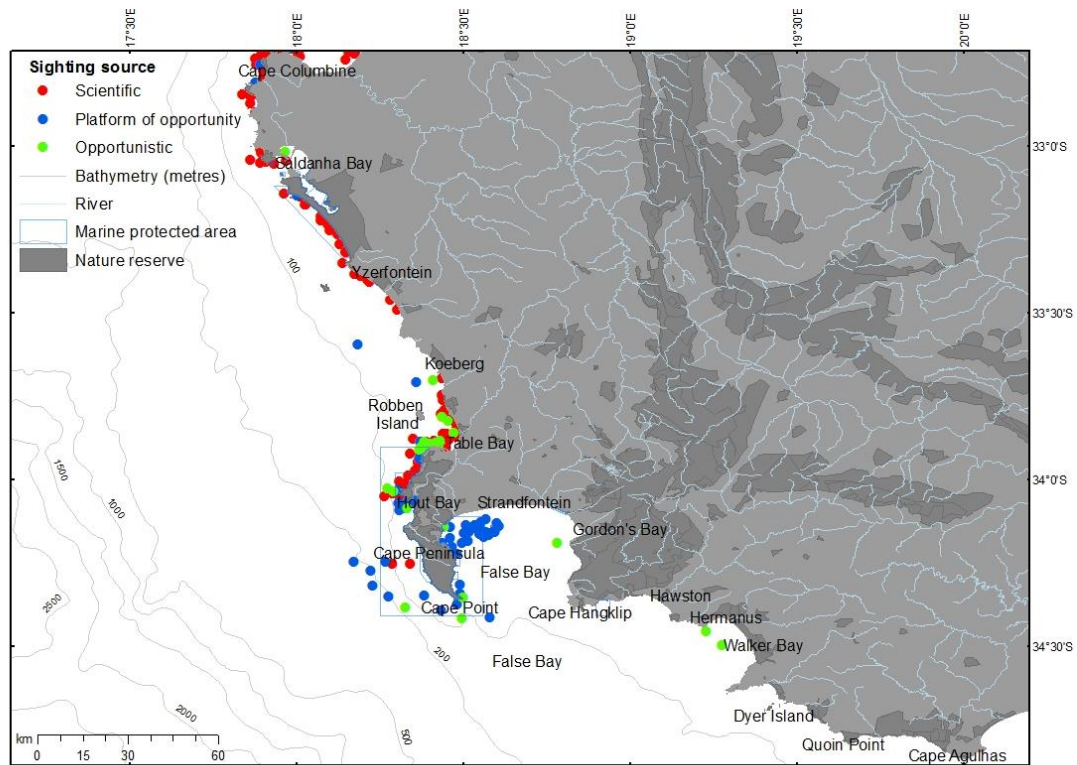


Figure 2.6: The distribution of dusky dolphin *Lagenorhynchus obscurus* sightings collated from different sources in the Western Cape, South Africa.

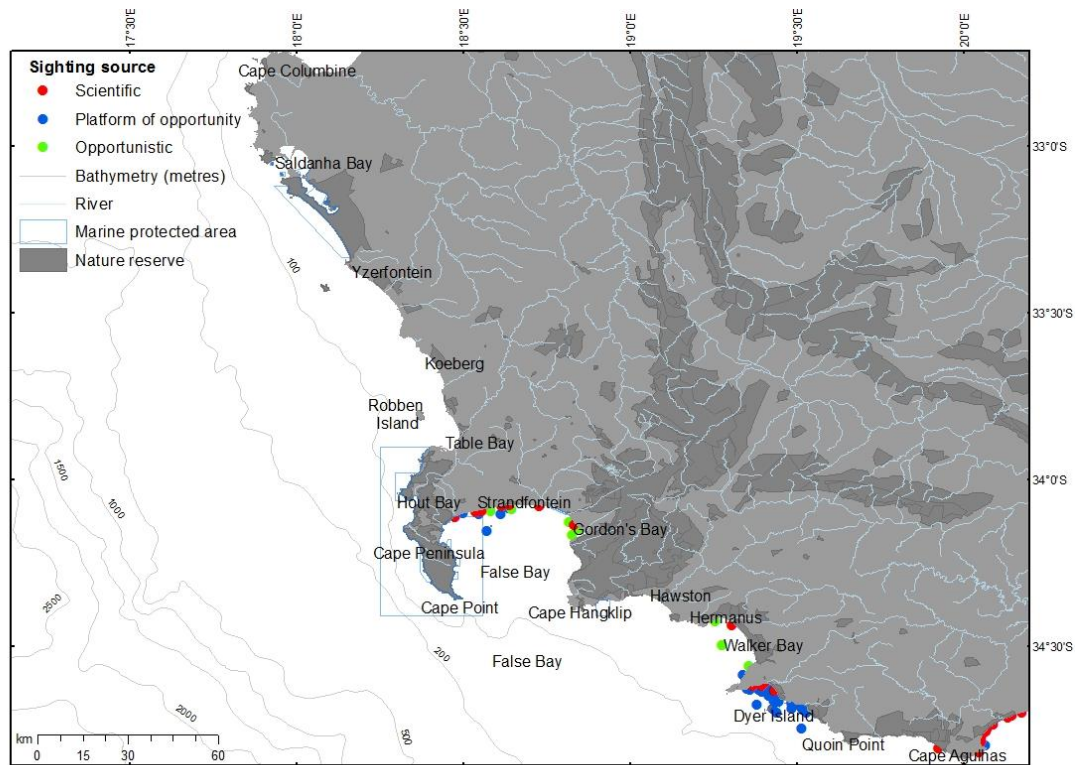


Figure 2.7: The distribution of humpback dolphin *Sousa plumbea* sightings collated from different sources in the Western Cape, South Africa.

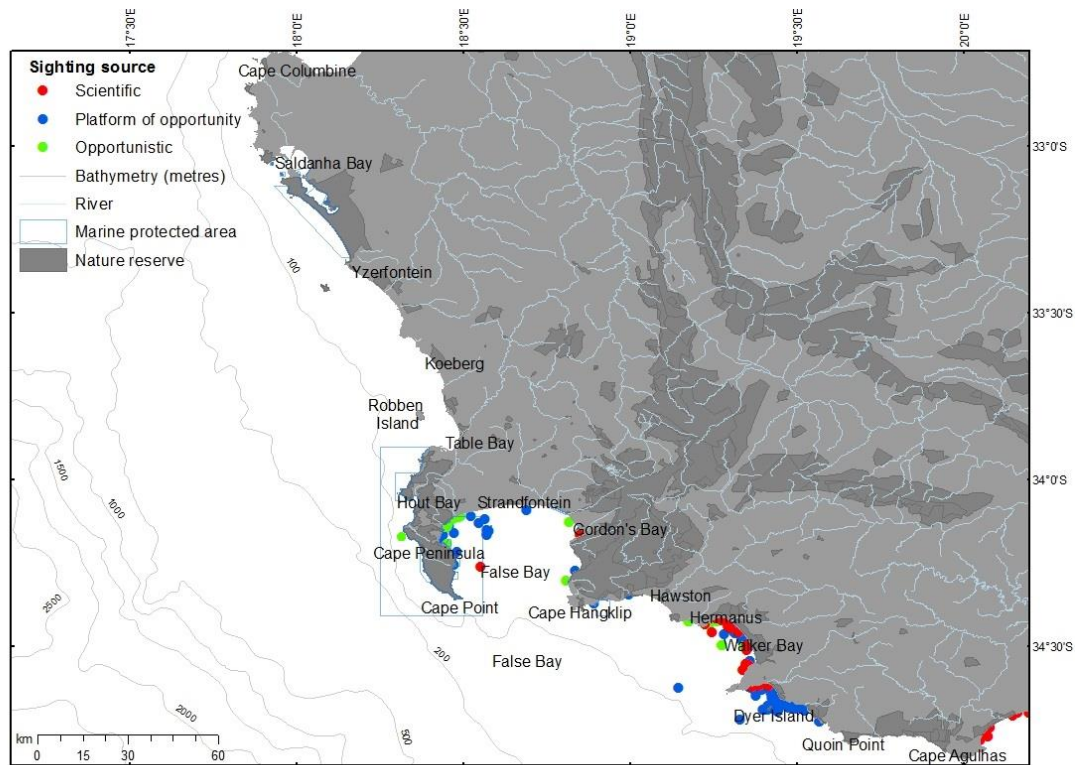


Figure 2.8: The distribution of bottlenose dolphin *Tursiops aduncus* sightings collated from different sources in the Western Cape, South Africa.

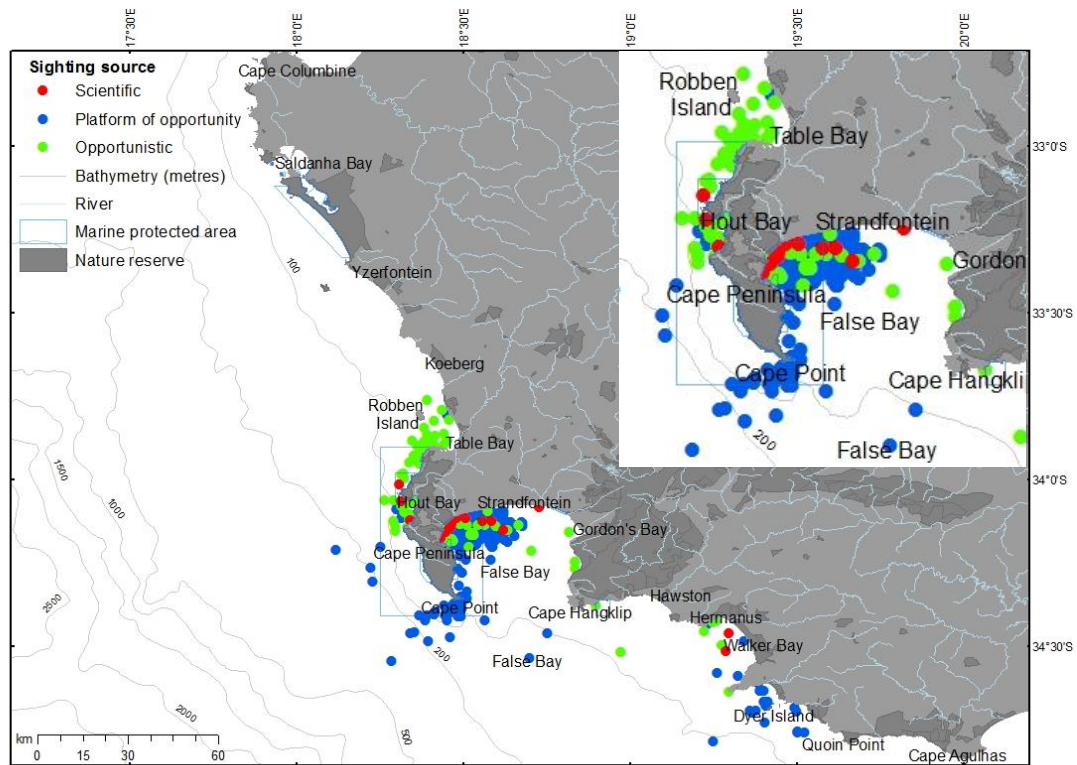


Figure 2.9: The distribution of common dolphin *Delphinus delphis* sightings collated from different sources in the Western Cape, South Africa.

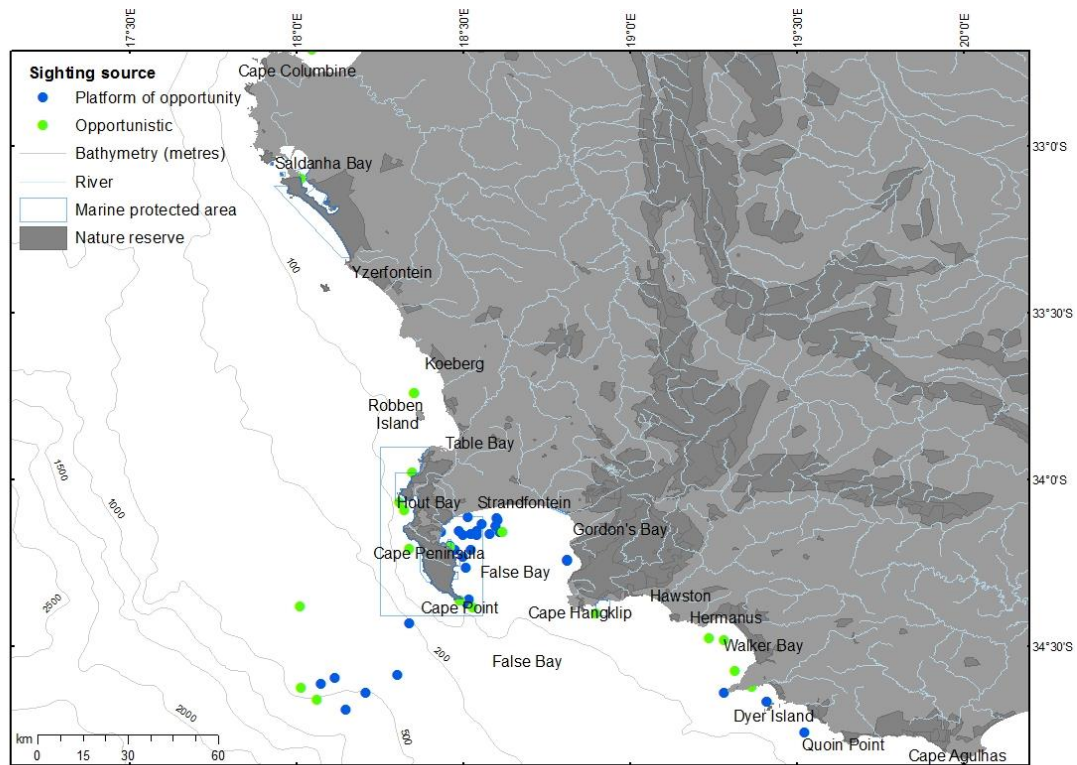


Figure 2.10: The distribution of killer whale *Orcinus orca* sightings collated from different sources in the Western Cape, South Africa.

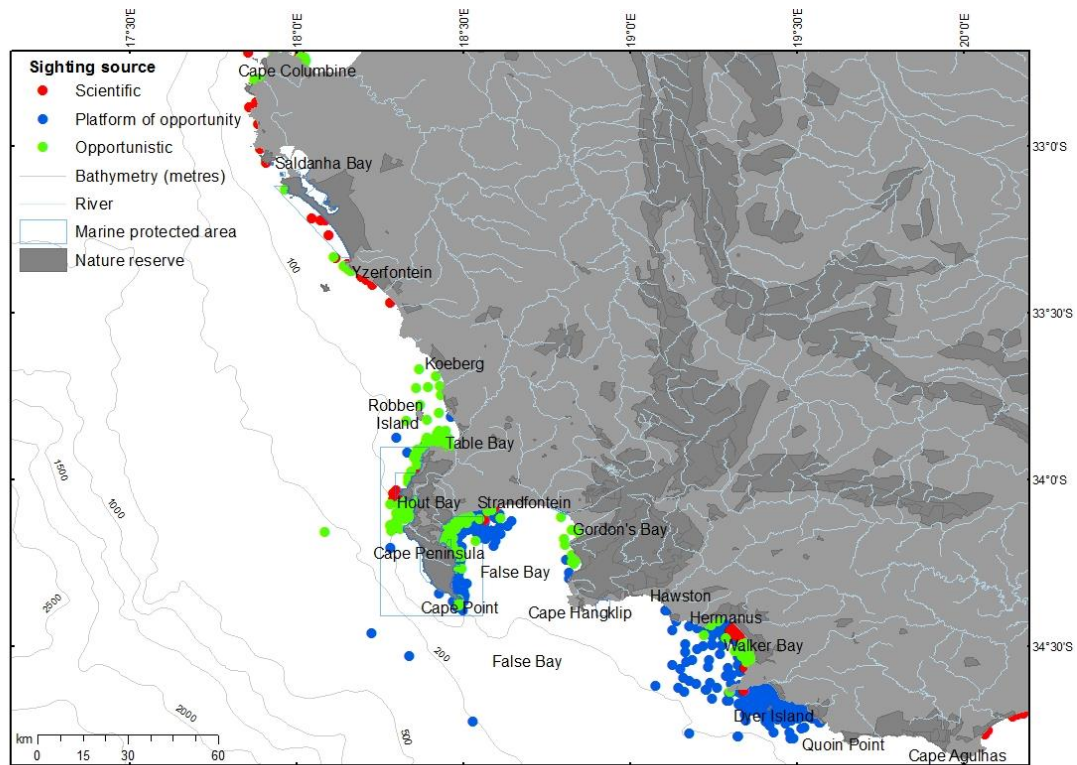


Figure 2.11: The distribution of southern right whale *Eubalaena australis* sightings collated from different sources in the Western Cape, South Africa.

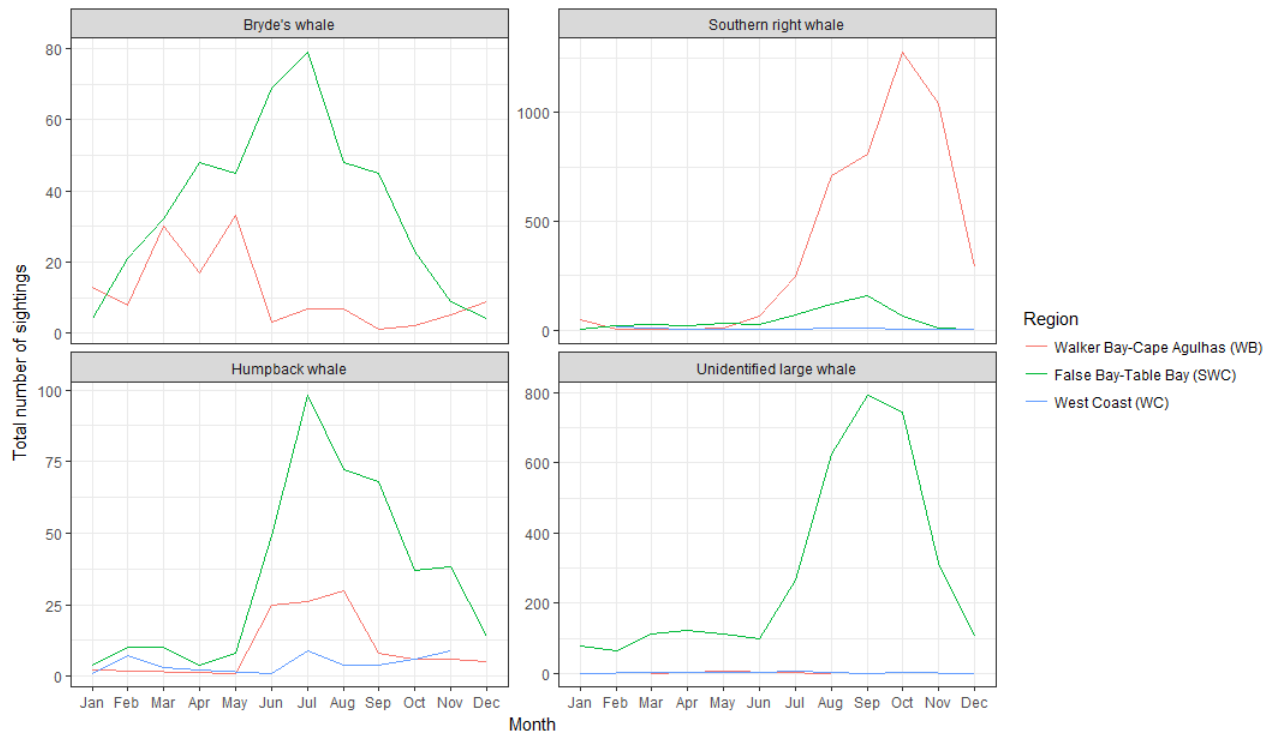


Figure 2.12: The total number of whale sightings during each month in different regions in the Western Cape, South Africa.

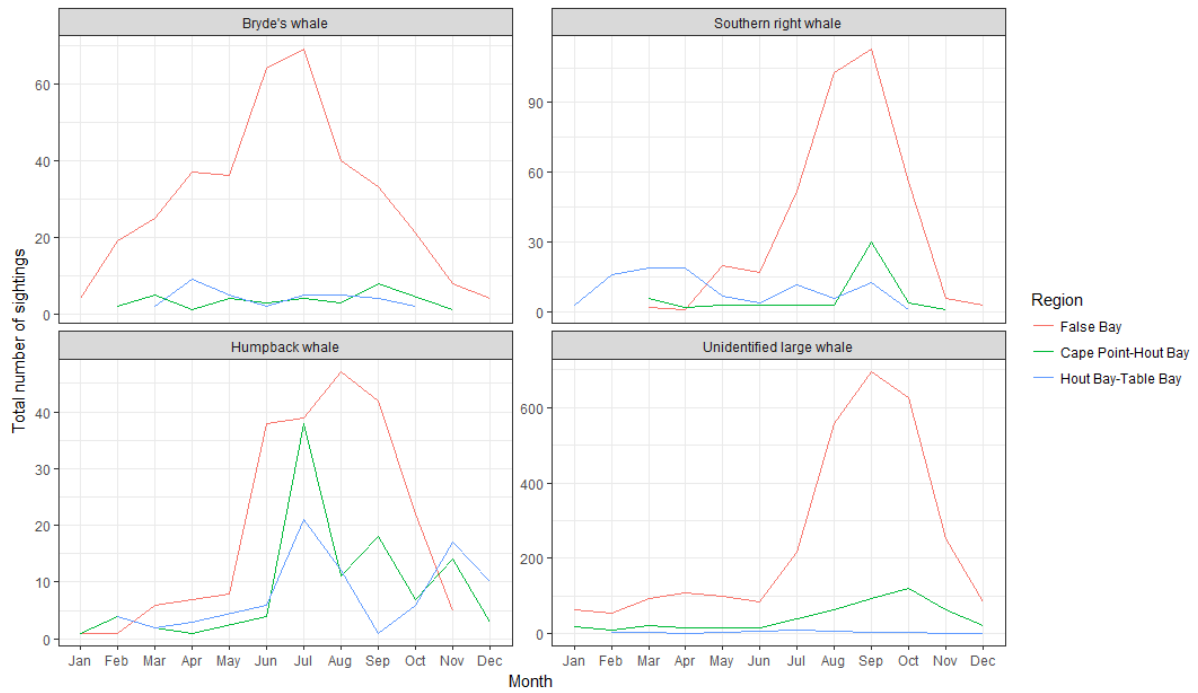


Figure 2.13: The total number of whale sightings during each month in different regions within the south western Cape, South Africa.

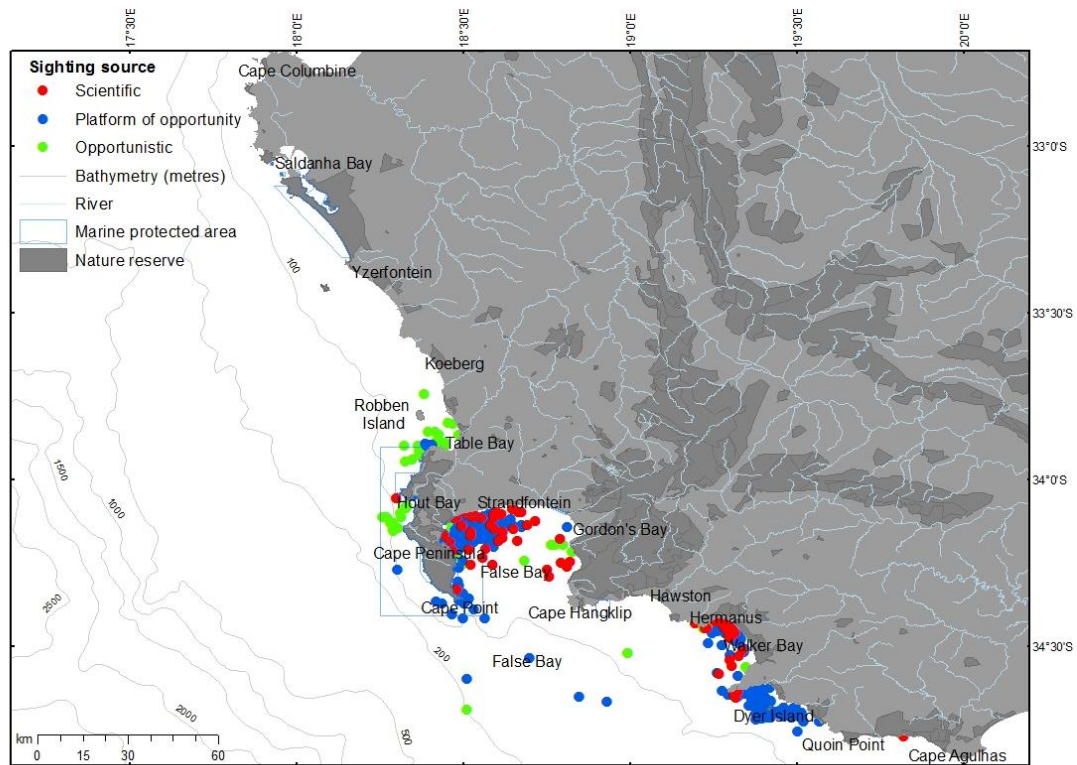


Figure 2.14: The distribution of Bryde's whale *Balaenoptera brydei* sightings collated from different sources in the Western Cape, South Africa.

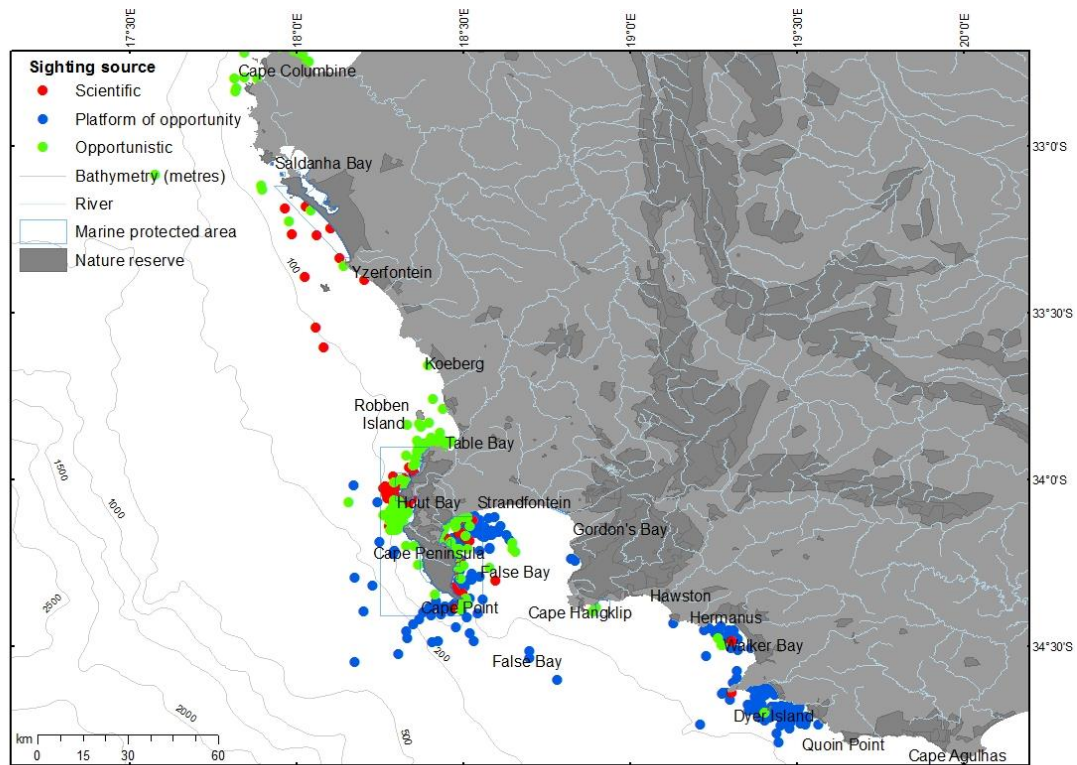


Figure 2.15: The distribution of humpback whale *Megaptera novaeangliae* sightings collated from different sources in the Western Cape, South Africa.

Chapter 3: Spatio-temporal patterns of cetaceans using Local Ecological Knowledge in the Western Cape, South Africa

3.1 Abstract

There has been increasing use of citizen science to study cetacean distributions since they are highly mobile animals and expensive to study. This study investigated spatial and temporal occurrences of cetacean species in the Western Cape of South Africa using data generated from local knowledge from experienced water users. The study focused on the five dolphin species which most frequently occurred in the region which included the dusky dolphin (*Lagenorhynchus obscurus*), Heaviside's dolphin (*Cephalorhynchus heavisidii*), common dolphin (*Delphinus delphis*), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and Indian Ocean humpback dolphin (*Sousa plumbea*). Whale species investigated included the Bryde's whale (*Balaenoptera brydei*), southern right whale (*Eubalaena australis*) and humpback whale (*Megaptera novaeangliae*). Interviews were conducted with 55 water users who had significant experience with the ocean and cetaceans ranging from 3 to 50 years of experience. Total cumulative days at sea ranged from 120-13 800 with an average of 3546 days per interviewee. The interviewees provided spatial and temporal information for each species they encountered as well information on their "search effort" as typical hours at sea per trip and per month. Spatial occurrence of each species (areas of high occurrence) was captured by interviewees drawing onto paper maps which were digitized, georeferenced and analysed using GIS. Temporal occurrence was captured by interviewees providing a probability estimate (%) of sighting a species during different months of the year. Most of the results obtained supported existing knowledge of the species' distribution range in South Africa. Results provided insight into seasonality and suggested that humpback whales are less seasonal than they used to be, occurring regularly throughout the year. Common dolphins occurrence peaked in March to May, likely linked to bait fish availability. Results suggested

that False Bay is an important habitat area for cetaceans and as such must be managed effectively to ensure the future conservation of local cetacean species.

Key words: climate change, cost-efficiency, distribution, dolphin, geographic information system, habitat use, interview, whale

3.2 Introduction

Wildlife populations change in size and distribution over time for a range of reasons.

Monitoring and identifying the cause of these changes forms the basis of conservation (Evans and Hammond 2004). Quantitative data on habitat use, movement patterns, population dynamics as well as relationships to the environment are required for effective conservation strategies (Gilchrist et al. 2005). Such data are often not available or are insufficient, especially in remote or isolated areas, most often due to the costly logistic constraints of conducting scientific research (Anadon et al. 2009). Local resource users who depend on nature for their livelihoods have a close relationship to the environment and natural resources; and from their observations, needs and experiences have developed a precise and detailed knowledge of local environmental conditions and ecological relations (Davis and Wagner 2003). Local ecological knowledge (LEK) is the term coined for this type of information and it is often passed down from generation to generation within a local community (Begossi 1995; Diegues 2002). LEK is increasingly being used to supplement natural resource management strategies and provides benefits to the natural resource users themselves by strengthening their cultural values, providing them with a political say, being acknowledged by managers and improving communication with managing authorities (Moller et al. 2004; Renato et al. 2008).

LEK has been used to answer research questions and obtain useful information in both terrestrial and marine contexts. LEK has been used to map the spatial and temporal

distribution of conflict between humans and carnivores by interviewing key informants (Mogwera et al. 2015), estimate the abundance of tortoises by interviewing shepherds (Anadon et al. 2009), obtain accurate maps based on memory of the substrate of a freshwater lake by interviewing fisherman (McKenna et al. 2008), identify sightings patterns of live and dead manatees by interviewing fisherman (Mayaka et al. 2015) and obtain valuable information on reproduction and migration of commercially important coastal fish species by interviewing artisanal fisherman (Silvano et al. 2006). LEK results compared well with scientific data and were substantially cheaper to obtain (Silvano et al. 2006; McKenna et al. 2008; Anadon et al. 2009; Mogwera et al. 2015).

The value of LEK in southern Africa has been recognised in the fisheries research community (Kalanda-Sabola et al. 2007; Blythe et al. 2013; Ratsimbazafy et al. 2016) and in terrestrial conservation communities (Phuthego and Chanda 2004; Gandiwa 2012) but has not yet been applied widely to cetacean research despite its great potential. Cetaceans are highly mobile animals and as such their spatial and temporal distribution patterns are difficult and typically expensive to study. Fishing communities can provide both theoretical and practical information on ecological and biological aspects of cetaceans based on their observations and interactions with them over time (Costa-Neto 2000; Zappes et al. 2013). LEK data derived from interviews with fisherman have been used to assess spatial and temporal patterns of the endangered Indo-Pacific humpback dolphin (*Sousa chinensis*) (Wang et al. 2016), identify the cause of population decline and subsequent extinction of the Yangtze River dolphin (*Lipotes vexillifer*) (Turvey et al. 2010) and identify interactions and conflicts between fisheries and the southern right whale (Zappes et al. 2014). Results were comparable to scientific survey findings and provided insight that has helped motivate for future conservation actions (Turvey et al. 2010; Zappes et al. 2014; Wang et al. 2016).

South Africa is a hotspot for cetacean diversity yet most cetacean species are not well studied (Elwen et al. 2011). To date there have been no published articles on the effect of climate change on cetaceans in South Africa. There is a need for the assessment of cetacean distributions in the region. Many cetaceans are apex predators in the ocean and play an active role in controlling lower trophic level populations (Roman and McCarthy 2010). Monitoring species at the top of the food web aids in conserving the entire food web below it (Bearzi et al. 2010). Coastal dolphin species consume many of the same sources of food as humans do and are important indicators of overall ecosystem health and pollution (Bearzi et al. 2010).

The Western Cape province of South Africa is a unique area to study cetacean research as it straddles two different oceans and ecosystems, the Atlantic Ocean on the west coast and the Indian Ocean on the east coast, and has correspondingly high species diversity. This contrast of ecosystems from one coast to the other creates a mosaic of habitats for fauna and flora resulting in rich biodiversity and subsequent biogeographic boundaries which are of interest in this study. Cetacean species found in the study area include five dolphin species; namely the dusky dolphin (*Lagenorhynchus obscurus*), Heaviside's dolphin (*Cephalorhynchus heavisidii*), common dolphin (*Delphinus delphis*), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), Indian Ocean humpback dolphin (*Sousa plumbea*) and three whale species; namely the southern right whale (*Eubalaena australis*), Bryde's whale (*Balaenoptera brydei*) and humpback whale (*Megaptera novaeangliae*). Bottlenose dolphin throughout this chapter refers to the nearshore species (*Tursiops aduncus*) and not the common bottlenose dolphin *Tursiops truncatus* which has an offshore distribution in South African waters. The killer whale (*Orcinus orca*) is a rarely encountered species in the study area but was also included in the study. Data on cetacean distribution and seasonality from this region is surprisingly sparse (Elwen et al. 2011), with much of the knowledge of range limits generated from strandings databases.

LEK provides a complementary technique to scientific surveys at a fraction of the cost and effort. This study aimed to map the distribution of cetacean species in the Western Cape of South Africa using LEK, essentially to understand the environmental factors limiting their distribution. This chapter forms part of a larger study which used small boat surveys, acoustic monitoring and opportunistic data to understand cetacean range limits. This study could provide a cost-effective method to identify important cetacean habitat areas.

3.3 Methods

3.3.1 Study area

The focus areas for this study encompassed the biogeographic boundary around the Cape Peninsula and the Walker Bay area ~100 km south east. This area encompasses the main zone of differentiation between the cold Benguela upwelling ecosystem on the west coast and the transition zone on the southern Cape coast (as far as Cape Agulhas) (Figure 3.1). There was an exception for some areas surrounding Walker Bay where six interviews were conducted. (Refer to chapter 1 for detailed description of the study area).

3.3.2 Ethical considerations

Ethical clearance for this study was approved by the Faculty of Humanities' Research Ethics Committee of the University of Pretoria. The ethics approval reference number is 15249213 (GW2017HS). A requirement for ethical clearance is that all interviewees sign a consent form prior to being interviewed. Refer to appendix 5 to view the consent form.

3.3.3 Interview procedure

Interviews were conducted from May-September 2017. The snowball sampling method (Bernard 2006) was used to identify and select interviewees to be interviewed. Potential interviewees were contacted via email and/or telephone as well as on social media platforms to inform them about the study and request their participation. If they agreed to participate a

date, time and location for the interview were decided upon by the interviewee. In a few cases potential interviewees were approached in person but most interviews were scheduled ahead of time. Suitable candidates were those people with several years of marine experience within the study area and ideally with some interest in the natural world. Interviewees mainly included experienced water users such as fisherman, tour operators, divers and conservationists. Interviewees were informed about the aim and scope of the study prior to agreeing to participate. Questionnaires were drawn up with considerable caution making sure not to ask interviewees any sensitive or unethical questions (Appendix 6). Interviews commenced after the questionnaire and consent form was approved by the Ethics Committee. Interviews were recorded with permission from the interviewee on a mobile smart phone using a voice memo recorder. At the start of the interview the researcher engaged with the participant in a friendly and conversational manner to explain the purpose of the study and allowed the participant to speak about his or her experiences. Interviewees were given a consent form to sign (Appendix 5) which detailed the purpose of the study, explained how the information they contributed would be used and to ensure their confidentiality and anonymity.

Data were captured on two types of forms by the interviewer during the interviews. Form 1 captured background information, effort, temporal patterns in sightings and environmental and biological changes (Appendix 6) and was filled in by the interviewer to ensure standardisation and legibility. Form 2 consisted of a series of maps of the study area to capture spatial data and was filled in by the interviewee under guidance from the interviewer (Appendix 7). A set of pictures of local cetacean species was available to aid in species identification (Heavisides, dusky, common, bottlenose and humpback dolphins and killer, Bryde's, southern right, humpback and minke whales).

To generate a proxy of temporal ‘search effort’, interviewees were asked about how many years they had been going to sea in the study area and how often they went out (the average number of days per month and hours per trip). To investigate temporal trends per species, interviewees were asked to estimate their probability of seeing a particular species at a monthly or seasonal scale throughout the year (either as a percentage or number between 1 and 10) and if they had noticed any population changes over time. Open ended questions relating to environmental and/or biological change over time were also asked to capture information outside of the above restricted data. Any unanswered questions were marked ‘999’ and ‘888’ was written when interviewees did not know the answer.

To capture spatial patterns interviewees were asked to outline the area they regularly cover at sea by drawing on the provided map using a black pen. The interviewee was guided to draw a polygon on the map showing where their effort was concentrated. On the same map interviewees were asked to indicate where they encounter different cetacean species on a regular basis making mention of any hotspot areas. A polygon was then drawn for each species the participant encountered to indicate where they are most encountered. Sporadic sightings of species were also recorded on the map as points. A different colour pen was used for each species. Pens were labelled with the name of the species to assist the researcher with the analyses.

3.3.4 Interview data processing

The researcher created a unique interview ID for each participant (LEK01 to LEK55). After each interview, the completed questionnaire, maps and consent form was scanned in order to back up data with digital copies and to prepare the data for analyses. All data obtained from the interview was entered into a Microsoft Access database, except for the maps which were stored as jpg images.

The jpg map output files were loaded into ArcMap 10.3.1 for georeferencing. The geographic coordinate system GCS_WGS_1984 was used for all spatial analyses. A South African country shapefile available from Department of Environmental Affairs, South Africa was used for georeferencing. In ArcMap the Georeferencing toolbar was activated and auto adjust was unchecked. The country file was zoomed to the study area which the jpeg image needed to match. The Fit to display option was selected on the Georeferencing toolbar. Multiple control points were then used to align the image with the map until the scanned image matched the country shapefile. Control points refer to points in common on the scanned map and the digital georeferenced map. The Update Georeferencing option was selected on the Georeferencing toolbar and resulted in the maps aligning.

The Draw tool in ArcMap was used to draw polygons and points on/over the georeferenced image to visualise the reported search effort, species occurrences and sporadic sightings provided by the interviewees. All features on the scanned image that needed to be digitized were traced with the drawing tool and each species polygon was converted to a shapefile by selecting the Convert Graphics to Features option. Each shapefile was labelled with the unique interview ID for each participant.

3.3.5 Data analyses

An index of total spatial search effort was calculated in two ways, as number of observers and as cumulative number of search (effort) hours for all observers combined. In ArcMap, the individual shapefiles for each interviewee's 'search effort' was merged and the Count Overlapping Polygons tool was used to count the number of overlapping polygons to show the distribution and concentration of effort across the study area. The cumulative number of effort days and hours for each participant was summed for each overlapping area and plotted in ArcMap to show the effort distribution by total days and total hours. For each species, all shapefiles (reported occurrences) were merged and the same tool was used to count the

overlaps. The resulting map illustrated where most interviewees saw a particular species and where potential hotspot areas were.

For temporal data, each interviewee recorded a value to estimate the probability of sighting a particular species during each month of the year. For every species, the monthly probability values provided by each interviewee were averaged and plotted using the program R (R 3.2.3). The sighting probability values derived from each interviewee for a particular species was averaged and plotted in R as line plots. For the temporal analyses, the study area was divided into region 1 (all areas around the Cape Peninsula from Table Bay to False Bay) and Region 2 (from Walker Bay to Dyer Island). Summer was considered as December, January and February; autumn as March, April and May; winter as June, July and August; and spring as September, October and November.

3.4 Results

Interviews were conducted with 55 interviewees (43 (78%) were male and 12 (22%) were female). There were 49 interviews conducted in Region 1 (Cape Peninsula from Table Bay to False Bay) and six interviews in Region 2 (Walker Bay to Dyer Island). Years of experience ranged from 3 - 50 years with an average of 16 years' experience (only one interviewee had three years of experience, all others had five or more). The earliest year an interviewee became an active water user was 1967 and the most recent was 2014. The type of activities undertaken by interviewees included tour related activities (38% of interviewees), marine research (24% of interviewees), observers such as shark spotters (20% of interviewees), leisure activities (15% of interviewees) and sea rescue (3%). The average number of cumulative hours was 9144 hours at sea ranging from 960 to 53 760 hours per interviewee (Figure 3.2). Total cumulative days at sea ranged from 120-13 800 with an average of 3546 days per interviewee. Interviewee effort was more concentrated around Cape Point, the western part of False Bay from Strandfontein to Cape Point and in nearshore waters of Table

Bay (Figure 3.3). It is important that results are interpreted with this bias in mind. In the below results n refers to the number of interviewees.

Heaviside's dolphins were reported by 30 out of 55 (54%) interviewees. All reported occurrences of Heaviside's dolphins were on the western side of the Cape Peninsula between Hout Bay and to the north of Table Bay with the majority of interviewees indicating high occurrences close to shore on the western side of Table Bay (Figure 3.4). There were a few sporadic sightings in False Bay (all in summer and prior to 2000 except for four sightings recorded in 2015) and two sightings south of Hout Bay near Cape Point. Only one report of a Heaviside's dolphin occurred to the east of False Bay (a juvenile observed in Walker Bay in spring 2016). The majority of interviewees (39%) did not know if populations changed, 30% thought it remained constant, 22% thought the population increased and 9% did not answer. Interviewees who encountered them regularly reported that they were usually in small groups of 2-7 individuals. There were 55% of interviewees who said they were more common in the morning than other times of the day. No environmental patterns were recorded. All interviewees who reported occurrences of Heaviside's dolphins in Table Bay and were able to provide sighting probability values ($n=20$) reported that they were encountered throughout the year (Figure 3.5) with an average sighting probability in summer, autumn, winter and spring of 70%, 66%, 60% and 77% respectively. The three interviewees who reported Hout Bay encounters all indicated low sighting probabilities (annual average probability of 0.7%). The probability of sighting Heaviside's dolphins in Walker Bay was zero.

Dusky dolphins were reported by 38 of 55 (69%) interviewees and were most commonly observed on the west side of Table Bay, around Cape Point and in the western side of False Bay (Figure 3.6). Only two sightings were reported east of False Bay, 100 dolphins in Walker Bay in 2012 and another two sightings by another participant near Walker Bay in 2003. Seven of the 10 interviewees who reported dusky dolphin occurrences in False Bay, reported

seeing them “only a few times”, suggesting occurrence is rare. A quarter of interviewees thought dusky dolphin populations were declining (25%), 32% did not know, 24% thought it remained the same, 11% did not answer and 3% thought it was increasing. No group size or diurnal patterns were recorded. There were 39% of interviewees who mentioned that dusky dolphins were driven by fish presence. Interviewees reported relatively low sighting probabilities of dusky dolphins (Figure 3.5) with a seasonal breakdown of 24%, 14%, 9% and 13% for summer, autumn, winter and spring respectively, which accounts for reports across all regions (n=28). There was a higher reported probability of sighting dusky dolphins in summer than in winter. For the four interviewees who reported probability values for False Bay, an average annual probability of 2.6% was reported. The reported probability of sighting dusky dolphins in Walker Bay was zero.

Only 10 out of all 55 interviewees (18%) reported seeing humpback dolphins. All reports were east of the Cape Peninsula. Four of the 10 interviewees encounter them ‘rarely’ in the nearshore waters on the north coast of False Bay (Figure 3.7). All interviewees in the Walker Bay area (n=5) reported occurrences, but also rarely. One interviewee encountered these dolphins in Kleinbaai on a regular basis. There were too few occurrences to report on population increases or decreases. Of the 10 interviewees, four described the average group size to range from 1-6 dolphins. No diurnal or environmental patterns were reported. Sighting probability in False Bay (n=6) in summer, autumn, winter and spring was 14%, 12%, 8% and 6% respectively (Figure 3.5). The average sighting probability for Walker Bay and surrounding areas (n=4) was 1% during all months. Sighting probabilities were much higher in Kleinbaai (n=1) with 65%, 45%, 35% and 65% reported for summer, autumn, winter and spring.

Bottlenose dolphins were reported by 31 out of 55 interviewees (56%) with regular encounters in Walker Bay and Kleinbaai and less regularly in False Bay. Only two records

west of Cape Point were noted, just to the south of Hout Bay (Figure 3.8). Occurrences in False Bay were infrequent and mainly close to shore along the northern coast. In Walker Bay and Kleinbaai bottlenose dolphins occurred both inshore and throughout the bay. No pattern was recorded for population increase or decrease, group size, diurnal patterns or environmental patterns. Seasonal patterns in encounter probability were similar in all bays with the highest occurrence in summer (Figure 3.5). Reported encounter probability values for False Bay (n=21) in summer, autumn, winter and spring was 19%, 11%, 12% and 13% respectively. In the Walker Bay region the average sighting probability (n=6) was 43%, 28%, 34%, 30% for summer, autumn, winter and spring.

Common dolphins were reported by 50 out of 55 interviewees (91%). Common dolphins were the most widely distributed dolphin species in the study area from Table Bay to Kleinbaai, although the highest occurrences were in the north western part of False Bay near Seal Island (Figure 3.9). Common dolphins were more pelagic in their distribution than bottlenose and humpback dolphins. The majority of interviewees (50%) thought common dolphin populations were increasing, 26% thought they remained constant, 14% did not know, 6% did not answer and 4% thought they decreased. No group size or diurnal patterns were recorded. There were 23 of 50 (46%) interviewees who said common dolphins were limited by where their prey was. Prey items interviewees have seen common dolphins feed on included horse mackerel (*Trachurus trachurus*), harders (*Liza richardsonii*), yellowtail (*Seriola lalandi*), anchovy (*Engraulis encrasicolus*), sardine (*Sardinops sagax*), redeye (*Etrumeus whiteheadi*), krill (*Euphausiacea* s) and maasbanker (*Trachurus capensis*). The average sighting probability for False Bay, Hout Bay and Table Bay (n=43) in summer, autumn, winter and spring was 28%, 38%, 19% and 18% respectively. In the Walker Bay region (n=5), sighting probabilities were 41%, 29%, 14% and 28% for summer, autumn, winter and spring (Figure 3.5).

Killer whales were reported by 16 of 55 (29%) interviewees (Figure 3.10), of which seven interviewees reported encountering them fewer than three times. No pattern was recorded for changes in population, group size or diurnal patterns. Seven interviewees reported that killer whales were in the region for hunting purposes and reported witnessing predation attempts on common dolphins, blue sharks (*Prionace glauca*) and seven gill sharks (*Notorynchus cepedianus*). Overall sighting probabilities were low (Figure 3.5) and only four interviewees provided sighting probabilities of killer whales, all for False Bay and Cape Point. Although there was no clear seasonality in killer whale occurrence, results indicated that the highest sighting probability on average was in summer (3%) and autumn (2%) with lowest probabilities in winter (0%) and spring (0%). The month with the highest sighting probability was January (4%), followed by March (3%). There was generally a higher sighting probability from December to April than other months of the year.

All 55 interviewees reported the occurrence of southern right whales in the study area. Right whales were reported throughout the study area with the highest concentration of occurrence close to shore in the north western part of False Bay, which is where effort was highest (36% of interviewees reported occurrences in this region) (Figure 3.11). The majority of interviewees (36%) thought populations were decreasing; 25% thought it was increasing with the exception of low numbers over the previous two years; 20% did not know; 9% did not answer and 7% thought populations remained constant. Of the interviewees who reported on group size, 89% (25/28) reported ranges between one and four animals. No diurnal patterns were recorded. There were 8 of 55 (15%) interviewees who reported witnessing southern right whales feeding. Results indicated a seasonal occurrence of southern right whales across all regions with sighting probabilities generally increasing from May and peaking between August and October (Figure 3.12). However there were 8 of 55 (15%) interviewees who reported sightings of southern right whales to be less seasonal than previously and to occur

more throughout the year. Seasonality was slightly different between the two regions with reported occurrence in False Bay, Table Bay and Hout Bay (n=48) to be 13%, 7%, 42% and 39% for summer, autumn, winter and spring respectively. In Walker Bay interviewees (n=6) reported sighting probabilities of 9%, 4%, 76% and 96% for summer, autumn, winter and spring.

Bryde's whale's occurrence was reported by 40 of 55 (73%) interviewees with most occurrences spread throughout False Bay (Figure 3.13). Occurrences to the west of Cape Point were rare. The majority of interviewees (33%) thought populations were increasing, 33% did not know, 15% thought they remained the same, 15% did not answer and 5% thought they declined. All interviewees who reported on group size (n=26) said Bryde's whales were mainly solitary or in pairs. No diurnal patterns were reported. There were 8/40 (20%) of interviewees who reported that Bryde's whale occurrence was linked to the presence of bait fish such as anchovy and sardine. Sightings were reported year round with no indication of seasonal trends in occurrence in False Bay and surrounding areas (Figure 3.12). The average sighting probabilities in False Bay, Hout Bay, Table Bay and surrounds was 25%, 26%, 25% and 24% for summer, autumn, winter and spring respectively with the highest probability in May (27%) and lowest in September and October (24%). In the Walker Bay region Bryde's whales were reported (n =5) to be more seasonal with a higher probability in summer (65%) and autumn (57%) than in winter (25%) and spring (36%).

Humpback whale occurrence was reported by 51 of 55 (93%) interviewees. Results indicated most occurrences were between Table Bay and the north western part of False Bay (Figure 3.14). Humpback whales were generally encountered throughout the study area but mainly concentrated south of Table Bay, south of Hout Bay and along the western corner of False Bay. The reported occurrences were further from shore and in more concentrated areas than southern right whales. The majority of interviewees (56%) thought humpback whale

numbers were increasing, 20% did not know, 8% thought it hasn't changed, 4% thought they were declining (one of these was from Walker Bay) and 4% did not answer. There were 8 of 51 (16%) interviewees who reported that humpback whales were occurring in much larger aggregations than in the past. No diurnal patterns were recorded. There were 7 of 51 (14%) interviewees who reported witnessing humpback whales feed on krill/plankton. Seasonality in False Bay, Hout Bay, Table Bay and surrounds (n=43) was reported as 29%, 11%, 29% and 35% for summer, autumn, winter and spring respectively with the highest sighting probability in November (27%) and lowest in April (10%). Results suggested less seasonality compared to southern right whales (Figure 3.12). There were 11 of 51 (22%) interviewees who commented on seeing them more often throughout the year than in the past. Interviewees in the Walker Bay area (n=5) reported humpback whale sighting probabilities of 4%, 0%, 36% and 12% for summer, autumn, winter and spring.

Cetacean species reported offshore Cape Point included the false killer whale (*Pseudorca crassidens* by two interviewees), pilot whale (*Globicephala spp* by three interviewees), Risso's dolphin (*Grampus griseus* by two interviewees) and common bottlenose dolphin (*Tursiops truncatus* by two interviewees, one of them reported only three sightings at the Cape Canyon in 30 years and the other encountered them once a year at least 20-60km SW of Cape Point). One interviewee reported common bottlenose dolphins inshore on the west coast between Saldanha Bay and St Helena Bay (~150km north of Table Bay) seen only in winter on five occasions over the last 10 years. In False Bay there was one interviewee who reported the occurrence of a minke whale (*Balaenoptera acutorostrata*) on one occasion in August 2016 and one interviewee reported the occurrence of pygmy right whales (*Caperea marginata*) in False Bay occurring only during summer months.

Most interviewees reported on at least some perception of environmental changes in the area. A change in wind patterns was reported by 28 of 55 (51%) interviewees, of which 21

suggested that the “South-Easter” (the predominant summer wind in the area) has changed. When change in the South-Easter was reported it was consistently that it was not as strong as it used to be and that its duration has extended. There were 7 of 55 (13%) interviewees who reported that the North-Wester wind was not as strong as it used to be and not as frequent in winter. There were 17 of 55 (31%) interviewees who reported that there were no changes in the wind and 10 of 55 (18%) responded that they did know whether there were changes or not. There were 12 of 55 (22%) interviewees who reported changes in sea temperature, although these were contradictory with seven interviewees reporting that it was getting warmer in False Bay and in the Cape Peninsula, and five suggested the area had cooled. Most interviewees (45%) did not report any major changes in temperature and 18 of 55 (33%) did not know.

There were 28 of 55 (51%) interviewees who reported changes in fish presence. It was mentioned by 7 of 55 (13%) interviewees that there was a lot less snoek. There were 6 of 55 (11%) interviewees who reported an overall increase in bait fish whereas 5 of 55 (9%) interviewees reported a lot less sardine in False Bay and Table Bay. There were 5 of 55 (9%) interviewees who mentioned harders used to be an extremely abundant fish in False Bay and now there are a lot less. There were 15 of 55 (27%) interviewees who did not notice changes in fish presence and 12 of 55 (22%) did not know whether there were any changes.

There were 13 of 55 (24%) interviewees who reported noticing changes in bird presence over the years. Five of the 13 interviewees reported a decrease in gannets and three of the 13 mentioned a huge population increase in cormorants. There were 30 of 55 (55%) interviewees who did not notice any changes in bird presence and 12 of 55 (22%) interviewees did not know whether there had been any changes.

3.5 Discussion

Local Ecological Knowledge is an extremely powerful tool. The LEK results obtained in this study provided valuable insight and baseline information of local cetacean species distribution. One of the main benefits of the approach was that it allowed me to effectively assess areas and times that would have been unavailable to me as a scientist due to logistical constraints, and effectively I was able to massively increase the survey effort including several years into the past. The single largest problem with the results in this study is that there was a clear bias in the spatial effort of interviewees towards Table Bay and the west side of False Bay, and I did not manage to achieve complete coverage across the study area. Effort was not accounted for mainly because many areas had only a single observer and would have resulted in a lot of 100% sighting rates. The results of reported cetacean distribution patterns must be interpreted in light of this bias.

This study clearly highlights an important habitat area for Heaviside's dolphins. The level of overlap among interviewees in comparison to where most effort occurred suggests confidence in the results obtained. The distribution information provided by interviewees supports existing descriptions of the species distribution range in South Africa (Findlay et al. 1992; Elwen et al. 2010) and knowledge of their general movement patterns (Elwen et al. 2006, 2010). However, Best (2007) describes the southern limit of the range as Cape Point based on an unconfirmed incidental sighting one mile east of Cape Point (Findlay et al. 1992), and one other unconfirmed sighting on the east coast (Cockcroft pers. comm. as cited in Best 2007). Based on findings in this study it is suggested that the southern limit of their range is more appropriately described as Hout Bay. Heaviside's dolphins are endemic to the Benguela Current Upwelling system and have a preference for sandy beaches, exposed headlands and areas where there are high availabilities of hake which is their primary prey (Sekiguchi et al. 1992; Elwen et al. 2010). The area off the Cape Peninsula where they do not

generally occur is exposed and rocky, possibly has low prey availability and is cold due to the upwelling cell (Elwen et al. 2010). These factors could all contribute to the region northwards being much more favourable for Heaviside's occurrence and the subsequent low occurrence in regions south of Hout Bay. The hotspot area where Heaviside's occur is close to shore and close to Cape Town harbour, an area that is associated with a lot of boat traffic and fishing activity offshore where Heaviside's dolphins feed. There is a concern regarding bycatch in inshore set-netting for Heaviside's conservation (Elwen et al. 2010). It is essential for on-going monitoring of Heaviside's dolphin occurrences and any potential conflict with human activities to ensure effective conservation.

Dusky dolphin occurrence ranged from the west of the study area as far south as False Bay, which supports existing descriptions of the species distribution range in South Africa (Findlay et al. 1992; Elwen et al. 2010). Highest dusky dolphin occurrence was in areas where most effort was conducted by interviewees, suggesting a potential bias in the results obtained. It is therefore not advisable to assume these overlap areas are 'hotspot' areas.

Dusky dolphins generally had a low occurrence, which further makes it difficult to identify specific geographic preferences. It is however evident that occurrence was more common on the west coast from Hout Bay to Table Bay. Dusky dolphins remain a poorly studied species in South Africa (Best and Mejer 2010). They usually occur in upwelling areas and their movement patterns are often linked to bait fish presence and abundance (Findlay et al. 1992; Sekiguchi et al. 1992). A previous study by Elwen et al. (2010) suggested dusky dolphins are seen less frequently than Heaviside's dolphins, have a less predictable distribution pattern than Heaviside's dolphins and prefer sandy rather than rocky shores, which is the same result this study obtained. This study however provided more detailed information at the southern limit of the species range and suggested a higher occurrence in summer also mentioned in Elwen et al. (2010). It is likely that this seasonal occurrence is linked to the wind induced

upwelling which occurs off the Cape Peninsula during the summer months and the associated availability of prey. Dusky dolphins among other species have been known to compete with fisheries and in South Africa the levels of bycatch are not known (Elwen et al. 2011). The temporal and spatial distribution of pelagic fish is likely a limiting factor for dusky dolphin distribution and impacts on fisheries could have a subsequent impact on dusky populations.

Humpback dolphin distribution within the study area occurred only to the east of Cape Point, along the beaches of the northern coast of False Bay. Although the lack of sightings on the east coast of False Bay is likely a result of no observer effort there, the lack of reports on the west side of the bay where search effort was highest suggest that this is a real lack of presence of the species here. The species presence here has been confirmed by research trips as part of this study (Laubscher unpublished data; Vermeulen et al. 2018). Just ten years ago the western limit of the species was reported as Danger Point between Walker Bay and Gansbaai (Best 2007), with the suggestion that the species had extended its range west of Cape Agulhas since the last time it had been described by Findlay et al. (1992). It is difficult to know if this is a real range extension or simply a case of increased survey effort and reporting over time. Humpback dolphins are associated with warm tropical and sub-tropical waters so this apparent extension of its range west of Cape Agulhas and into the transition zone is at odds with the general cooling of the area that has occurred since the 1980s (Blamey et al. 2015). Presence on the north end of False Bay is where the water is warm. The lack of presence west of this is where water gets cold quickly so it is likely that temperature plays a role in limiting expansion west/south of Fish Hoek. Humpback dolphins have a preference for shallow rocky reefs (Karczmarski et al. 2000). Therefore it does not seem unusual for the absence of the species west of Cape Point where water is cold and for the low sightings in False Bay where water temperature is variable. I suggest that temperature might be limiting humpback dolphins from occurring west of False Bay. Within Walker Bay occurrence is also

low but due to only six interviews conducted in the region; I cannot draw any conclusions on frequency of occurrence. Since humpback dolphins are almost always encountered close to shore they are at risk of a number of anthropogenic impacts such as coastal development, by-catch, noise, pollution, overfishing and climate change (Plön et al. 2016). The current population trend of humpback dolphins is not fully understood but there are indications of a declining population in some areas and it has recently been listed as endangered in South African waters (Plön et al. 2016; Vermeulen et al. 2018). The lack of reported occurrences obtained from this study is concerning. It is imperative that sightings are monitored and it is suggested that conservation and monitoring interventions be put in place.

Bottlenose dolphin occurrence was reported as far west as the western side of the Cape Peninsula, south of Hout Bay. The western limit of the species range has previously been described as False Bay, based solely on a stranding, with regular sightings only reported from Cape Agulhas eastwards (Best 2007). Data from a whale watching company in the Dyer Island area reported regular year round sightings dating back to at least 2002 (Vinding et al. 2002). The common bottlenose dolphin (*Tursiops truncatus*) occurs in offshore waters off South Africa and sightings close to shore have been reported but only rarely. It is often difficult to distinguish between the Indo-Pacific and common bottlenose dolphins (Best 2007). There is therefore some uncertainty which form was reported on the western side of the peninsula by interviewees. Photographic documentation of reported occurrences west of Cape Point could provide valuable insight and confirm species identification. Bottlenose dolphins are distributed in temperate and tropical regions of the Indian Ocean and south-west Pacific (Best 2007). Based on our findings, bottlenose dolphins are not encountered regularly in False Bay whereas a mere ~100km east in Walker Bay and the Dyer Island area they are encountered regularly (Vinding et al. 2015) and their distribution is continuous to the east until the Mozambican border and beyond (Best 2007). There is a gradual decrease in sea

surface temperature west of Cape Agulhas and it gets even colder west of Walker Bay until it hits a warm peak in False Bay (Smit et al. 2013). Based on the regular occurrence of bottlenose dolphins in warmer waters up the east coast of South Africa and in Walker Bay, it is possible the cold water between Walker Bay and False Bay might be acting as an environmental barrier limiting their movement westwards. The upwelling cell off the Cape Peninsula near Cape Point where water is considerably cold is also another potential environmental barrier limiting the dolphins' movement westwards. Future studies could focus on comparing accurate *in situ* sea temperature data to bottlenose sightings to establish if there is any real relation.

Common dolphins were encountered in all regions assessed in this study by nearly all interviewees making it the most widely distributed species and supporting existing literature on its distribution (Best 2007). Existing knowledge describes the western limit of the species range as St Helena Bay on the west coast of South Africa which is ~150km north of Table Bay. Reports in this study of regular sightings in Table Bay support this. Common dolphin occurrence peaked in April and May and showed a clear preference for False Bay. The presence of common dolphins is most likely linked to the spatial and temporal distribution of their prey which primarily includes anchovy, sardine and mackerel. Common dolphins can inhabit a wide range of water temperatures so it is more likely that their distribution is limited by the distribution of their prey. Common dolphins are known to be primary indicators of the presence of sardines during the annual sardine run on the east coast of South Africa (O'Donoghue et al. 2010). There was a high level of reported occurrences in False Bay as opposed to Table Bay which was much lower, suggesting a drop in occurrence further into the Benguela region. The results obtained highlights False Bay as an important habitat area for common dolphins.

Killer whales were rarely encountered. Sporadic sightings ranged throughout the study area supporting existing knowledge of its range in South Africa (Best 2007). Killer whales are considered the most widely distributed mammal ranging from coastal to oceanic waters and from high to low latitude waters in both hemispheres (Best 2007). In South Africa the species are known to occur in all depths from 0- 3000m but are more common in offshore waters (Best 2007). Best et al. (2010) suggested the species is an opportunistic predator of mega-vertebrates within southern Africa. Therefore based on our findings it is suggested that killer whale occurrence is probably limited by the presence of potential prey such as common dolphins and even sharks. It is unclear whether any clear seasonal pattern exists due to a small sample size and a general low sighting probability. However highest sighting probabilities were in summer and autumn and likely correspond to the presence of other mammals in the region, especially common dolphins in False Bay.

Bryde's whales reported in this study were almost certainly from the inshore population (Best 2007). Existing knowledge suggests the inshore population in South Africa is resident over the Agulhas Bank (Best 2007), extending from St Helena Bay in the west to southern Kwa-Zulu Natal in the east where they are often associated with the winter sardine run (O'Donoghue et al. 2010). The results of this study support this range with distribution reported throughout the study area but a clear preference in False Bay. Bryde's whales are known to be opportunistic feeders who feed intensively throughout the year, mainly on pelagic shoaling fish such as sardine and anchovy (Best 1977; Penry et al. 2011). Movements between regions are most likely driven by that of their prey (Tershy 1992; Zerbini et al. 1997; Best 2001). In Algoa Bay ~700km east of False Bay, Bryde's whales are encountered throughout the year with more sightings in autumn and less sightings between August and November, probably due to the presence of prey (Melly et al. 2017). In Plettenberg Bay ~500km east of False Bay, Bryde's whales showed a seasonal increase in encounters during

summer and autumn which also corresponded to feeding activity (Penry et al. 2011). Similar results were found in the Dyer Island region (Vinding et al. 2015). On the north east coast of South Africa there is a high occurrence of Bryde's whales in winter coinciding with the annual migration of sardine (Best 2001; Penry et al. 2011). Bryde's whales are often involved in multispecies feeding events especially with common dolphins who feed on the same prey. Based on these local studies our findings suggest that Bryde's whale distribution within the study area is likely linked to the presence of prey. Our findings indicate nearly the same sighting probability throughout the year in False Bay which could mean there is sufficient food throughout the year. As in other studies along the South African coast, Bryde's whales were predominantly in deeper waters than right and humpback whales (Vinding et al. 2015; Melly et al. 2017). The high occurrence close to shore on the western side of False Bay is likely due to high effort of interviewees. Bryde's whale occurrence was reported by nearly all interviewees suggesting it is a relatively common species in the bay. A third of interviewees thought that Bryde's whale numbers were increasing but it is uncertain whether this is due to more effort and eyes on the water than in previous years. Further studies focusing on photo-identification could be useful to estimate population sizes in False Bay. The absence of reported occurrences on the western side of the Cape Peninsula could be due to lack of effort in the region; however the cold water temperatures could also play a role. Bryde's whales have been positively correlated to sea surface temperature and the cold waters of the Benguela might be restricting their movement. Further investigation into sea surface temperature and Bryde's whale presence in the study area could provide insight into potential patterns. The high occurrence of Bryde's whales and common dolphins in False Bay suggests the bay probably has an abundance of bait fish and is in a healthy condition. Furthermore the majority of interviewees thought common dolphins and Bryde's whale populations were increasing, which could potentially reflect an increase in the abundance of bait fish.

Humpback whales were distributed throughout the study area predominantly in False Bay and on the west coast supporting existing knowledge of its range (Best 2007). Humpback whales follow the general baleen whale migration pattern of moving between feeding grounds in high latitudes during summer to breeding grounds in low latitudes during winter (Best 2007). Humpback whales have previously been recorded feeding off the west coast of South Africa during summer (Barendse et al. 2010). More than half of interviewees said they had noticed an increase in the number of humpback whales. Recent studies have shown humpback whales feeding in large aggregations off the west coast of South Africa in groups of up to 200 individuals (Findlay et al. 2017). The intense feeding behaviour was observed during October and November on three research cruises conducted in 2011, 2014 and 2015. The reason for the pattern observed remains speculative however it might relate to the increase of humpback whale abundance during summer (Findlay et al. 2017). Our findings support both the breeding and feeding season with humpback whales present throughout the year. The average sighting probability was the same in summer as in winter. Although sighting probability started increasing from winter onwards supporting the migration season, the highest occurrence was in spring (November) and there was a substantial reported presence of whales in summer. Based on the presence of large groups feeding during October and November (Findlay et al. 2017), our findings suggest humpback whales are likely here to feed during spring and summer whereas their presence in winter is linked to breeding. Investigations into the temporal and spatial distributions of their prey could be useful in predicting future humpback whale distribution patterns. A third of interviewees said they had notice an increase in the frequency of humpback whale sightings. While these are only anecdotal, recent research has indeed shown a recovery of the previously hunted whales (Barendse et al. 2011; Findlay et al. 2011).

Southern right whales are migratory species and their distribution is described as generally south of 20° S (Best 2007). Southern right whales occur off the South African coast during winter to calve and mate and at other times of the year they are found in the feeding grounds which extend as far south as 55° S (Best 2007). Female right whales have an apparent preference for sheltered and shallow areas which are protected from the wind and swell (Elwen and Best 2004). In this study southern right whales occurred throughout the study region predominantly close to shore which supports existing descriptions of the species distribution range in South Africa (Best 2007). Our findings support the migratory pattern of southern right whales which peaks in August. Best (2007) suggests maximum occurrence of southern right whales is in September/October. Further structured research is needed in order to deduce if there has been a shift in the timing and duration of the breeding season off South Africa. Whales were present throughout the year and although occurrence peaked in winter and spring, the presence of whales in summer is apparent and if explored could provide useful insight. Previous studies have documented the presence of non-migratory southern right whales feeding off South Africa on the west coast (Best 2006). It is suggested that the presence of southern right whales in summer is possibly linked to feeding and the presence during winter is linked to breeding. Future research could focus on observational effort during summer to investigate the potential presence and intensity of feeding. A closer look into the spatial and temporal distribution of southern right whale prey could provide insight and potentially predict future right whale movements. The Western Cape coast is an important habitat area for southern right whales throughout the year. It is important to monitor right whale movements essentially to inform marine conservation, legislation and management decisions.

3.6 LEK method review

3.6.1 Limitations and concerns

The primary concerns with LEK are the validity of the information obtained, the methods used to identify the most knowledgeable informants and the complexity of the study/information required. It would not be appropriate to use LEK to study inconspicuous species that are difficult to identify or which are easily confused with other species.

Furthermore, it is not advisable to use LEK if your research aim is vague or unclear, sampling is small-scale, protocol is complicated and if the reasons to participate are unclear (Pocock et al. 2014). LEK is particularly appropriate to use in areas where the population density is low and scientific or traditional sampling methods are too expensive or difficult to implement, provided there are higher density populations elsewhere that could be used to validate the LEK obtained (Anadon et al. 2009). The accuracy of LEK data can be validated when compared to professionally collected scientific data, by assessing if results were congruent as well as if the majority of informants provided similar results. It would be best to use LEK if there is some sort of scientific baseline information to compare the data to.

In this study; the main limitation was finding suitable candidates who could distinguish between all the different cetacean species and the time consuming nature of the study in terms of the time it took to track down and make an appointment with interviewees who usually had busy schedules and limited availability, the limit to the number of interviews that could be conducted per day considering traffic and driving time to different locations and the actual interview duration. Interviewees were asked to provide information for nine cetacean species due to the high species diversity in South Africa and this resulted in taking up a lot of time. Furthermore interviews only started taking place in May of year two of this study and as a result of time constraints it was a rushed process to complete all interviews.

The unequal effort of the interviewees across the study region was another limitation. There were no interviews conducted along the eastern shore of False Bay where there is a big gap in knowledge of cetacean occurrence. This was mainly due to not being able to find reliable interviewees in the region who had sufficient experience with the ocean and cetaceans.

Regarding the actual interview, the main challenge for interviewees was trying to remember which months they saw a particular species and accurately estimating a probability of encountering it. Some interviewees had a good memory whereas others did not. Some interviewees got confused between different species, mainly between bottlenose and common dolphins which look similar. I found that the interviewees who had an interest in marine life and the ocean were the best candidates, whereas fisherman and surfers could not always confidently distinguish between different species.

3.6.2 Advantages

Local Ecological Knowledge is an extremely useful tool and in most cases yielded the same results as scientific studies. The method used in this study is unique in that it was developed by the researcher with supervisory guidance and tailored to the specific aim and objectives of this study. It is therefore a new method that has never been used in South Africa or in any other published research, to our knowledge. It is a low cost and effective method that could be of great benefit for other studies especially in data scarce regions. LEK has the ability to identify gaps to structure future research questions, identify species which require conservation efforts as well as identify important habitat areas that require good management. The diverse range of information and the geographic spread of the information obtained is probably the biggest advantage of LEK in this study. LEK is generally underestimated and could be useful if incorporated more frequently in other research fields and in policymaking. LEK empowers and includes resource users by making them feel like they are part of the decision making process by contributing to the management of natural resources. The social

benefits of LEK are important, especially since ‘indigenoussness’ has in many regions been forgotten.

3.6.3 Recommendations

It is suggested that for future studies different approaches be reviewed on how to identify suitable interviewees particularly in data scarce regions. It might be useful to involve government in the process as they may be able to assist in sourcing experienced interviewees. Regarding the type of people who are interviewed, it would be useful to target potential interviewees who have a keen interest in the ocean and marine life, especially people who need to be able to distinguish between species as part of their job such as marine tour operators.

The questionnaire must be thoroughly reviewed and tested prior to the commencement of interviews. Questioning interviewees on fewer species might yield better quality data. For example, questions relating to only dolphins or only whales could be applied in future studies. The more detailed data that is required the less species must be included in the questionnaire. It is recommended that interviews are completed within 40 minutes since many people lose interest when it extends much longer. Creating a questionnaire that is as simple as possible is important.

A bigger sample size would be beneficial and must aim to be equal across geographic regions to allow for a more comprehensive understanding. Sufficient time put aside for identifying potential interviewees and conducting the interviews would greatly enhance the quality of the results obtained.

This study was the first of its kind in South Africa and as a pilot study, the magnitude and value of the results obtained has been extremely successful. LEK definitely has the potential to fill the gaps in knowledge of cetacean presence in South Africa.

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3.8 Figures



Figure 3.1: Map of the study area where interviews were conducted in the Western Cape, South Africa. Main focus areas included False Bay, Hout Bay and Table Bay.

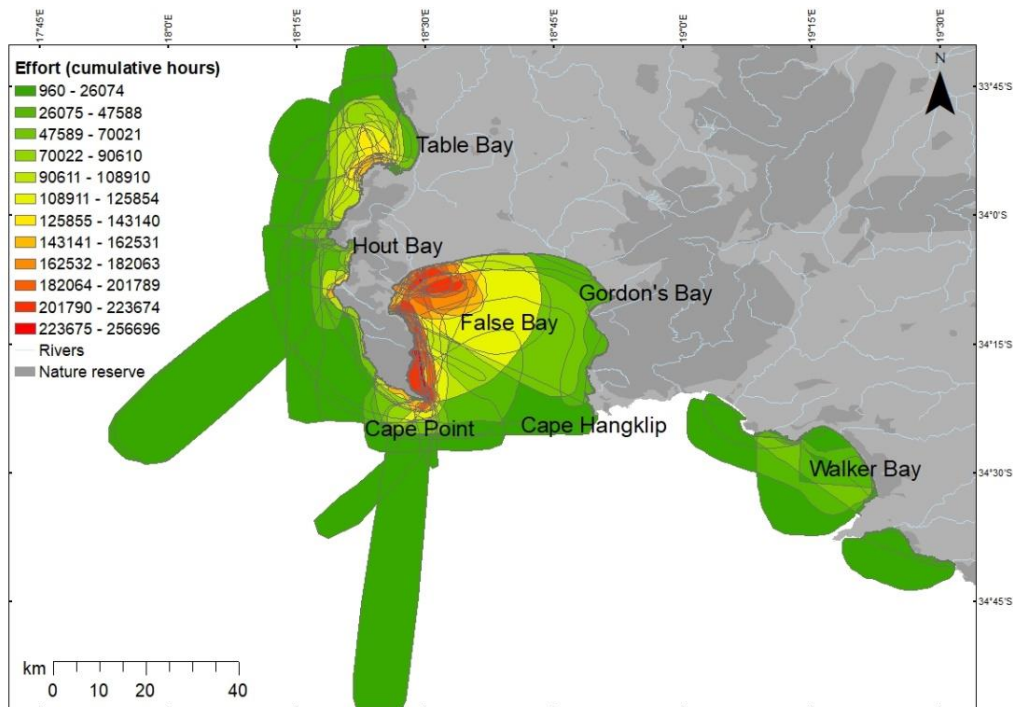


Figure 3.2: The geographic distribution of cumulative effort hours at sea for 55 interviewees in the Western Cape, South Africa. Cumulative hours were calculated by summing the total effort hours at sea for each interviewee and then combining the total hours of all interviewees.

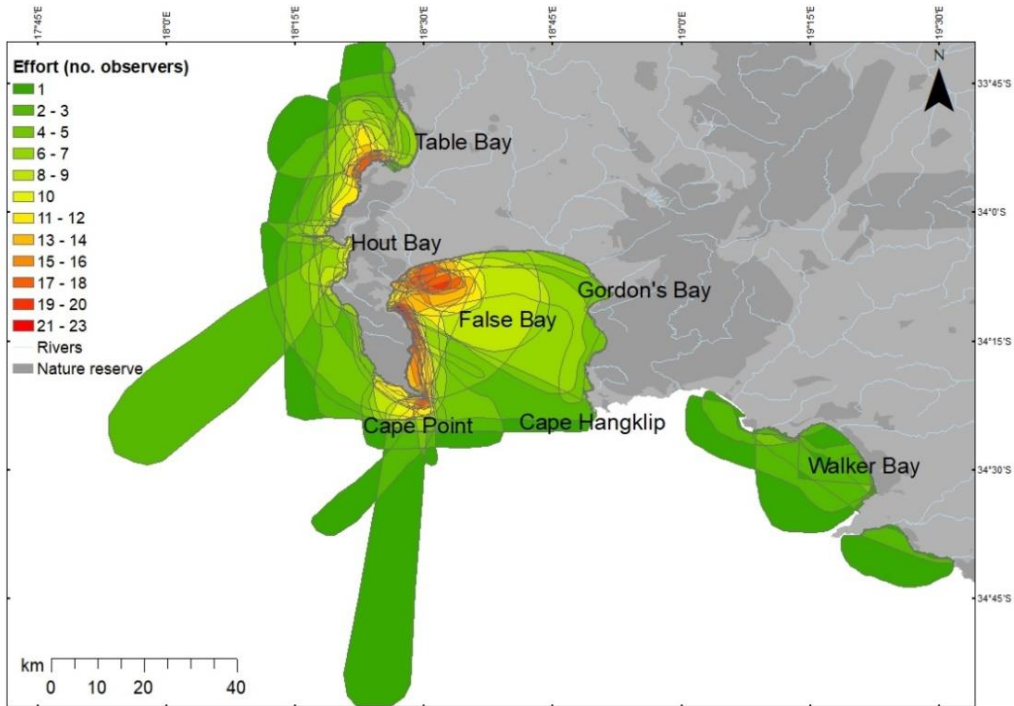


Figure 3.3: The number of observers illustrating the geographic effort coverage in the Western Cape, South Africa.

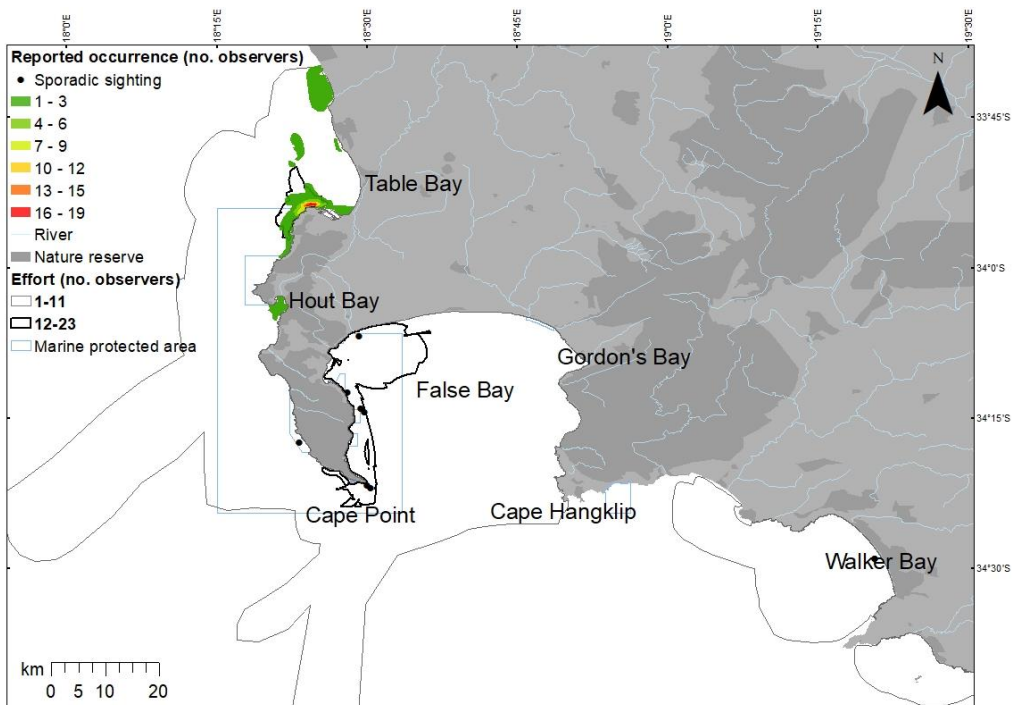


Figure 3.4: The reported occurrence of Heaviside's dolphins *Cephalorhynchus heavisidii* in the Western Cape, South Africa.

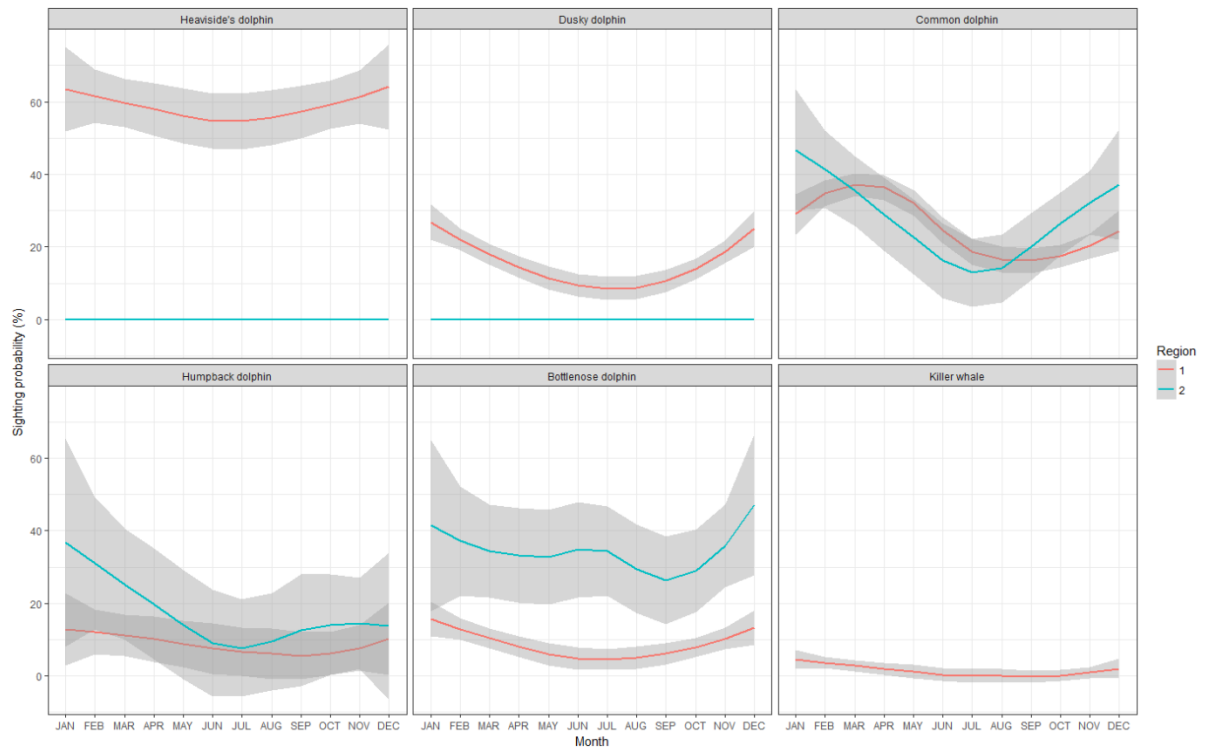


Figure 3.5: Sighting probabilities of dolphin species reported by interviewees for Region 1 (False Bay-Table Bay) and Region 2 (east of False Bay to Dyer Island).

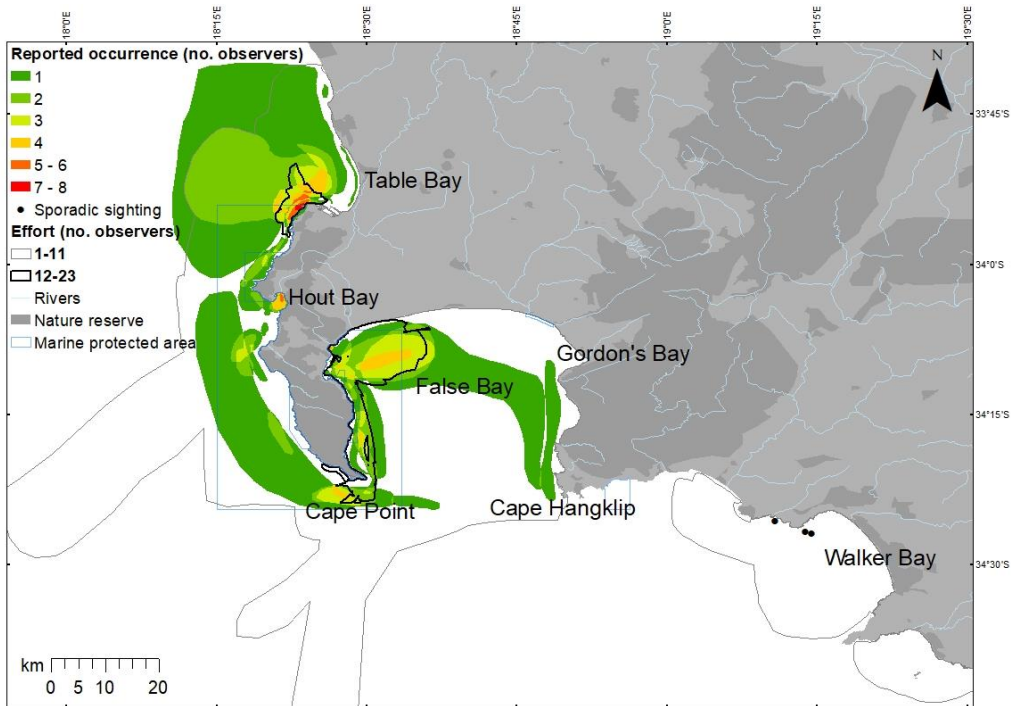


Figure 3.6: The reported occurrence of dusky dolphins *Lagenorhynchus obscurus* in the Western Cape, South Africa.

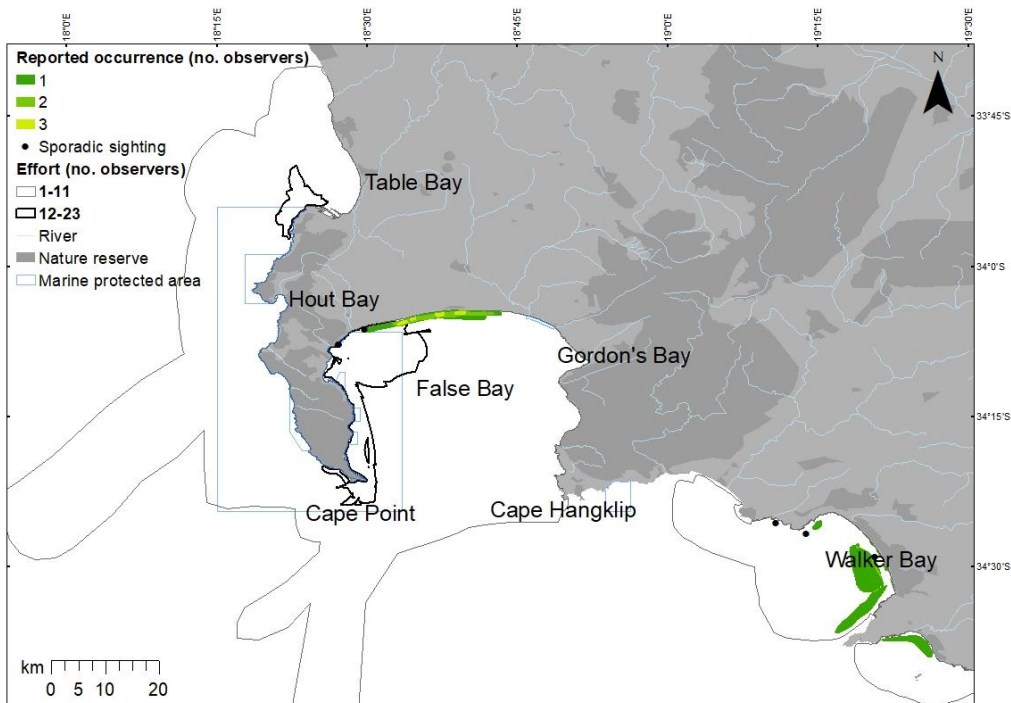


Figure 3.7: The reported occurrence of humpback dolphins *Sousa plumbea* in the Western Cape, South Africa.

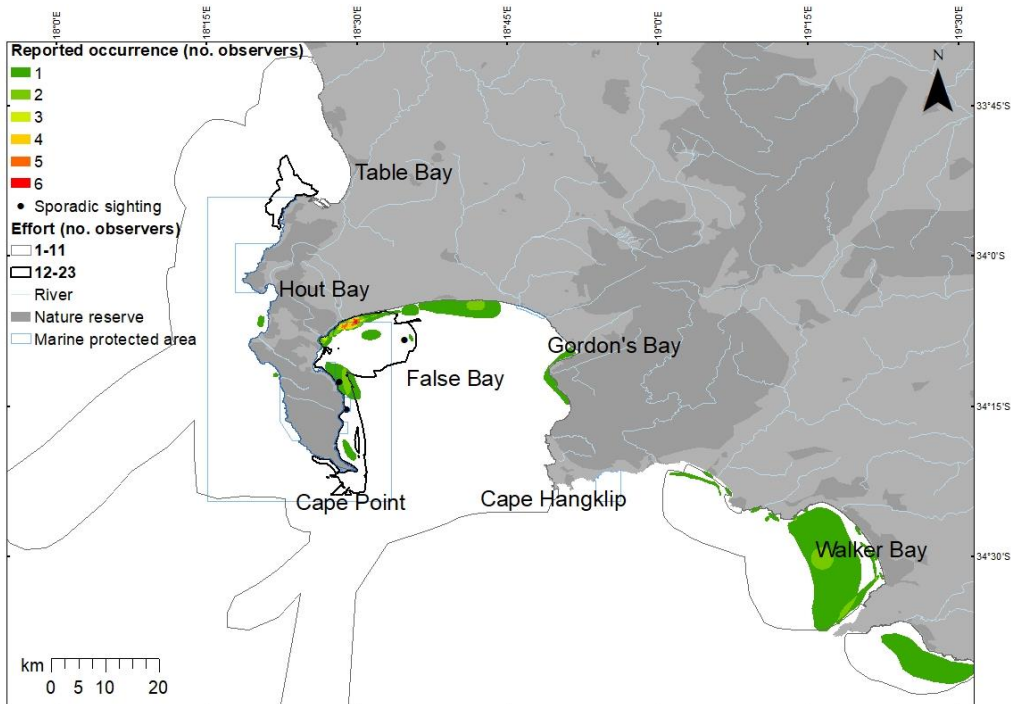


Figure 3.8: The reported occurrence of bottlenose dolphins *Tursiops aduncus* in the Western Cape, South Africa.

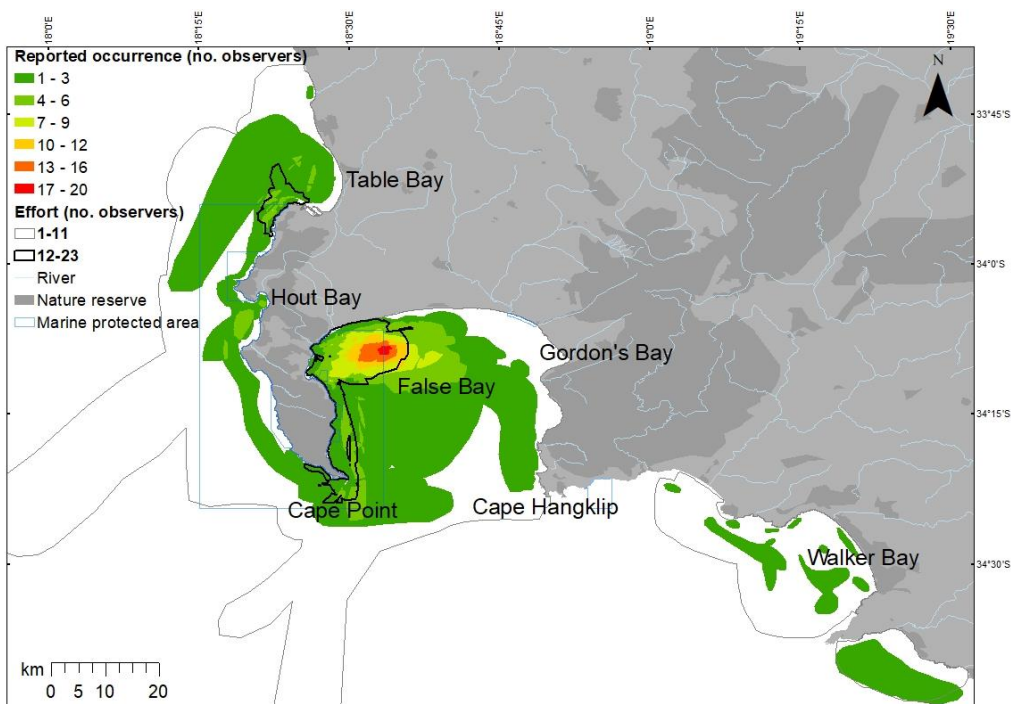


Figure 3.9: The reported occurrence of common dolphins *Delphinus delphis* the Western Cape, South Africa.

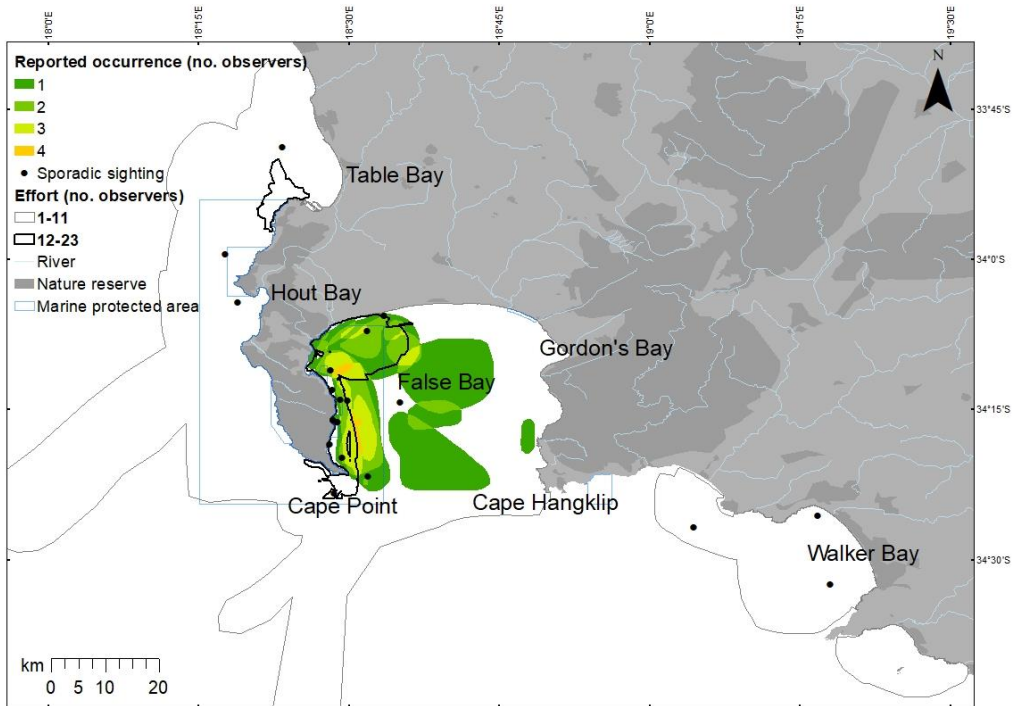


Figure 3.10: The reported occurrence of killer whales *Orcinus orca* in the Western Cape, South Africa.

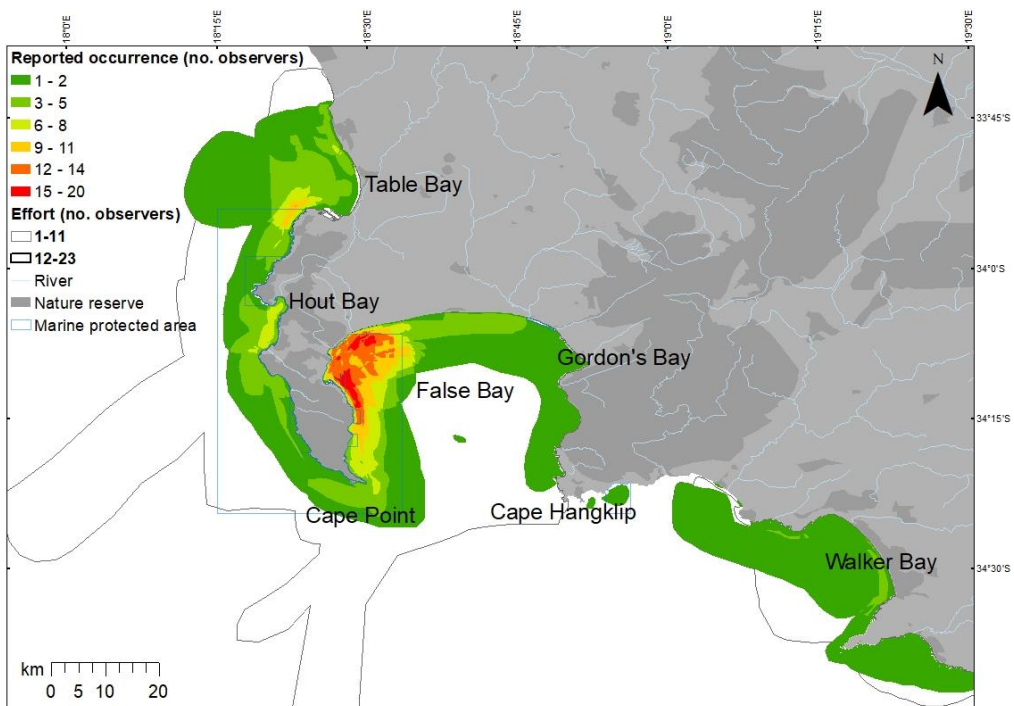


Figure 3.11: The reported occurrence of southern right whales *Eubalaena australis* in the Western Cape, South Africa.

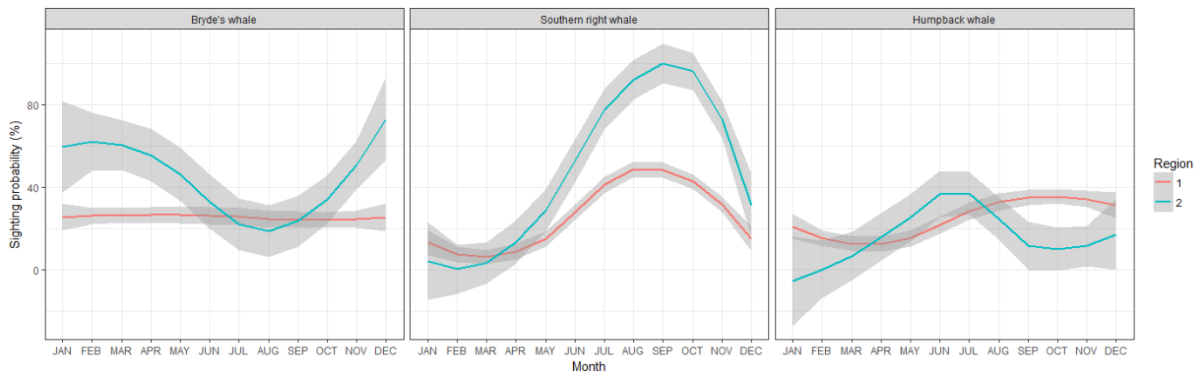


Figure 3.12: Sighting probabilities of whale species reported by interviewees for Region 1(False Bay-Table Bay) and Region 2 (east of False Bay to Dyer Island).

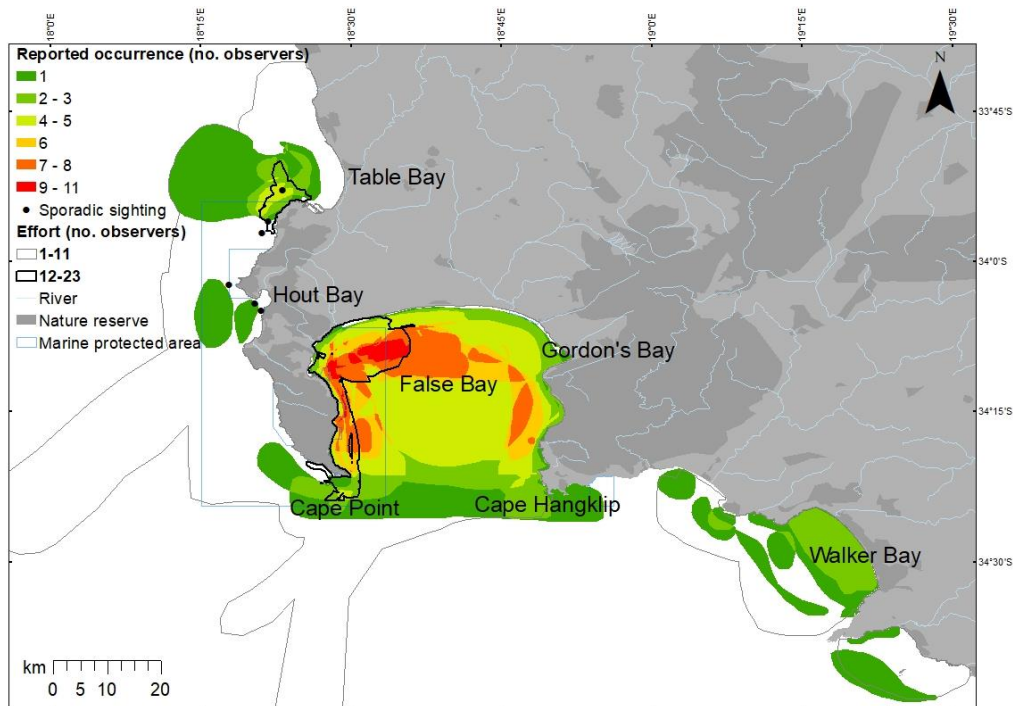


Figure 3.13: The reported occurrence of Bryde's whales *Balaenoptera brydei* in the Western, South Africa.

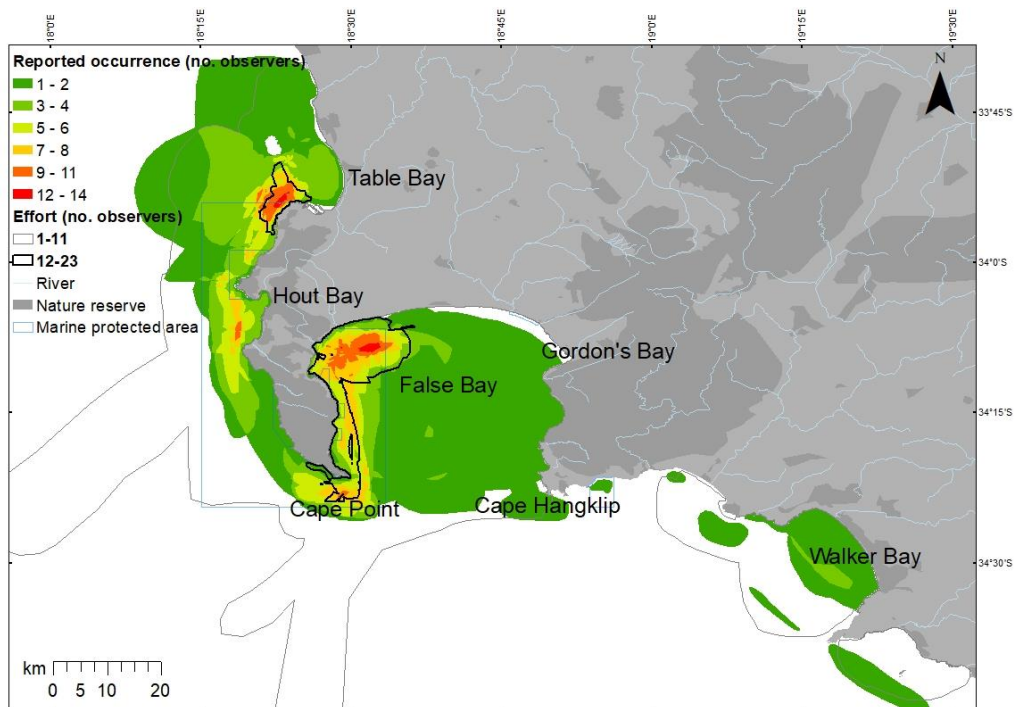


Figure 3.14: The reported occurrence of humpback whales *Megaptera novaeangliae* in the Western Cape, South Africa.

Chapter 4: Conclusion

4.1 Overall conclusion

This study aimed to map the distribution of cetaceans in the Western Cape, South Africa using citizen science. This aim was successfully achieved; not least due to the geographic range over which data were collected, the diversity of the data sources and the quantity of data obtained. The rapidly increasing field of citizen science has opened many new doors for researchers. The combined effect of citizen scientists contributing to a common goal has yielded data which provides complementary insight to scientific studies. The similarity in the findings of the two citizen science methods used in this study; opportunistically collected data and Local Ecological Knowledge (LEK); instils confidence and reliability in the methods used and results obtained. Results supported existing distribution descriptions for all encountered species in South Africa which clearly validates the effectiveness of the methods used and citizen science in general.

Findings in this study suggested some cetacean species ranges are probably limited by that of their prey, most evidently Bryde's whales and common dolphins. Therefore distribution changes in prey species are likely to cause changes in cetacean distributions. The variables affecting temporal and spatial distributions of prey species such as anchovy and sardine are important since they are likely to cause shifts in species at all trophic levels. Previous shifts have been driven by mesozooplankton availability as a result of changing environmental conditions (Shannon et al. 2004). This emphasises the importance of monitoring species at the base of the coastal food web as a precursor for predicting distribution shifts in species higher up on the food web such as cetaceans. It would be extremely valuable for future research to focus on analysing cetacean diets as it could provide valuable insight into future distribution shifts and was last studied by Sekiguchi et al. (1992). It is suggested that climate change indirectly affects cetaceans by the impact it has on species in lower trophic levels of

the food web such as small pelagic fish and plankton. Monitoring these changes and the causes thereof can potentially provide insight into future distribution shifts of cetaceans.

Our findings suggest a year-round presence of the migratory southern right and humpback whales. The year-round occurrence of typically seasonal whales coupled with previous studies describing feeding events off the South African coast suggests that the persistence and/or increase of their prey is likely to increase whale occurrences during summer months. The distribution and abundance of prey species such as euphausiids, amphipods, and clupeid fish which humpback whales have been recorded feeding on off the South African coast could have implications for whale presence throughout the year. Monitoring the spatio-temporal distribution patterns of these prey species could be used as a basis for predicting future range shifts in whales. Furthermore it is possible whale distributions might be returning to what they were before the whaling period. Increasing whale occurrences off our coast is likely to increase the risk of conflict with humans. Whale movements and distribution patterns and interactions with anthropogenic threats like shipping must be carefully and regularly monitored and mitigated. It is important that marine spatial planners and policymakers consider whale migration patterns when producing marine and coastal management plans.

The absence of long term data on cetacean presence in the Western Cape has made it difficult to assess distribution and abundance changes which may have occurred from past to present. Distribution shifts in South Africa have been recorded for small pelagic fish, rock lobster, kelp and seabirds (Blamey et al. 2015). It is possible cetacean ranges have also shifted but evidence is lacking due to paucity of distribution data. Results from this thesis suggest a distribution shift in humpback dolphins and possibly bottlenose dolphins too, compared to previous distribution patterns described in Best (2007). There is also a potential increase in common dolphins and Bryde's whales on the west side of the peninsula. These changes

highlight the value of long-term monitoring of cetaceans species in South Africa to build a consistent long term dataset which can be used to compare to environmental and biological variables to identify patterns.

The environmental drivers remain unclear for the infrequently reported species such as bottlenose and humpback dolphins. As suggested by Bouveroux et al. (2018), knowledge of the distribution and abundance of both predators and prey are required to understand the variables driving movements. Human induced changes including overfishing, bycatch, pollution, ocean acidification and habitat destruction are all factors which probably play a role in cetacean distribution and need to be assessed individually.

While citizen science has its limitations as do all scientific methods, the positives certainly outweigh the limits. Obtaining the type of data collected in this study by a small group of researchers would virtually be impossible in the same time frame. Our findings can be used to structure future research which could aim to analyse cetacean diet; relate cetacean presence to environmental variables such as sea surface temperature, wind, chlorophyll and upwelling and focus research effort in data scarce regions. The Western Cape is unique and oceanographically diverse, and our results highlight False Bay as an important habitat area for most local cetaceans. False Bay in itself has clear seasonality in sea surface temperature which could be one of the reasons it attracts cetaceans. Further research investigating recent SST data and other environmental data is needed.

This research has effectively contributed to the knowledge of cetacean species in the Western Cape of South Africa and is extremely valuable given the general paucity of cetacean data in the region. The unique methods used in this study can be used for other species both in South Africa and in other regions of the world. It is highly recommended that local knowledge be incorporated in future policy and management decisions relating to marine resource

management. This study highlighted the effective use of an unconventional and low cost approach to address scientific research questions. Citizen science is powerful, effective and has the potential to make a significant contribution to the conservation of earth's natural resources.

4.2 References

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5. Appendices

Appendix 1: Species identification flyer.

The flyer features a dark blue background with a silhouette of a whale's head in the upper left. At the top center is the 'SEA SEARCH' logo, which includes a stylized map of South Africa in yellow and blue, with the text 'SEA SEARCH' in bold yellow and 'RESEARCH - CONSERVATION - EDUCATION' in smaller white text below it. The main title 'The cetaceans of South Africa' is written in white. Below this, there is a 3x3 grid of nine images, each showing a different cetacean species in their natural habitat. Each image is accompanied by a white text box containing the species name and its scientific name. At the bottom, a large white question 'Have you seen a dolphin or whale?' is followed by a call to action: 'Become a Citizen Scientist and contribute your sightings to the Effect of Climate Change on Cetaceans (E3C) project' and the website 'www.seasearch.co.za/sightings'.

SEA SEARCH
RESEARCH - CONSERVATION - EDUCATION

The cetaceans of South Africa

 <p>Killer Whale <i>Orcinus orca</i></p>	 <p>Bottlenose Dolphin <i>Tursiops aduncus & T. truncatus</i></p>	 <p>Indian Ocean Humpback Dolphin <i>Sousa plumbea</i></p>
 <p>Common Dolphin <i>Delphinus capensis</i></p>	 <p>Dusky Dolphin <i>Lagenorhynchus obscurus</i></p>	 <p>Southern Right Whale <i>Eubalaena australis</i></p>
 <p>Heaviside's Dolphin <i>Cephalorhynchus heavisidii</i></p>	 <p>Humpback Whale <i>Megaptera novaeangliae</i></p>	 <p>Bryde's Whale <i>Balaenoptera brydei</i></p>



Have you seen a dolphin or whale?

Become a Citizen Scientist and contribute your sightings to the
Effect of Climate Change on Cetaceans (E3C) project

www.seasearch.co.za/sightings



Appendix 2: Sightings submission flyer.



**Cetacean Research,
Conservation and Education
In Southern Africa**

How to submit a sighting?

Friend and tag our Facebook Profile:	SeaSearch Sightings
Tag us on Twitter :	@Seasearch
Register on ISpot :	www.ispotnature.org (tag SeaSearch)
Email us:	sightings@seasearch.co.za

WWW.SEASEARCH.CO.ZA/sightings

Appendix 3: National Sea Rescue Institute winter issue newsletter.

MARITIME RESEARCH



BECOME A CITIZEN SCIENTIST

How does climate change affect our whale and dolphin populations? You can help us with an important study by reporting whale and dolphin sightings. By Teyva Lotriet and Simon Elwen

Climate and environmental change is real. It is affecting biological systems at all levels from plants to top predators, both on land and at sea. Combined with other human threats like overfishing, pollution and habitat degradation, global biodiversity is under an ever-increasing pressure. A range of studies has shown that these changes to the environment can have serious implications for marine species, including for cetaceans (whales and dolphins). The response of cetaceans to climate change has been relatively poorly studied globally, and as yet, not at all in South Africa. The Sea Search team, led by Dr Simon Elwen,

Dr Tess Gridley and students, aims to remedy this lack of knowledge. The Sea Search group consists of a number of scientists and students from several universities (including the University of Pretoria and the University of Cape Town) who study various aspects of whale and dolphin biology.

THE E3C PROJECT:
WHAT IT'S ALL ABOUT
Sea Search has recently launched a project called E3C - Effect of Climate Change on Cetaceans. The main aim is to study cetacean distribution, and the environmental (such as sea temperature and salinity) and biological variables (such as the presence of prey, predators or competitors) shaping that distribution. By studying these questions close to the end of species ranges, our research team hopes to pinpoint which of these factors act to limit that range. Subsequently we aim to model how these are likely to change over time, with predicted environmental changes. The results from this study can be used to predict future distributions patterns and to inform marine conservation and management. A multidisciplinary approach is being used in this study. Firstly, hydrophones (sound recorders) are installed at key locations to continually record cetacean presence (vocalisa-

tions). Dedicated research surveys using our small research boat are conducted around Cape Town, which provide information on search effort (where we've looked and haven't, where cetaceans are and aren't), as well as their behaviour in these areas, and give us the opportunity to collect skin samples for genetic and diet analysis and acoustic recordings of animals in situ for species classification. However, we can't be everywhere all the time, so we are trying to take advantage of all the other eyes on the water by collating sightings from commercial operators (mainly tourism vessels), other scientists and the general public to help us spread the search effort as far as possible.

STUDY AREA
The South African coastline is a unique area to undertake research due to the confluence of the cool Benguela current on the West Coast and the warm Agulhas current on the East Coast. As a result of the wide range of oceanographic conditions around our coast, southern Africa has one of the most diverse assemblages of whale and dolphin species in the world. The study area lies within the southwestern Cape, with a focus on the coastal areas from Cape Hanglip to Melkbosstrand. However, sightings from all regions are very valuable and most welcome.

STUDY SPECIES
We are interested in all whale and dolphin species but are focused on the five dolphin species that all have the southernmost limits of their range end in the approximately 150km of coast around Cape Town. The five focal species are the Heaviside's dolphin (*Cephalorhynchus heavisidii*) and dusky dolphin (*Lagenorhynchus obscurus*), which are most common in the cooler waters along the West Coast; and the long-beaked common dolphin (*Delphinus delphis*), the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and Indian Ocean humpback dolphin (*Sousa plumbeus*), which prefer warmer waters along the South and East Coasts.

HOW YOU CAN ASSIST
Help us by becoming a citizen scientist and contributing sightings to the E3C project. Citizen scientists are members of the public who are willing to contribute to science and research. It is the combined power of all these sightings that helps us add more dots to maps and better understand their distributions. Harnessing the power of citizen science can greatly help scientists to understand more about cetacean range limits and general habitat use.

HOW TO SUBMIT A SIGHTING
We have created a range of platforms so that there's a convenient option for everyone:

- ▶ iSpot is an online platform where you can upload a picture of your sighting, have the species verified and choose coordinates from an interactive map (sign up at www.ispotnature.org/user/register). Tag your sightings with the word 'SeaSearch'.
- ▶ Visit our Facebook page (www.facebook.com/seasearch), send us a 'friend' request and tag us in your photographs.
- ▶ Submit details via Twitter @seasearchza
- ▶ Email sighting information to sightings@seasearch.co.za



WHAT TO SUBMIT
The most important information we need is the species, the date and time, the location and the group size. Further observations on presence of calves and behaviour are also really appreciated. Sightings should be submitted with as much detail as possible. Photographs are really valuable in the species ID confirmation process, therefore we encourage members of the community to send a picture with their sighting details, if possible. Information on shore-based sightings are also welcome.

- ▶ For more information, visit www.seasearch.co.za or call 021 788 1206.

PLEASE OBEY THE LAW
It is illegal to approach a whale and come within 300m of it in South African waters without a specific permit.

38 / SEA RESCUE / WINTER 2016

SEA RESCUE / WINTER 2016 / 39

Appendix 4: Hout Bay Sentinel Newspaper article.



Calling all 'citizen scientists'

By TEVYA LOTRIET · June 15, 2017

Share on Facebook Tweet on Twitter G+



Cape Town is one of the best places in the world to watch whales from shore and we are lucky to have three different species which can be seen regularly around our coast – the southern right, humpback and Bryde's whale. But did you know there are also five species of dolphin which can be seen around Cape Town from shore which is more than in any other town in South Africa?

Even more amazingly, because of the unique location of Cape Town straddling the "two oceans", the dolphin species are different on each side of the Cape Peninsula. On the west side of the peninsula we see mainly the dusky and Heaviside's dolphins and on the east side we see the bottlenose and the endangered humpback dolphin. Common dolphins can be seen on either side of the peninsula and are often found in large groups ranging up to hundreds and even thousands of dolphins.

Despite this amazing diversity of species around the Cape Peninsula, there is actually very little scientific data available and most of what we know is based on very old records and strandings of dead animals. The Sea Search team, made up of scientists and students from the University of Pretoria and the University of Cape Town are trying to study the effect of climate change on cetaceans by mapping their distributions and figuring out what's causing their range limits. Could it be sea water temperature, wind, availability of fish?

You can help us find out.

"Citizen scientists" are members of the public who voluntarily assist scientists with research.

Citizen science has become a very valuable tool and is used in a range of different study fields.

The E3C project uses two citizen science approaches to study whale and dolphin distribution. The first is to collect opportunistic sightings. In other words, if you have seen a whale/dolphin we would like to know what you saw, where you saw it, the date and time, and the group size, even if you saw it 10 years ago.

We are especially interested in sightings where you could provide a picture or video.

The second is to interview experienced water users, preferably people who have at least five to 10 years of experience with cetaceans and the ocean. Your knowledge on cetacean presence is really valuable and we would love to chat to you about what you know. This is a call to all citizen scientists including fisherman, tour operators, divers, surfers, scientific water users, and the general public to contribute sightings and/or be interviewed by us so that we can gain a better understanding about our local cetacean species.

If you or anybody you know can assist in any way, please send an email to sightings@seasearch.co.za or call 021 788 1206 / 071 682 4774.

If you're unsure how to tell between different species, contact us and we'll send you a species guide or send us a picture and we'll try to identify it for you.

Feel free to follow our Facebook page called Sea Search and add Seasearch sightings as a friend to submit your sightings on our timeline. If you prefer Twitter you can tweet us at [@seasearchafrica](https://twitter.com/seasearchafrica) or Instagram us [@seasearchafrica](https://www.instagram.com/seasearchafrica)



Appendix 5: Interview consent form.



Department of Zoology and Entomology, Mammal Research Institute

Research project title: The Effects of Climate Change on Cetaceans – Mapping dolphin distribution using citizen science in the south western Cape, South Africa

Research investigator: Ms Tevya Lotriet (Student number: 16394853 Cell: 0716824774)

Dear Participant,

You are invited to participate in an academic research study conducted by Tevya Lotriet, Masters student from the Department of Zoology and Entomology’s Mammal Research Institute at the University of Pretoria. The purpose of the study is to extract local ecological knowledge from experienced water users on whale and dolphin distributions in the south western Cape, so where and when different species are seen, essentially so we can map their distribution and subsequently understand what the effect of climate change will be on them. Please note the following;

- You are voluntarily taking part in this project and understand that you do not have to take part, and can stop the interview at any time;
- The interview will be recorded and a transcript will be produced;
- The transcript of the interview will be analysed by Tevya Lotriet as research investigator;
- Access to the interview analyses will be limited to Tevya Lotriet, supervisor and academic colleagues directly involved in the research process;
- Before commencing with any interviewing, the research aims, objectives and outcomes will be explained and the requirements of each participant will be highlighted;
- You may ask any questions you have and you understand that you are free to contact the researcher with any questions you may have in the future (Tevya Lotriet Cell: 0716824774);
- Please answer the questions as completely and honestly as possible. This should not take more than 40 minutes of your time;
- The results obtained will be used for academic purposes only and will form part of Tevya Lotriet’s master’s thesis;
- All or part of the content of your interview combined with other interviews may be used in academic papers/ website and social media/ conferences in a pooled summarised format;
- Under no circumstances will the identity of interview participants be made known to any parties/organisations that may be involved in the research process;
- Hard copy data will be stored in a locked location and computerised data on a secure server for 15 years.

Please sign the form to indicate that:

- You have read and understand the information provided above.
- You give your consent to participate in the study on a voluntary basis

Printed name.....

Participant’s Signature.....

Date.....

Researchers Signature.....

Date.....



8. Have you noticed any changes (increase or decrease) in the occurrence and population size of any of the species you see (comments)?

9. Have you observed any patterns relative to environmental conditions (such as wind, sea water temperature, tide, water clarity, fish catches)?

10. Do you think the water temperature or wind has changed over time?

Temp: Yes No Remained constant I don't know Comment _____

Wind: Yes No Remained constant I don't know Comment _____

11. Do you feel/Or have you witnessed that whale/dolphin presence and behaviour changes around human activity? And if so, what and how? _____

12. Have you noticed changes in fish and or bird presence over time?

Fish: Yes No I don't know Comment _____

Bird: Yes No I don't know Comment _____

13. If you're a fisherman, when was your best day catch (number of individuals – what year and month)? And when was your largest catch caught (year and month)? _____

14. Do you recall any other changes/patterns that could be relevant to our study on whale and dolphin distribution _____

Thank you for your time

Appendix 7: Interview maps.

