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Distribution, habitat use, and behaviour of cetaceans in the Greater Dyer Island Area, Western Cape, South Africa

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I, Katja Vinding Petersen declare that the thesis/dissertation, which I hereby submit for the degree Doctor of Philosophy 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.

Katja Vinding Petersen

21. June 2016

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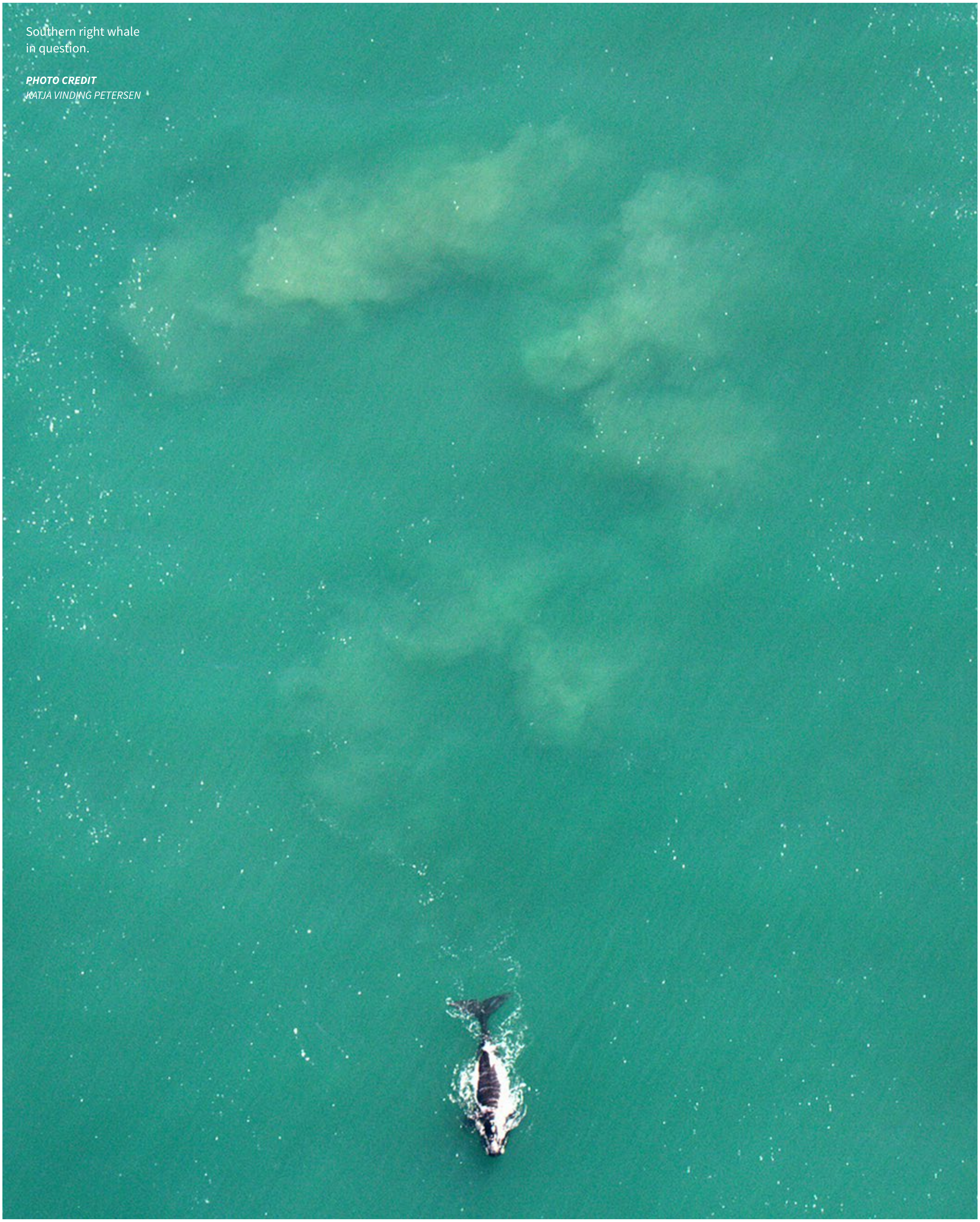

Southern right whale in question.

PHOTO CREDIT
KATJA VINDING PETERSEN

Summary

This thesis is a study of the occurrence, behaviour, spatial distribution, and temporal distribution of cetaceans in the Greater Dyer Island area, Western Cape, South Africa. Three main methods were used in the study: Analysis of data from a local whale-watching vessel (WWV) (2000 – 2012), visual land-based theodolite tracking (during four southern right whale seasons (August – December) from 2011 – 2014 and one summer/autumn season in 2013), and passive acoustic monitoring (PAM) using a single bottom moored hydrophone (DSG-Ocean Loggerhead) in the months of January/February, September, and October, 2014). Methods were chosen, due to suitability, cost efficiency, and because they complement each other. Data from the WWV covered more than a ten-year period and provided indications of temporal and spatial distribution trends, but data were limited with respect to survey effort and behavioural data. Shore-based observations provided spatial, temporal, and behaviour patterns of the cetacean species in the area, but the method is labour intensive, requires daylight and is restricted by weather conditions. PAM could be conducted 24 hours a day and in poor weather conditions and enabled a temporal extension of the monitoring of cetaceans in the area, but individual hydrophones, are expensive and can break down or be lost. Simultaneous visual observations and PAM were used to investigate the vocalisation patterns of southern right whales and the possibility of using PAM to monitor presence of southern right whales.

An analysis of the consistency and validity of the opportunistic data from the WWV was conducted before the data was used in a spatial and temporal analysis. The Consistency Index (CI) was defined as the proportion of times a data field was recorded per total number of trips during all years. The validity of the data were assessed to determine accuracy of the data. The validity and consistency analysis of the sighting records revealed that the dataset was useful but data fields varied considerably in their consistency of collection. The trip duration and route was recorded in less than 5% of cases, making analysis of temporal and spatial patterns difficult. The validity of species identification was excellent with 100% agreement between observer records and photographic documentation in 152 encounters of seven cetacean species. Behavioural data were described in overly subjective terms, thus not allowing for any analysis of patterns. The analysis also resulted in a list of suggestions for the design of future observation sheets, and data collection methods and the development and implementation of worldwide standards are encouraged (guidelines and protocols), which should address different levels and scenarios of data collection from WWV. This work has made a novel contribution to the global research field by submission of a paper and direct communication with the whale watching subcommittee at the International Whaling Commission (IWC) concerning content in the International guidelines for "platform of opportunity guiding principles on data collection".

An analysis of opportunistic cetacean sightings from the local WWV consisted of more than 5500 cetacean encounters during more than 2500 trips from 2003 to 2012. Results were twofold; 1) discovering that there are five main cetacean species using the area: Southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Balaenoptera brydeii*), Indian Ocean humpback dolphins (*Sousa plumbea*), and Indo-Pacific

bottlenose dolphins (*Tursiops aduncus*) and providing spatial and temporal distribution patterns for these species as well as the first long-term, year round dataset for this area. Three other species of incidental visitors were: Common dolphins (*Delphinus delphis*), killer whales (*Orcinus orca*) and Heaviside's dolphins (*Cephalorhynchus heavisidii*). 2) Showing that opportunistic data of cetacean encounters collected regularly from a WWV constitute an important source of baseline information of the wildlife abundance and distribution. Caveats and limitations of data from the WWV are discussed and advice regarding data collection from platforms of opportunities are provided. Particularly, the lack of basic data on search effort and of clearly defined behavioural categories is emphasised and standardisation of guidelines for data-collection methods worldwide is suggested. Southern right whales were by far the most frequently occurring cetaceans with a marked seasonal presence from August to December. Numbers peaked consistently between June and January each year and only a single encounter was recorded between 31 January and 26 May in the entire dataset. They appeared either as unaccompanied adults (UAs), as part of surface active groups (SAGs) or as cows accompanied by their calves (cc-pairs). Single right whales were more commonly encountered at the beginning of high season (June – September) while groups of two or more were most commonly encountered in the middle of the season (July – September) and the modal group size was two. Cow-calf pairs were encountered most frequently late in the season with highest encounters in October – December. All right whales were predominantly located close to shore, as were the two main dolphin species. Bryde's whales and humpback whales were located farther from shore. Bryde's whales were observed in all years, except 2006. The highest encounter of Bryde's whales were between March and May. Bryde's whale calves were encountered year round. The highest number of encounters occurred during 2003 (n= 25), dropping to 0 in 2006 and then slowly increased at 1% per annum after 2006. Humpback whales showed two peaks in seasonality: the majority of animals were encountered in June (last month of low season), July and August, with a much smaller peak in late November and December. Most encounters with humpback whale cow-calf pairs occurred during October – December. Humpback whale encounters varied considerably from year to year, with most encounters in 2008 (n= 28), 2011 (n= 15), and 2012 (n=12), but showed a slow average increase at 0.4% per annum. Encounters of Indian Ocean humpback dolphins were more frequent during summer months, and most encounters occurred in 2003-2007 and in 2011, a slightly negative annual trend existed (0.9%). Calves were mainly encountered occurring in December (n = 25) and January (n = 12). Indo-Pacific bottlenose dolphins showed a clear seasonal peak occurred from December to April and most encounters occurred in 2004-2006 and in 2009 with a slightly negative annual trend over time (0.2%). Seasonality of calves followed the same pattern of as adults. This study was the first to reveal that there are five cetacean species using the area and provide temporal and spatial patterns based on long term data.

Shore-based observations, using a surveyor's theodolite, enabled an analysis of behaviour in addition to confirming the spatial and temporal distributions of cetacean species obtained from the WWV-data. Hourly scans were conducted to provide information on species presence, location, group size, group composition, and surface behaviour. In addition, focal groups that were tracked provided and detailed information on movements and behaviours. Effort totalled 1558 hours and 26 minutes (1204 scans) over 270 days between 24 August 2011 and 11 December 2014. All sighting data were filtered to remove periods of poor weather conditions, only observations collected at sea state ≤ 2 for dolphin species, and ≤ 5 for baleen whales were analysed. The area is an important location for nursing and socialising southern right whales and it might be a summer feeding area for Bryde's whales. The primarily observed behaviour of humpback whales was travelling and 80% of the tracked animals were travelling south-east towards Cape Agulhas. Finally, it was found that the area serves as a year round socialising and resting area for the two dolphin species. Swimming speed was calculated, using the longest focal follow from each day for southern right whales and all focal follow tracks of dolphin species. All southern right whales were found to be swimming at a speed less than 5.1 km/h.

The dolphin species with the highest leg speed was the common dolphin (n = 8) with a top speed of 17.5 km/h down to 3 Km/h, followed by the Indo-Pacific bottlenose dolphin (n = 19) ranging from 1.5 to 9.3 Km/h, and the Indian Ocean humpback dolphin (n = 17) ranging from 0.9 to 6.3 Km/h.

The number of sightings on simultaneous days of southern right whales from the WWV and the theodolite scans were compared. The total number of sightings from the theodolite station was generally higher than the total number of sightings from the WWV during the months of September, October, and November. Sightings of other species were too few to provide any patterns.

This study was the first to measure swimming speed and investigate the behaviour of the cetacean species in the area. A comparison of the results from the analysis of 10 years of cetacean observation data obtained from the local WWV with the results of the present study, showed a very similar temporal and spatial distribution pattern, which could indicate that such data sources from platforms of opportunity can be useful and indicative of distribution of cetacean species.

PAM was used in combination with the visual observations to investigate the vocalisation patterns of southern right whales and the possibility of using PAM to monitor presence of southern right whales in the area. A total of 44 days of sound recordings was obtained from a bottom moored DSG-Ocean Loggerhead during three periods in January/February, September, and October 2014. The acoustic recordings from September were analysed together with 26 hours and 28 minutes of simultaneous visual theodolite observations. Sound recordings were analysed using Raven Pro 1.5 (Bioacoustics Research Program, 2013). Vocalisations were classified following Urazghildiiev and Parks, and the species identification calls: narrow-band up-calls (NU) and wideband gunshots (WG) were analysed. Southern right whale groups observed during visual scans were categorised as either: SAGs, cc-pairs, or UAs. A total of 193 SAGs (group size: 2 – 8, 2.8 ± 1.0 individuals), 97 cc-pairs and 124 UAs were observed. The total number of up-calls and gunshots during the visual scan observation periods and call rate per hour was calculated for comparison to number of visually counted animals. Gunshots were short in duration 0.11 ± 0.09 sec (SD) with a start frequency of 80 ± 47 Hz (SD) and a high end frequency above 30 kHz. Up-calls had a centre frequency of 107 ± 16 Hz (SD), a start frequency of 56 ± 13 Hz (SD), and a duration of 0.92 ± 0.28 sec (SD). Due to the simultaneous presence and large number of individuals from the three group categories, it was not possible to link a specific vocalisation type to any of the group types. Southern right whale sounds were acoustically recorded in 79% of the time when they were visually present, which indicates that PAM is a useful technique when monitoring the presence of this species in this area but, in the high density study area with simultaneous occurrence of several group types, it was not possible to correlate specific behaviour or group type to specific sounds. Future studies should include localization of vocalising individuals, which may enable a linkage between vocalisation, group type, and behaviour.

Surprisingly, the sound recordings contained songs from humpback whales during periods when no humpback whales were visually observed. One of the sounds used by humpback whales during their song was very similar to the up-call of right whales; these were compared with data from this and other studies. The up-call of right whales differed significantly from up-calls registered as part of a theme of a humpback whale song where a centre frequency 149 ± 6 Hz (SD), a start frequency of 94 ± 12 Hz (SD), and duration of 0.63 ± 0.11 s was found. This novel finding of humpback vocalisation needs to be further investigated.

The study area is populated year-round with cetacean species of which one is the endangered Indian Ocean humpback dolphin. As three of the five main species are reliant on the inshore habitat, which is particularly vulnerable to anthropogenic threats such as industrial development, underwater noise, and pollution, it is advisable to continuously monitor the presence and behaviour of the cetaceans in the area. The use of PAM is a potentially valuable part of such monitoring. The area is part of the Cape Whale Coast Hope Spot and even though this status does not provide any specific protection, it serves to increase attention on special marine areas. Particularly because the area is hosting three inshore cetacean species, it is hoped that the area can be assigned the status of a Marine Protected Area in the future.

Foreword and acknowledgements

This project has been a journey in many ways. First of all, a physical journey, relocating from my country of origin, the Viking country of Denmark, to the rainbow nation of South Africa. The first journey leading me to South Africa was in 2006 when I participated in the Danish Ocean expedition "Galathea 3", a round-the-world science and communication project, where I joined for two months from the Azores to South Africa. Arriving at the shores of Cape Town on an early morning, I instantly had a feeling of returning to home. This feeling only grew as I made my way to the Dyer Island Area, which later became the study area of my PhD project. If I had known then, the journey that awaited me, I would not hesitate to do it all again and undertake this project which lies very close to my heart.

The journey has also been filled with amazing souls and unforgettable lifetime experiences, and I am deeply thankful for the warmth and help I generally experienced all around in the beautiful country of South Africa, from the local public, government officials, to friends.

The financial history of the project has also been a journey, starting with Dyer Island Conservation Trust as an association and work base, and with Wilderness Wildlife Trust donating the first funds, which were enough to cover petrol costs and similar practicalities to enable the theodolite fieldwork to commence. Thank you to Russel Friedman, Steve Rimer, and Brennan Rimer from Wilderness Wildlife Trust and Journeys Unforgettable for the consistent support throughout the project.

The list of sponsors grew during the years and I am forever humbled and grateful for the financial support of the sponsors. I would like to thank the Danish Order of Freemasons (the Grand Lodge of Denmark) and their Grand Master Walter Schwartz for the special donation, which enabled me to devote my time completely to the project and take a break from tour guiding for "Albatros Travel". A special thank you to "Knud Højgaards Fond" who has supported the project throughout all the years. Thank you to Seiche, Limited and Roy Wyatt for the very generous donation. Thank you to the two Danish funds Skjold Burnes Fond and Torben og Alice Frimodts Fond for your donations. Thank you to the Society of Marine Mammology (SMM) for donating toward the costs related to the theodolite work. A special thank you to the Danish land-surveyor Brian Lund for establishing the contact with Leica, Denmark, and thank you to Rikke Riishøj and the team from Leica, Denmark, for providing the total station for the entire duration of the project. Thank you to PADI Aware for financial support in relation to the diving and service of the acoustic loggers. Thank you to Save Our Seas for donating towards a remote controlled aerial vehicle. Thank you to the private persons who have kindly donated to the project: Ralph Immerman, Jenni Chang, and Michael Bergen, and to the Hermanus Whale Festival for a thoughtful donation after the festival in 2013. All of your donations enabled this research to unfold and materialize. A complete list of sponsors, year of support, and amounts, is presented in Table 1 "Overview of list of supporting funds and private donations". Thank you to Mogens Trolle for spending a year in South Africa while assisting in fundraising and designing the booklet about the project (Appendix 9).

I gratefully acknowledge the contribution of the following helpful, kind, and supporting people, who have been there for me along the journey.

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This project would not have been possible without the help of all my specially selected volunteers, who spent countless hours collecting data in the field, entering data, and being enthusiastic about the "floating rocks in the sea". I cherish the help I have received from all of you and I am very thankful that you dedicated time to join and participate in the project. I will always remember the special experiences we have shared. Thank you to: Alicia Grant, Amanda Hall, Anders Launer Bæk, Andrea Lagomarsino, Anita Hansen, Anna Hilbert, Anna Skinnars, Beate Le Maire Madsen, Benjamin Jones, Camilla Camel Rhodes, Caroline Johansen, Christopher Chalk, Dana Roberson, Daniela Hilfiker, Daragh Kervick, Eleanor Cooper, Emma Fitzmaurice Vestergaard, Emma Thacker, Guilia Roncon, Harry Stone, Jennifer Karnik, Jennifer Shearing, Jessica Greenston, Karina Liebmann Madsen, Karla van der Westhuizen, Kathrine Leone, Katja Schröder, Laura Nikoline Petersen, Larissa Kato, Maria Palner, Mogens Trolle, Nick Jones, Nicole du Plessis, Nina Kelch, Peet Botes, Puk Faxe Sabinsky, Ren Rufus, Talya Davidoff, Uriël Maarsen, Valeria Gonzalez Borasca, and Weilun Chang. I would like to give a special thank you to Marianne Cannon, whom we would have liked to have had with us for much longer. You were a very special soul and you will always be remembered by the team.

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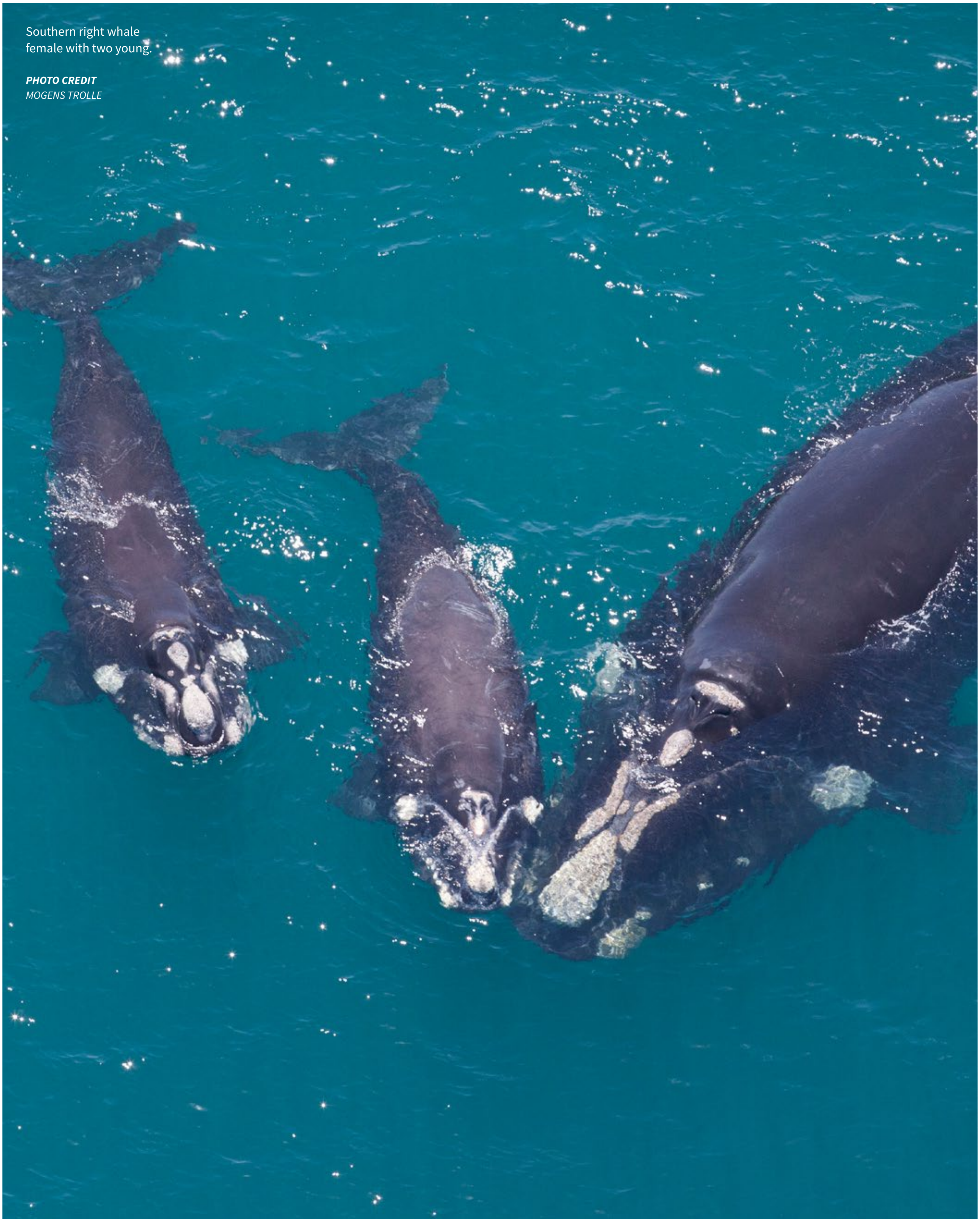

Southern right whale female with two young.

PHOTO CREDIT
MOGENS TROLLE

Thank you to Jason Stafford from Ivanhoe Sea Safaries for always having space on the whale-watching vessel for the volunteers and visitors from overseas. Thank you to Shark Diving Unlimited and White Shark Diving Company for always being accommodating and having space on your shark cage diving vessels for the volunteers, friends, family, and collaborators, for them to see the sharks.

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Thank you!
Sincerely yours

Whale Coast Cetacean Project
SOUTH AFRICA

The PhD project has been known as the Whale Coast Cetacean Project since December 2012 and part of my role as a researcher has also been to educate the public about cetaceans and the unique marine environment of South Africa. Educational activities from; public talks at Pearly Beach angling club, talks at De Hoop nature reserve, a stand at the major whale festival in Hermanus, to a Facebook page, are some of the main activities which I and the volunteers have been involved in.

List of funding sources

This project would not have been possible without the financial support of the following sponsors, I am forever thankful towards the funds who have supported the project in various ways, and it is my sincere hope that I will make you all proud, and that the results of the project will benefit the cetaceans for many years to come. Thank you for your support.

TABLE 1 OVERVIEW OF SUPPORTING FUNDS AND PRIVATE DONATIONS

Supporting Funds	Outcome and year of received financial support
Den Danske Frimurerorden	100.000 DKK (2014/2015) Living expenses
Knud Højgaards Fond	25.000 DKK (2012) Living expenses / 36.000 DKK (2013) Living expenses / 16.000 DKK (2014) Living expenses **Total 77.000 DKK**
Wilderness Wildlife Trust	30.000 ZAR (2011) / 11.000 ZAR (2012) / 36.000 ZAR (2014) / 10.000 ZAR (2015) **Total 87.000 ZAR**
Marine Mammal Society	1000$ (2011) Small grants in aid of research
Seiche	4.000£ (2013)
Skjold Burnes Fond	10.000 DKK (2013)
Torben og Alice Frimodts Fond	25.000 DKK (2013)
Michael Bergen (private donation)	100$ (2013)
Ralph Immerman (private donation)	3.500 ZAR (2014)
Project Aware Foundation	4.000$ (2011)
Leica, Denmark	TC207 Total station to be used during the field work in South Africa
Shark Diving UnLimited	Divers, vessel, and skipper available on request for servicing of the acoustic logger
Save Our Seas Foundation	3640$ (2014)
Jenni Chang (private donation)	500 ZAR
Whale Festival 2013	3.000 ZAR

Abbreviations

BSB1	Breeding Stock B off tropical West Africa (humpback whales)
BSB2	Breeding Stock B off west of South Africa (humpback whales)
BSC1	Breeding Stock C off Mozambique (humpback whales)
Cc-pair	Cow-calf pair
DEA	Department of Environmental Affairs (South Africa)
DIC	Dyer Island Cruises
DICT	Dyer Island Conservation Trust
ESKOM	Electricity Supply Commission (South African electricity public utility)
GRT	Geyser Rock Tours
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
MPA	Marine Protected Area
PAM	Passive Acoustic Monitoring
SAG	Surface active group
SE	Standard error over the mean value
SST	Sea surface temperature
TIME	Tourism In Marine Environments
UA	Unaccompanied adult
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WWV	Whale watching vessel

1 General introduction

1.1 Cetaceans

The order Cetacea (whales, dolphins, and porpoises) is a diverse group of aquatic mammals found widespread throughout the world. They live their entire life in water with habitats spanning open oceans, inshore environment, estuaries to large river systems (Berta et al. 2006). All cetaceans share fairly similar external features, with a streamlined body, horizontal tail fluke, flipper-shaped fore limbs, and hind limbs reduced to vestigials (Hong-Yan and Xi-Jun 2015). Cetaceans originate from a group of land mammals of the order Artiodactyla (even-toed ungulates) (Berta et al. 2006) roaming about 50 million years ago in the Himalayas (Thewissen et al. 2007). The cetaceans are nested within the artiodactyls and most recently a common order Cetartiodactyla is recognised (Claudine et al. 1997). The best support for this is the "missing link" between cetaceans and the artiodactyls is the small *Indohyus* (Thewissen et al. 2007) which belongs to the artiodactyl family "Raoellidae" and is believed to be the sister group to of all cetaceans. This ancestry is based on the morphological synapomorphic features shared between cetaceans and *Indohyus*; thick limb bones (to reduce buoyancy), dense inner ear bones (protection against pressure (Ketten 1997)), and teeth structure (Thewissen et al. 2007, Thewissen et al. 2009). Of all the land living mammals today, the cetaceans share the closest common ancestor with the hippopotamus (Geisler and Uhen 2003, Boisserie et al. 2005). Among the mammals adaptions to an aquatic life have evolved at least three times independently (Berta et al. 2006) and cetaceans are not related to any of the other marine mammals orders and groups; the sirenians (manatees and dugongs) distantly related to elephants and rock dassies (Berta et al. 2006), the pinnipeds (walruses, seals, and sea lions) related to terrestrial carnivores (Berta et al. 1989, Berta et al. 2006), the mustelid sea otters and the polar bear a recently "budding" of the brown bear (Berta et al. 2006).

Mammalian features are not always obvious in cetaceans which during their evolutionary process of adapting to aquatic life became highly transformed. In many species there is no longer any presence of hair or fur left. A few species still possess a few hairs on their upper lips and dolphin foetuses have whiskers (Thewissen et al. 2009). Being warm blooded, they have developed an insulating layer of blubber, to prevent heat loss to the surrounding water (Berta et al. 2006). Cetaceans have a unique morphology and possess many extreme adaptations to aquatic life, including sonar, physiology, neurobiology, and behaviour (Berta et al. 2006).

The order consists of 14 families and 87-89 species divided into two suborders; Mysticeti (baleen whales) and Odontoceti (toothed whales) (McGowen et al. 2009, Chen et al. 2011, Hong-Yan and Xi-Jun 2015). Mysticetes are carry baleens, keratinous plates that grow continuously throughout their life span used to skim the water masses for food items. Odontocetes have teeth, anything from 2 to in Curvier´s beaked whales (*Ziphius cavirostris*) to around 255 in long-beaked common dolphins (*Delphinus capensis*) (Best 2007), asymmetric cranial vertex, and use echolocation to locate and catch prey.

Four families of mysticetes are commonly recognised; Balaenidae, comprising four species including the southern right whale (*Eubalaena australis*), Neobalaenidae, withonly one species, the pygmy right whale (*Caperea marginata*), Eschrichtidae, also only with a single species, the grey whale (*Eschrichtius robustus*) and the largest family the rorquals orbalaenopterids, with at least eight species including the humpback whale (*Megaptera novaeangliae*), the Bryde's whale (*Balaenoptera edeni*) and the largest of all mammals, the blue whale (*Balaenoptera musculus*) with a maximum length of 33 m (Arnason et al. 1992, Sasaki et al. 2005, Sasaki et al. 2006, Demere et al. 2008, McGowen et al. 2009). The suborder of Odontoceti contains 10 families and far more species than the suborder of Mysticeti. Families with just one or two species are: Physeteridae (sperm whale, *Physeter macrocephalus*), Kogiidae (pygmy sperm whale *Kogia breviceps* and dwarf sperm whale *Kogia sima*), Platanistidae (South Asian river dolphin, *Platanista gangetica gangetica dwelling in the Indus and Ganges rivers*), Pontoporiidae (franciscana, *Pontoporia blainvillei*), Lipotidae (Baiji, *Lipotes vexillifer*), Iniidae (boto *Inia geoffrensis*), and Monodontidae (white whale, *Delphinapterus leucas* and narwhal, *Monodon monoceros*) (McGowen et al. 2009). The Phocoenidae contains 6 species of porpoises, including the smallest of all cetacean species the vaquita (*Phocoena sinus*) measuring only 1.45 m (McGowen et al. 2009). The largest and most wide-spread family is the dolphin family, Delphinidae whicht contains at least 36 species including the largest dolphin, the killer whale (*Orcinus orca*) and the smallest the Maui dolphin (*Cephalorhynchus hectori*). The family is traditionally subdivided into three subfamlies: Lissodelphininae, Globicephalinae, and Delphininae (McGowen et al. 2009). The exact numbers of species are still unsettled due to the wealth of new genetic results and scientific dispute over species recognition. Finally, the family, which has expanded the most over the recent years due to more advanced research technologies, are the beaked whales, Ziphiidae. So far, this family accounts for 21 species and contains deep diving species such as Cuvier´s beaked whale (*Ziphius cavirostris*) (McGowen et al. 2009).

A total of 51 species of cetaceans are believed to occur in the Southern African subregion (Best 2007) (between the equator and Antarctica), accounting 3 families and 9 species of mysticetes and 5 families and 42 species of odontocetes (Best 2007). A review by Elwen et al. (2011) counted a total of 550 peer-reviewed articles and books covering this region, with more than over half published after 1990 and 36% of the material specifically relating to South Africa. The most intensively studied species were the coastal, due to their accessibility, with the southern right whale (*Eubalaena australis*) accounting for most publications (45), and the other coastal species (humpback whales (*Megaptera novaeangliae*), killer whales (*Orcinus orca*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and Indian Ocean humpback dolphins (*Sousa plumbea*)) accounted for 25 - 31 publications per species (Elwen et al. 2011). Year round and long term studies of cetacean species are scarce along the South African coast and hence detailed seasonal and temporal distribution patterns of the coastal species are not available. Knowledge about temporal and spatial distribution, genetic variance within species, is of paramount importance for the monitoring and protecting these species.

1.2 Aim and motivation of the study

This project was initiated in 2010 and entailed contacting the local supervisors in South Africa, establishing field stations, fund raising, managing volunteers, and collecting and analysing the data. The core motivation was to provide scientific evidence of the distribution, habitat use, and behaviour of cetacean species in the Greater Dyer Island Area, Western Cape.

Another objective was to investigate the possibilities of using passive acoustic monitoring (PAM) as a tool for measuring cetacean presence and behaviour in the Western Cape.

The study sought to answer the following questions:

- What is the seasonality of cetacean species using the area?
- Which types of behaviours are observed in the area?
- What is the seasonality of the different behaviours?
- How vocal are the cetaceans in the area?
- Can the vocalisations be used to monitor cetacean habitat use?

1.3 Research area

1.3.1 GREATER DYER ISLAND AREA

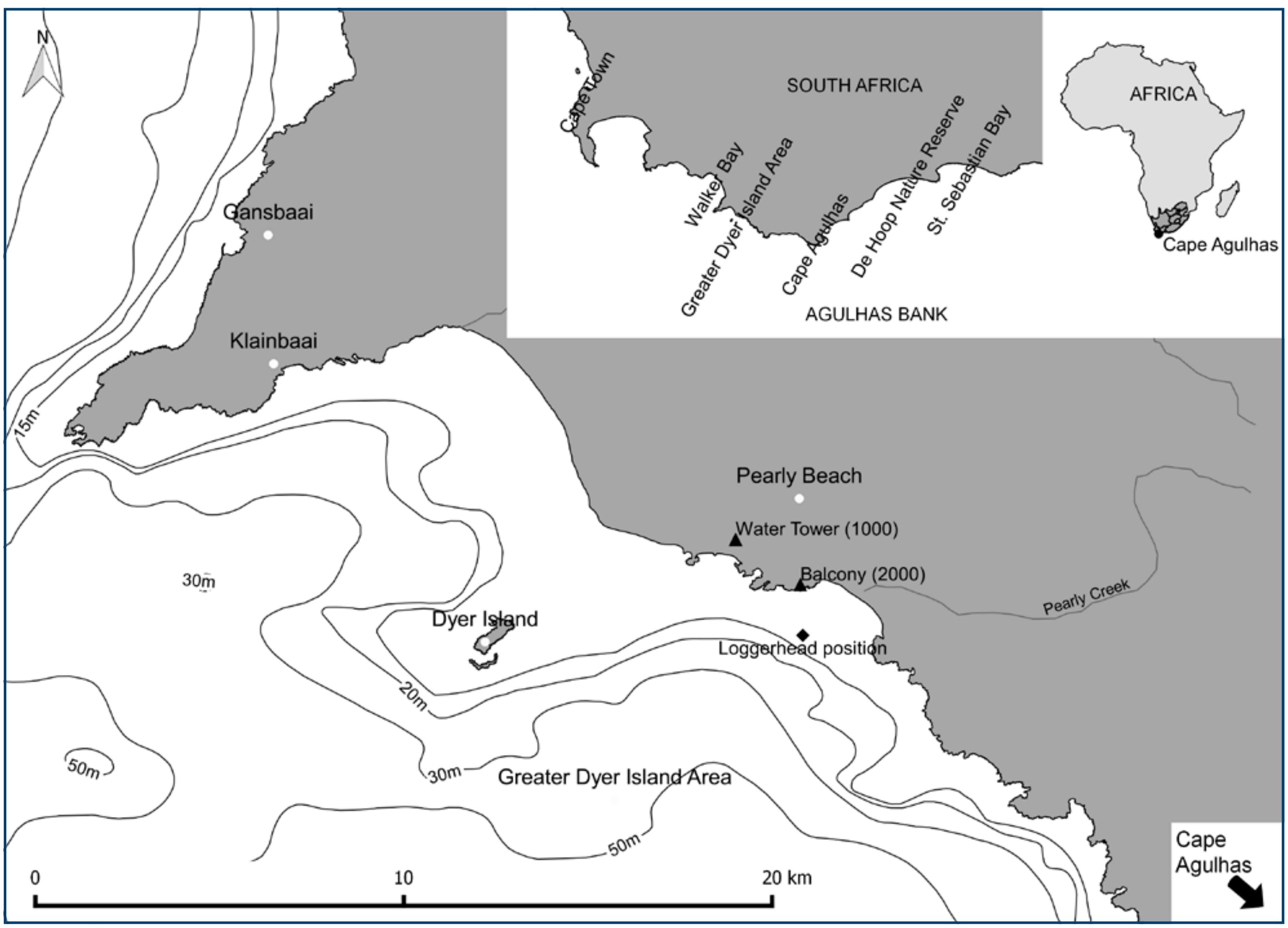
The South African coastline is approximately 3000 km long stretching from the border of Namibia on the west coast to the border of Mozambique on the east coast. The entire coast-line can be divided into three main regions based on differences in sea temperatures; the subtropical east coast, the warm temperate south coast, and the cold temperate west coast (Emanuel et al. 1992). The temperature gradients are generated by cool wind-driven upwelling of the nutrient rich Benguela ecosystem on the west coast and the warm relatively nutrient poor Agulhas current running from the north to the south on the east coast (Ansorge and Lutjeharms 2007). There is no specific meeting point of the two currents but rather an oscillating mixture of the water masses occurring perpendicular to the continental shelf and forming eddies of warm water which move from the Agulhas current into the southern Atlantic Ocean with the Agulhas current retroflecting back into the southern Indian Ocean (Ansorge and Lutjeharms 2007). The study area is situated approximately 55 km west of Cape Agulhas, the southernmost point in South Africa and is part of the inshore Agulhas Bank shelf system which forms the southern boundary of the Benguela upwelling system and hence is affected by both current systems (Hutchings et al. 2009).

The Dyer Island and Geyser Rock (34°40.61' S, 019°23.93' E) comprise the island complex from (Figure 1) which the research area has obtained its name. The 390 ha island complex is a fully protected nature reserve. Dyer Island (Figure 2) is a relatively small and flat island of 20 ha and an access controlled important bird area (IBA), with 12 different seabird and five terrestrial bird species breeding on the island, including the endangered African penguin (*Spheniscus demersus*) (BirdLife South Africa 2015). Geyser Rock is a small rocky island of 3 ha without any vegetation, which hosts more than 60,000 Cape fur seals (*Arctocephalus pusillus*) (Kirkman et al. 2013), making it the fourth largest colony out of a total of 23 in South Africa with an increasing population since 1971 (Kirkman 2010). The island complex is situated 8 km from Kleinbaai harbor and 7 km from Pearly Beach. The nature reserve is managed by the Walker Bay office of CapeNature (BirdLife South Africa 2015). The area is also well known for its year round presence of great white sharks (*Carcharodon carcharias*) (Towner et al. 2013).

The study area consists of two main bays with sandy beaches, namely Franskraal and Pearly, which are separated by a rocky kelp-covered reef extending out from the island complex and the inshore reef system stretching parallel to the coast line (Figure 1). Both bays are characterised by a mixture of sandy gently sloping bottoms, a few shallow reefs, and kelp forests. Water depth in the study area does not exceed 100 m and the inshore area does not exceed 50 m (Figure 1). Two small fresh water rivers flow into each of the main bays, Pearly Beach Bay (Pearly Creek) and Franskraal Bay (Uilkraal estuary). Pearly Creek is the smaller of the two, Uilkraal and has been temporarily closed since 2009 (Anchor-Environmental 2010). It opens only in the summer period sometimes creating inland lake characteristics with brackish waters. Uilkraals estuary is also temporarily closed occasionally creating brackish lake characteristics.

Sea surface temperature (SST) does not exhibit strong seasonal variations. Towner et al. (2013) measured the annual mean SST at 14.9 °C with mean monthly temperatures ranging from 13.5 °C to 16.2 °C. Half-hourly sea temperature was measured with a Starmon mini, underwater temperature recorder (Star Oddi 2016) conducted by the South African Government, Ocean & Coast, from 25th July 2012 until 2nd September 2013, close to Quoin Point (34°45'48.50"S, 19°35'12.28"E, approximately 10 km from the study site and at 35 m depth), showed similar results with an average temperature over the entire period at 13.3 °C, a summer average at 11.7 °C (December - February) and a winter average at 14.8 °C (June – August). SST in the study area has short periods of cold water fluctuation due to upwelling in the summer period driven by the south-easterly winds (Jury 1985) causing the water temperature to be more variable in the summer period (Roberts 2005). The prevailing wind direction shifts throughout the year: in summer (December – February) winds are predominantly southerly or south-easterly (resulting in upwelling, caused by water from Benguela origin to enter the bay), in autumn (March – May) they are southerly, south-easterly or north-westerly, in winter (June – August) they are north-westerly, south-easterly or south-westerly, and in spring (September – November) they are south-easterly, southerly or south-westerly (Law 1999). Because the winter periods are dominated by northwards winds, upwelling is reduced and patches of warm water from Agulhas Bank enters the bay (Lutjeharms J R E et al. 2000).

FIGURE 1
Overview map of the study area, the Greater Dyer Island Area. The two land-based theodolite stations are denoted "Water Tower (1000)" and "Balcony (2000)". The position of the bottom-moored hydrophone is the "Loggerhead position".



Until this study, there has been no in-depth study of the cetacean species in the area. To enable an assessment of the need for protection of the cetacean species, it is crucial to obtain more specific information about their use of the area, as well as seasonal and spatial distribution patterns. The research area faces the potential establishment of a nuclear power station, and with the lack of baseline knowledge of the cetaceans in the area, prior to this study, it has not previously been possible to conduct an analysis of the potential impacts on cetacean species in the area.

FIGURE 2
Aerial photo of the island complex consisting of Dyer Island (the larger island to the right) and Geyser Rock (smaller rocky island to the left) with Shark Alley between the islands.

PHOTO CREDIT
KATJA VINDING PETERSEN AND HARRY WILLIAM STONE

1.3.2 POTENTIAL HUMAN IMPACTS

Particularly inshore cetacean species face more challenges from potential human impacts (Sciara and Gordon 1997, Hoyt 2012). The two main potential human impacts in the research area are underwater noise pollution from vessels and the projected construction of a nuclear power station.

1.3.2.1 Vessel noise; whale watching and shark cage diving

Interaction between vessels and cetaceans are known to cause anti-predator type response from the cetaceans through for example, avoidance of high vessel impact areas (Bejder et al. 2006a, Bejder et al. 2006b) and measurable changes in ecology and behaviour (Stensland and Berggren 2007, Christiansen and Lusseau 2014), with changes in surfacing intervals, acoustics, swimming behaviour and changes in group structure (Parsons 2012). Vessels, and in particular, whale watching vessels which spend extended periods in close proximity to animals, have been identified as one of the most pervasive threats to cetaceans, with threats such as avoidance of areas (Bejder et al. 2006b), behavioural change (Ng and Leung 2003), injury (Laist et al. 2014), and decreased nursing periods (Stensland and Berggren 2007). The potential impacts from the vessels include underwater noise (Richardson and Würsig 1997, Wright 2006, Jensen et al. 2009, Munger et al. 2011), time spent in close proximity to animals (Lusseau et al. 2006), and the number of vessels (Bejder et al. 2006b). Responses of cetaceans to different impacts of vessels have been documented to have both short (Bejder et al. 1999, Lundquist et al. 2012, Lundquist et al. 2013) and long-term effects (Bejder et al. 2006b, Lundquist et al. 2013). Regulations of particularly whale watching vessels are therefore important in order to mitigate human impacts from vessel interaction. Particularly distance to the whales, number of vessels, and reinforcement of the legal rules was found (in a number of studies) to be the most important factors to include in regulations (Parsons and Scarpaci 2011).

In South Africa, commercial whale and dolphin watching has been regulated by the government, Department of Environmental Affairs (DEA) since 1998 (MLRA 2008a). Regulation began in 1998 when 20 license holder areas were designated along the approximately 3000 km coastline, increasing to 25 areas in 2002 (Turpie et al. 2005). Each license area has one to four (maximum) operating whale watching vessels (WWV). By law, the WWVs may not approach cetaceans closer than 50 m, not spend more than 20 min at any encounter nor spend time with cow-calf pairs, and operators must collect information on trip statistics including the species, number-, and behaviour of animals encountered, and submit it to DEA. The study area, from Danger Point in the west to Quoin Point in the east (Figure 1), is whale watching license area 10 (Turpie et al. 2005), where the company 'Dyer Island Cruises' (DIC) was the sole license-holder from 2000 until 2010 when "Geyser Rock Tours" (GRT) started as the second whale-watching company. A total of eight licensed shark cage-diving companies operates in the area between Kleinbaai harbour, Franskraal Bay, and Dyer Island (MLRA 2008b). Activities of the cage-diving vessels are weather dependant, and the number of trips per day can vary from 1 up to 5 in the high season (December). Only one of these vessels holds a dual license (whale watching and cage diving and vessels without a license can approach whales up to 300 m, hence the cage diving vessels transfer from the local harbour to an anchoring location at sea. Anchoring locations of the cage-diving vessels are mainly in the southern part of Franskraal Bay (known locally as Joubertsdam) or adjacent to Dyer Island (known locally as Geldsteen), depending on the season and distribution of great white sharks (Towner 2012). Shark cage-diving are also required to collect and submit information on trip statistics to DEA.

1.3.2.2 Nuclear power station

South Africa is a developing country with a great need for increased power production. The South African national energy supplier ESKOM (Electricity Supply Commission, Ownership of ESKOM vests in the South African government (ESKOM 2016)) owns the earmarked farm "Groot Hagelkraal" also known as Bantamsklip, which is situated less than 10 km from the Dyer Island Nature Reserve Complex, 4 km from Pearly Beach and a nuclear power plant is projected for this location. The construction of a nuclear power station could have potential impacts on the marine environment in the area.

A number of reports have been submitted since 2007 as part of the public hearings on the establishment of a nuclear power station in the area. The PhD student primarily compiled the documents with contributions from the team at Dyer Island Conservation Trust. The submitted letters of concern and the response from the engineering company "ARCUS GIBB" can be acquired upon request from the PhD student. An important outcome from the submitted "Letters of concern" was that the revised edition of the Marine Ecology Impact Assessment (Griffiths and Robinson 2011) had included some information about the cetacean species in the area, particularly on dolphin species which was not present in the previous report (Griffiths and Robinson 2007), and most importantly, the revised edition contained some requirements of potential monitoring of inshore dolphin species *"Monitoring of coastal dolphin in the area around Bantamsklip. Should Bantamsklip be chosen as the site for the power station, Professor Peter Best of the University of Pretoria should be asked to evaluate whether a monitoring programme considering behaviour and density of the Indo-Pacific humpback dolphin (Sousa chinensis) and the Indo-Pacific bottle-nosed dolphin (Tursiops aduncus) should be designed and implemented. Such monitoring could, inter alia, take into account the potential affects of noise levels and turbidity during the construction phase, noise levels and the thermal plume during the operational phase."* p. 59 (Griffiths and Robinson 2011).

A major improvement of the most recent EIA from 2012 is the participation of the marine mammal specialist, Dr. Simon Elwen, who is part of the team behind the EIA (Griffiths et al. 2012). Such participation was not previously part of the team and one of the strong concerns in the "Letters of concern".

1.3.3 PROTECTION STATUS

The study area is currently not assigned any protected status, nor is it a whale sanctuary. South Africa has currently a total of 23 MPA´s which are protected and managed under the Marine Living Resources Act no. 18 of 1998 (MLRA 2001). The closest MPA´s to the study area are De Hoop to the east of the study area and Bettys´ Bay to the west. There are two areas in the immediate vicinity of the study area which are protected; Walker Bay, where approximately half of the Bay is a whale sanctuary from 1st July until 30th November, and Dyer Island, a year-round important bird area (BirdLife South Africa 2015). The Walker Bay area, which also host southern right whales (Elwen and Best 2004, Elwen and Best 2004*a,* Elwen and Best 2004*b,* Hofmeyr-Juritz and Best 2011) is used by the local fishing industry and boat based whale watching. It is the area with the most WWV licenses in South Africa (MLRA 2008a) and the "whale sanctuary" is only covering half of the bay. The rest of the bay (Restricted area) is open towards a wide variety of vessels year round including a fishing fleet. *"The provisions of section 43(2)(a) of the Act shall not apply to vessels authorised to undertake boat based whale watching in the areas as published in Government Notice No. 417 of 18 February 2000 (Government Gazette No. 20877), or to authorised commercial linefishing, recreational linefishing and harvesting of seaweed or any other marine resource within the Restricted Area."* Stipulation 3.3 (MLRA 2001). Future studies of the impacts of the cumulated effects of underwater noise from fishing vessels and WWV is highly recommended.

In December 2014 there were six marine locations along the South African shore which were assigned the status of a "Hope Spot" by Dr. Sylvia Earle and Sustainable Seas Trust & SEA Pledge. The entire coast of the Overstrand Municipality stretching from Rooi Als to Quoin Point and known as the Cape Whale Coast, was recognised as one of these Hope Spots. This status does not provide any specific protection, but Hope Spots are special conservation areas which are critical to the health of the ocean, and the status helps to attract attention to such areas (de Villiers 2014). One of the major benefits for the particular Cape Whale Coast Hope Spot has been the increase of collaboration and communication between different parties e.g. local NGOs´, government, and the public. Through such strengthening of collaboration it is hoped that the area will remain pristine and potentially in the future be assigned the status of an MPA (de Villiers 2014).


CWCHS

Dr. Sylvia Earle listening to southern right whale sounds during the official launch of the Cape Whale Coast Hope Spot.

PHOTO CREDIT
HARRY STONE

1.4 Research design and methods

Knowledge of the abundance of animals, their distribution, genetic variability, and behaviour is essential when applying effective conservation effort of ecosystems and species (Caughley and Sinclair 1994, Perrin et al. 2007). Obtaining the necessary abundance, distribution, and behaviour data can be difficult and expensive to obtain (Redfern et al. 2006). The following combination of three different and fairly low cost methods, namely platforms of opportunity, land-based observation, and passive acoustic monitoring, was used to investigate the cetacean species in the research area (see research questions at the end of this chapter).

1.4.1 PLATFORMS OF OPPORTUNITY (WHALE WATCHING)

Whale-watching operations (Ingram et al. 2007), cruise ships (Williams et al. 2006), seismic survey vessels (de Boer 2010, Weir 2011), or ferries (Weir et al. 2004, Kiszka et al. 2007), are all regarded as platforms of opportunities. The location and routes of such platforms can be situated in places where traditional scientific studies of marine life are rare, very costly, or never conducted. Observations from these platforms can provide a low cost alternative and potential supplement to scientifically conducted research, especially in developing countries (Hauser et al. 2007, Koslovsky et al. 2008) and be utilised for data collection on spatial distribution, temporal patterns in abundance, and behaviour (Hoyt 2001, Koslovsky et al. 2008), (Weinrich et al. 1997, Macleod et al. 2004, Ingram et al. 2007, Koslovsky et al. 2008, Vinding et al. 2015). However, such data need to be interpreted with caution, especially given spatial or temporal differences in effort or variation in observer ability to correctly identify species (Evans and Hammond 2004, Hauser et al. 2007). From a research point of view, the collected data must be valid and consistent to be useful. Hauser et al. (2007) recommend that a proper evaluation and understanding of the limitations of the dataset is conducted before a spatial analysis can be applied.

Whale watching has become an increasingly popular activity and has often led to local economic upliftment (Higham et al. 2014). In 1998, an estimated nine million participants took part in commercial whale watching activities in 87 countries. This number has increased annually by approximately 12.1% since 1991 (Hoyt 2001). By 2008, the industry had increased to an estimated 13 million whale watchers in 119 countries and particularly in developing countries as for example China, Cambodia and Panama it is still a fast growing industry (O'Connor et al. 2009). This increase in numbers and geographic coverage broadens the potential scope for collection of scientific information from this type of platform. Opportunistic data from whale watching vessels (WWV) are collected world-wide and in 2004 there were at least 80 projects which were either ongoing or finalized (Palazzo et al. 2004). For example the study of Ritter et al. (2011) in La Gomera (Canary Island, Spain) established that at least 23 cetacean species use the area based on 15 years of whale watching data and Scheidat et al. (2000) photo-ID study of humpback whales (*Megaptera novaeangliae*) in Ecuador found an increase in reproductive behaviour, number of calves, and relative abundance and concluded that the Machalilla National Park constitute a reproductive area for humpback whales.

12 years of data collected (2000 – 2012) from the local whale watching company DIC was firstly analysed for consistency and validity and used to investigate which cetacean species use the area and their spatial and temporal distribution.

1.4.2 LAND-BASED OBSERVATIONS (THEODOLITE TRACKING)

Collecting spatial distribution of cetacean species can be done using a variety of methods, including satellite-, radio-, and theodolite tracking. These techniques have different constraints and benefits and should be used in relation to the research question in focus. Satellite and radio tracking requires that the attachment of a tag on the animal, which can be challenging for some species. The tags can be programmed to collect different data, such a location, water depth, and pressure at different intervals. Data is either collected internal in the tag or transmitted through satellites (not possible for radio tags). These tags follow the animals over long periods and potentially long distances, the main constrains are the battery life and costs. The number of individuals included is also often low, unless the study stretches over a long period (Sveegaard et al. 2011) and there is a risk of behavioural changes since the tags available today are deployed can be invasive (Mate et al. 2007, McIntyre 2014). Satellite tags have been deployed successfully on many cetacean species (McIntyre 2014). The tagging techniques were not used in this study because the aim was to investigate the fine scale movements of cetacean species in the study area (see "aim and motivation of the study"). A theodolite (total station) was used instead, since it can provide an accurate position of animals in a relative small area in the vicinity of the theodolite station, it is inexpensive, and it is non-invasive (Frankel et al. 2009). The qualitative data provided would give an estimate of how important the area is to animals studied. If used by well-trained observers and an animal or a group is tracked properly, swim-speed can be measured and a good estimate of the amount of time spend at the surface can be obtained.

The theodolite or total station as the more modern models are called, measures a horizontal and vertical bearing very precisely from a known position to a target and by using trigonometry and the latitude and longitude position of the instrument it is possible to calculate a geo-referenced position of the animals (Lerczak and Hobbs 1998). When positions are collected successively it is possible to calculate the swimming speed of the animals (Würsig et al. 1991). The method was first introduced by Roger Payne for marine mammals in 1972 and for dolphins by Würsig and Würsig in 1979 (Würsig et al. 1991). Before this time, behavioural aspects of cetology were mainly anecdotal information (Matthews 1938, Cummings et al. 1971), and the use of theodolites provided some of the first more detailed studies. Through the 1980'ies and 1990'ies an increase in using this method to study the behaviour and area use of cetaceans and has become a common way of studying behavior (Würsig and Würsig 1980, Bejder et al. 1999, Boye et al. 2010, Photopoulou et al. 2011, Barendse and Best 2014).

To obtain the highest possible precision of the target, it is important that the theodolite is positioned at a stable platform, in the same position and calibrated before conducting measurements of animals. Several environmental factors can influence the delectability of the animals, both in positive and negative directions. These environmental factors include; swell height, glare, sea state, rain, fog, wind direction and wind strength. A theodolite cannot be used during nighttime as the data collection relies on vision. The behaviour of the species in question is also important, since the technique rely on the animals spending time at the surface. It is not suitable for greater areas as the detectability decreases with distance. There might also be observer bias as due to different levels of training, experience and other variable circumstances.

Studies using theodolite tracking which focused specifically on southern right whales has so far only been conducted at the West coast of South Africa from Saldanha Bay (Barendse and Best 2014), and Cape Columbine (Best 2000). This area has been identified as a non-nursing area (Barendse and Best 2014) and it is therefore interesting to investigate the fine scale movements of southern right whales in a known nursing area. Theodolite tracking has been used in a number of other cetacean studies in South Africa, which include Ken Findlay extensive work on humpback whales at the East coast, Cape Vidal (Findlay and Best 1995, Findlay and Best 1996a, Findlay and Best 1996b, Findlay et al. 2011b), Photopoulou et al. (2011) study of Indo-Pacific bottlenose dolphins Tursiops aduncus (conducted as a master study during Ken Findlay humpback studies), and James (2015) and Betts (2016) master studies on Indian Ocean humpback dolphins in Mossel Bay. Swimming speed of right whales has been measured in number of studies (Table 1). Barendse and Best (2014) measured the swimming speed of right whales ($n = 57$) at the South African West coast and found that it ranged from 0.2 to a maximum of 7.6 km/h with a mean of 2.71 ± 0.08 km/h SE. Barendse and Best (2014) also found that the swimming speed decreased with increasing group size. Best (2000) previously measured the swimming speed of southern right whales at the West coast ($n = 4$) where speed ranged from 0.4 to 3.25 km/h (mean = 2.02

± 1.17 km/h SE), which is similar to what Hain et al. (2013) found in North-eastern Florida for cc-pairs (n = 70) ranging from 0.05 to 4.07 km/h and a mean speed of 1.2 ± 0.76 km/h SE. Satellite tracking of southern right whales in South Africa also showed that the net speed of cc-pairs could reach 10.5 km /h but 88% of the net speed was less than 2 km/h (Mate et al. 2011).

Combining theodolite tracking with passive acoustic monitoring it can be possible to determine the vocalization rate of a species, (taking into account that different behavior in most marine

TABLE 1 OVERVIEW OF STUDIES WHERE SOUTHERN RIGHT WHALE SWIMMING SPEED WERE MEASURED

Author	Species	Location / method	Average swimming speed (km/h)
Barendse and Best, 2014	Southern right whale	South Africa, Saldanha bay, West coast / Theoodolite	All (n= 57): 0.2 – 7.6 (mean = 2.71 ± 0.08)
Best, 2000	Southern right whale	South Africa, Cape Columbine, West coast / Theodolite	All (n = 34, including cc-pairs n = 4): 0.4 – 3.62 (mean = 1.67 ± 0.85) cc-pairs (n = 4): 0.4 – 3.25 (mean = 2.02 ± 1.17)
Mate et al., 2011	Southern right whale	South African South coast / Satellite tracking	cc-pairs (n = 4): 0.6 – 1.5 (mean 1.1 ± na) Unaccompanied adults (n = 11): 1.0 – 2.8 (mean = 1.6 ± 0.59)
Lundquist et al., 2013	Southern right whale	Argentina, Península Valdés / Theodolite	All (n = 93): mean = 1.56 ± 0.77 cc-pairs (n = 38): mean = 1.54 ± 0.85 Juvenile (n = 25): mean = 1.59 ± 0.73 Adult/Mixed (n = 30): mean = 1.57 ± 0.73
Mate et al., 1997	North Atlantic right whales	North America, Bay of Fundy / Satellite tracking	All (n = 9) 0.8 – 4.6 (mean = 2.7 ± 1.33) Within bay average speed = 1.1 ± 0.4 (n = 3) Out side of the bay average speed 3.5 (n = 2) cc-pairs (n = 2) within the bay average speed < 1 Juvenile (n = 1) out side of the bay average swim speed = 3.5
Hain et al., 2013	North Atlantic right whales	Northeastern Florida / Theodolite	All categories (n = 109) Swim speed ≤ 0.9 occurred in 36% of all records Swim speed ≤ 1.9 occurred in 79% of all records cc-pairs (n = 70) 0.05 – 4.07 (mean = 1.2 ± 0.76) non-cc-pair (n = 29) 0.48 – 5.37 (mean = 1.88 ± 1.27) group ≥ 3 (n = 10) 0.81 – 2.44 (mean = 1.26 ± 0.5)

mammals have different types and rate of vocalizing). Van Parijs et al. (2002) combined theodolite and acoustic monitoring in their study of humpback dolphins in Australia and the vocalization rate could be correlated with the number of animals present and hence it was possible to calculate population estimates from vocalization rate.

Theodolite tracking was used in this study from 2011 – 2014 (complete data-set: 7 August to 13 December 2011, 5 May 2012 to 26 December 2013, and 6 June 2014 to 11 December 2014) to investigate the spatial, temporal and behavioral distribution of the cetacean species occurring in the Pearly Beach area. Land-based focal follows were taken from two high vantage points; water tower (station 1000) 34°39'34.37" S, 19°29'21.53" E, 38.79 m above mean sea level (MSL) and a private balcony (station 2000) 34°40'15.03" S, 19°30'29.84" E, 14.65 m above MSL. A Leica TC307 digital total station was connected to a DELL E6430 ATG with a custom set up version of the computer program VADAR (Visual & Acoustic Detection and Ranging at Sea, Dr. Eric Kniest, Newcastle University, Australia).

1.4.3 PASSIVE ACOUSTIC MONITORING

The sound scape of the sea is highly diverse, consisting of sounds originating from human related and natural occurring sources. Human related sources include seismic surveys (oil exploration), shipping noise (propeller cavitations, engine noise (Hofmeyr-Juritz 2010, McKenna et al. 2012, Webster 2015), construction (for example pile driving, off shore windmills, harbours), and military sonar (Richardson et al. 1995, Richardson and Würsig 1997, Koper and Plon 2012, Williams et al. 2015). Anthropogenic underwater noise levels at 30-50 Hz have increased in the North Pacific by 10-12 dB between the 1960s and 2003 (McDonald et al. 2006). This increase is regarded to be caused mainly by shipping (McDonald et al. 2006). Anthropogenic underwater noise is regarded and recognised as a world-wide problem and the number of research and publications has increased drastically in recent years (Williams et al. 2015). Natural occurring sources include volcanoes and similar natural seismic events, wave and wind action, reef systems, underwater currents, aquatic fauna for example spawning fish and crustaceans (Richardson et al. 1995). All cetacean species are vocal (Richardson and Würsig 1997) and use sound for various aspects of communication, orientation, and feeding (Au and Hastings 2008, Mercado et al. 2010, Gridley et al. 2012, Herman et al. 2013, Janik and Sayigh 2013) and use sound for various aspects of communication, orientation, and feeding (Au and Hastings 2008, Mercado et al. 2010, Gridley et al. 2012, Herman et al. 2013, Janik and Sayigh 2013). Hence cetaceans also contribute to the natural occurring sounds by producing a wide variety of sounds (Richardson et al. 1995, Richardson and Würsig 1997) from the low frequency rumbles of a blue whale (McDonald et al. 2001, Akamatsu et al. 2014) to the high frequency echolocation clicks of harbour porpoises (Møhl and Andersen 1973, Villadsgaard et al. 2007).

The use of bioacoustic methods to investigate cetaceans has increased in recent years (Sciara and Gordon 1997, Moore et al. 2006, Mellinger et al. 2007b), and covers different techniques and types of passive acoustic recorders such as D-Tags (Stimpert et al. 2007, Johnson et al. 2009), T-pods (Philpott et al. 2007, Bailey et al. 2009), hydrophone arrays (Madsen et al. 2004), and bottom moored stationary hydrophones. Passive acoustic monitoring (PAM) is a non-invasive technology providing a valuable tool for recording the sounds in the surrounding aquatic environment. Using PAM it is possible to it is also possible to document the presence of species in an area (Mellinger et al. 2007b). Several studies have described the sound production of southern (*Eubalaena australis*), northern (*E. glacialis*), and northern Pacific right whales (*E. japonica*), although different categorisation schemes have been used to describe their call repertoire and direct comparisons are challenging (Table 2). In all species the majority of energy is below 1 kHz (Clark 1982, Parks and Tyack 2005, Urazghildiiev and Parks 2014) and studies from Argentina show that the vocalisation of the southern right whales is mainly concentrated in the frequency range 50 – 500 Hz (Clark 1982, Urazghildiiev and Parks 2014).

Two call types are considered characteristic of all right whale species and have been used in several studies to identify the presence of the right whale species (Matthews et al. 2001, Ildar R.

Urazghildiiev et al. 2002, Parks et al. 2005, Laurinolli et al. 2006, Urazghildiiev and Clark 2006, Urazghildiiev and Clark 2007, Munger et al. 2008, Urazghildiiev et al. 2008, Clark et al. 2010, Hofmeyr-Juritz and Best 2011, Munger et al. 2011, Mussoline et al. 2012). These call types are: a) up calls and b) gunshots. Up-calls have been described as a contact call (Urazghildiiev and Clark 2006, Clark et al. 2010) and produced by all age-groups and both males and females (Parks et al. 2011). Gunshots are believed to be produced by right whale males in a reproductive context and may function as an antagonistic sound towards other males and/or an advertisement sound to attract females (Parks et al. 2005). Gunshot sounds are known to be distinctive and have not been recorded from other cetacean species, such as the humpback whale (Parks et al. 2005, Stimpert et al. 2007). Table 3 lists previous studies and classification of southern right whale up-calls and gunshot sounds.

The benefits with bottom moored hydrophones is that the equipment can be left for long periods (up to years) in the water and will collect in all kind of weather and light (Mellinger et al. 2007a, Mellinger et al. 2007b), depending on the capacity and settings of the recording unit. They can also be placed in remote locations (Clark et al. 1996, Webster and Dawson 2011). The equipment will have to be deployed and retrieved again once the recording period has ended. One DSG-Ocean Loggerhead hydrophone (Loggerhead Instriuments 2013) was moored off Pearly Beach (34°40’59.70” S, 19°30’31.75” E) at 15 m depth, approximately 8 m above the sea floor. Mooring and

TABLE 2 OVERVIEW OF STUDIES OF RIGHT WHALE VOCALISATION AND CATEGORISATION (INCLUDING ALL SPECIES OF RIGHT WHALES).

Location/Species	Number of call type categories	Name of calls	Author
South Africa / southern right whale	12 plus the gunshot	Up (low, medium, high), down (low, medium, high), flat (low, medium, high), and gunshot.	Hofmeyr-Juritz (2010)
Argentina / southern right whales	8	Upcall, down call, constant call, high call, hybrid call, pulsive call, blows, and slaps.	Clark (1982)
Argentina / southern right whales	5	Belches, simple moans, complex moans, pulses and miscellaneous phonation.	Cummings et al. (1971)
Argentina / southern right whales	No categories	Points along a continuum. Single utterances. Not songs.	Payne and Payne (1971)
Auckland islands / southern right whales	10	**Tonal**: upcall, downcall, tonal low, high, very high and long tonal low. **Non tonal**: gunshot, pulsive and blow. **Combination of tonal and pulsive elements**: hybrid.	Webster (2015)
Cape Cod Bay / North Atlantic right whales	6	Upsweep, downsweep, narrowband low frequency complex signals, narrowband high frequency signals, wideband complex signals, gunshot.	Urazghildiiev and Parks (2014)
Southeastern United States/ North Atlantic right whales	9	Upcall, downcall, upcall high, tonal low, constant, modulated, pulsive, hybrid, gunshot.	Trygonis et al. (2013)
Bay of Fundy / North Atlantic right whales	6	Upcall, downcall, scream, warble, gunshot, blow.	Parks and Tyack (2005)
Bay of Fundy / North Atlantic right whales	4	Up- and downsweeping modulations, and lower and higher frequency sounds.	Vanderlaan et al. (2003)
Great south channel Cape Cod and Bay of Fundy / North Atlantic right whales	3	Moans, low frequency, gunshot.	Matthews et al. (2001)
Gulf of Alaska / North Pacific right whales	2	Upcall, downcall.	Mellinger et al. (2004)
Eastern Bering Sea / North Pacific right whales	5	Upcall, downcall, down-up, constant, unclassified.	McDonald and Moore (2002)

location tests were conducted in 2013. Three successful deployments were conducted in 2014 (January, September and October). Simultaneous theodolite tracking was conducted during the month of September and a total of 26 hours and 28 minutes of land-based visual observations were conducted while the DSG-Ocean loggerhead was recording.

TABLE 3 OVERVIEW OF PREVIOUS ACOUSTIC STUDIES OF RIGHT WHALE UP-CALLS AND GUNSHOTS

Author	Location / species	Up call	Gunshot
This study	South Africa Southern right whale	Start frequency: 56 ± 13 Hz End frequency: 184 ± 54.5 Hz Center frequency: 107 ± 16 Hz Duration: 0.92 ± 0.28 s	Start frequency: 80 ± 46 Hz End frequency: 5714 ± 5603 Hz Center frequency: 833 ± 713 s Duration: 0.36 ± 0.15 Hz
Hofmeyr-Juritz and Best, 2011	South Africa Southern right whale	Low up (LU 55 – 110 Hz	Broadband, explosive “gunshot” sound
Clark, 1982 in Parks and Tyack, 2005	Argentina Southern right whale	Minimum frequency: 0.08 ± 0.04 kHz (range 0.05 – 0.16 Peak frequency: 0.19 ± 0.05 kHz (range 0.11 – 0.51 Maximum frequency: 3.14 ± 2.96 kHz (range 0.25 – 11.23 Duration: 0.99 ± 0.35 s (range 0.45 – 2.08	Minimum frequency: 0.15 ± 0.17 kHz (range 0.02 - 0.51) Peak frequency: 1.19 ± 1.05 kHz (range 0.02 – 11.51) Maximum frequency: 15.59 ± 6.63 kHz (range 2.99 - 21.92) Duration: 0.07 ± 0.04 s (range 0.01 - 0.17)
Cummings et al., 1971	Argentina Southern right whale	Data not available	Range: 30 – 2100 Hz Duration 0.06 s
Webster, 2015	New Zealand Southern right whale	(n = 701) Peak frequency 121 ± 1 Hz (range 43 – 281 Hz) Start frequency 87 ± 1 Hz (range 32 – 293 Hz) End frequency 143 ± 2 Hz (range 35 – 293 Hz) Duration 0.9 ± 0.01 s (range 0.3 – 2.7s)	(n = 116) Peak frequency 795 ± 65 Hz (range 118 Hz – 3984 Hz) Start frequency 1520 ± 156 Hz (range 597 – 8379 Hz) End frequency 807 ± 72 Hz (range 59 – 3246 Hz) Duration 0.2 ± 001 s (range 0.1 - 0.4 s)
Parks et al., 2005	North Atlantic right whale	Data not available	Duration 0.036 ± 0.015 s
Parks and Tyack, 2005	North Atlantic right whale	Low tonal up sweeps 50 – 200 Hz mean = 0.08 ± 0.04 Hz (range 0.05 – 0.16 Hz) 0.7 – 2.2 Hz	Noisy, broadband, sharp onset 50 – 2000Hz mean = 0.15 ± 0.17 Hz (range 0.02 - 0.51 Hz) 0.2 – 0.3 s
Urazghildiiev and Parks, 2014	North Atlantic right whale	Narrowband low frequency up-sweep signal. One infliction point. Peak frequency < 200Hz	Wideband gunshot sound. Very distinguishable on the spectrogram. Shorter duration than 1.5 s Bandwidth ≥ 100 Hz extending above 5 kHz
McDonald and Moore, 2002	North Pacific right whale	90 - 150 Hz Duration: 0.7s	No data available

1.5 Coastal cetacean species

A total of five cetacean species have been found to frequent the area regularly and three more incidental species have been described (Table 4).

1.5.1 RIGHT WHALES

Placed among the mysticetes, the right whales are known as one of the bulkiest and most robust of the baleen whales with a maximum length of 18.3 m for females with males being slightly smaller at 17.1 m (Northern Pacific right whales) (Best et al. 2001). Right whales are characterized by their callosities in the head region, a significant arched mouth, a V-shaped blow, and lack of a dorsal fin (Best 2007). Three species of right whales are recognised globally based on phylogenetics and phylogeographic analysis; North Pacific right whales (*Eubalaena japonica*), North Atlantic right whales (*E. glacialis*) and the southern right whales (*E. australis*), with the North Atlantic right whales being distinct and closer related to the southern right whales than the North Pacific right whales (Rosenbaum et al. 2000). The only recognised morphological distinction between the North Atlantic right whales (*E. glacialis*) and the southern right whales (*E. australis*) is the alisphenoid bone in the orbital region of the skull (Müller 1954).

All species has been exposed to severe commercial whale hunting particularly in the 1800s and early 1900s (Dawbin 1986, Scarff 2001, Richards 2002, Best 2007). The name originates from this period because it was the right whale to hunt, since they were slow swimmers, distributed close to shore (easy to access), stayed afloat when dead (because of the thick blubber) and provided a high oil and baleen outcome. The southern right whale was the first of the large whales to be protected. The International Whaling Commission (IWC) banned commercial hunting of southern right whales in 1935 and has maintained this status since then.

Distribution and migratory patterns differ between the species and none of the species have been recorded to cross the equator, hence considered as an abiotic barrier to a potential gene flow

TABLE 4 OVERVIEW OF SPECIES OBSERVED FREQUENTLY IN THE AREA

Frequently encountered species	Common name	Population estimate	IUCN international Red list status
Eubalaena australis	Southern right whale	4600 in 2008 (Brandao et al. 2010)	Least concern
Megaptera novaeangliae	Humpback whale	7,134 individuals, B1 substock (Collins et al. 2010) 500 individuals, B2 substock (Barendse 2010) 5.965 individuals, C1 substock (Findlay et al. 2011a)	Least concern
Balaenoptera brydei	Bryde's whale	The South African Inshore stock estimated at 582 (±184) in 1983 (Best et al. 1984)	Data deficient
Sousa plumbea	Indian Ocean humpback dolphin	1000 individuals (Karczmarski 1999)	Endangered
Tursiops aduncus	Indo-Pacific bottlenose dolphin	28,482 individuals (Reisinger and Karczmarski 2010)	Data deficient
Incidential species			
Delphinus spp	Common dolphin	Delphinus capensis 15,000-20,000 off South Africa (Cockroft 1990, Cockroft and Peddemors 1990)	Data deficient
Orcinus orca	Killer whale	Unknown for South Africa	Data deficient
Cephalorhynchus heavisidii	Heaviside's dolphin	6,345 animals, Southwestern coast of South Africa (Elwen et al. 2009)	Data deficient

FIGURE 3
Southern right whale (*Eubalaena australis*), Surface Active Group (top) and cow-calf pair (bottom).

PHOTO CREDIT
KATJA VINDING PETERSEN

FIGURE 4
Humpback whale
(*Megaptera novaeangliae*).

PHOTO CREDIT
EVAN AUSTIN, AFRICAN WINGS

FIGURE 5
Bryde's whale
(*Balaenoptera brydei*).

PHOTO CREDIT
MOGENS TROLLE

between the species (Rosenbaum et al. 2000). As a consequence of this barrier each of the three populations maintain their current species distinctions and geographical distribution making the southern right whale the only right whale species in the Southern Hemisphere (Best 2007). There are three main areas in the southern hemisphere used by southern right whales; off the coasts of eastern South America, Australia/New Zealand, and Southern Africa. They are distributed in the southern hemisphere generally between 20 °S and 60 °S (Mate et al. 2011). They are filter feeders feeding on zooplankton including Antarctic krill (*Euphausia superba*) (Hamner et al. 1988) and migrate between the winter feeding grounds across a broad latitudinal range 32 °S and 65 °S, with the main feeding areas thought to occur between 40 °S and 55 °S and calving/mating grounds in the near shore waters of the southern coastlines of South Africa, Argentina, and Australia between 20 °S and 45 °S (IWC 2001). Smaller numbers of whales are found around oceanic islands including the New Zealand sub-Antarctic Auckland and Campbell Islands and around Tristan da Cunha and Gough Island in the South Atlantic (IWC 2001). Southern right whales are known to exhibit site fidelity (Best 2007) occurring primarily along the southwest coast of South Africa (Best 2007), and are the most frequently observed species in the study area (Vinding et al. 2015). The population of right whales off southern Africa is considered healthy and has been increasing at approximately 7% per year since 1969 when monitoring began and was estimated at 4600 animals (roughly 23% of pre-exploitation numbers) in 2008 (Brandao et al. 2010). This species is listed as least concern the International Union for Conservation of Nature (IUCN 2001c) The winter breeding range of southern right whales around southern Africa extends from Namibia in the west (Roux et al. 2011, Roux et al. 2013) to southern Mozambique in the east (Banks et al. 2011). The vast majority of right whales are found in the sheltered bays of the Cape south coast, usually within 2 km from shore (Elwen and Best 2004*a*) and the entire coastline is recognised as one homogeneous winter assemblage area particularly for pregnant and nursing cows (Best 2000). They appeared either as unaccompanied adults (UAs), as part of surface active groups (SAGs) or as cows accompanied by their calves (cc-pairs). SAGs are defined as groups with high levels of social interaction at the surface with physical interaction between individuals, and where most attention is directed towards a focal animal (or animals) (Kraus and Hatch 2001, Best et al. 2003). Right whales, especially cc-pairs, prefer shallow sloping bay areas with a sandy or muddy bottom, protected from open ocean swell and seasonal winds (Elwen and Best 2004*a*, Elwen and Best 2004*b*). The study area exhibits these environmental factors, especially at Pearly Beach. Right whale 'season' is generally regarded as June to November along the Cape south coast. A peak in numbers have been found in De Hoop (the main nursery area) from August to October (Best and Scott 1993) although there is a general westward shift of whales over the season (Mate et al. 1997, Best 2000) and peaks may occur at different times at different places along the coast line. The population shows some level of segregation with the majority of cc-pairs found off De Hoop and in St Sebastian Bay to the east of Cape Agulhas, and the majority of adults without calves and SAGs (Figure 3) observed in Walker Bay immediately to the west of the study site (Elwen and Best 2004*b*). Annual aerial surveys since 1969 have shown a slight westward shift in distribution and changes in relative uses of different bays along the Cape south coast during the season (Best 2000). Since approximately year 2000, a large proportion of the right whale population has been observed feeding in summer months in the upwelling systems on the west coast, a behaviour also apparent in historic whaling records (Best 2006, Peters et al. 2011).

1.5.2 HUMPBACK WHALES

A single species of humpback whale (*Megaptera novaeangliae*) is recognised world-wide and usually follows the general migration pattern of baleen whales between summer-feeding grounds and winter-mating grounds (Best 2007). There are two breeding stocks which might migrate through the study area. The population migrating up the east coast of southern Africa is *en route* to breeding grounds off Mozambique and possibly beyond and is referred to as Breeding Stock C (BSC1) by the International whaling commission (IWC) (Best et al. 1998). Those passing the west coast are part of Breeding Stock B (BSB), which consists of a large breeding population (BSB1) off tropical West Africa, and a much smaller sub-stock BSB2 (estimated at approximately

500 individuals in 2010) (Barendse et al. 2011), which feeds off the South African west coast in spring and summer (Barendse et al. 2010b). The study area is located between the western most area predicted to be used by BSC whales, namely Cape Agulhas (Cerchio et al. 2008), and the south-eastern most location where BSB humpback whales have been identified, namely Cape Point (Barendse et al. 2011), therefore the affinity of the humpback whales sighted in the study area is uncertain and evidence from genetic, acoustic, or photographic matches is needed. Certainly the low overall number of sightings in the current study suggests that the study area is not part of a main migration route (c.f.Findlay et al. 2011b), and the whales observed may have miscued their point of arrival at the continent on their northward migration. This species is listed as least concern (IUCN 2001d).

1.5.3 BRYDE'S WHALES

An assessment of the distribution of Bryde's whales and a comparison with other data is complicated as there is considerable taxonomic confusion about the definition of the species, and very little is known about its potential migrations, both large-scale and short term. Around Southern Africa there appear to be three allopatric populations: The inshore population which inhabits the Agulhas Bank off the south coast of South Africa between approximately Saint Helena Bay on the west coast and Durban on the east coast (Best 2001). The 'offshore' population in the south east Atlantic found 100 to 200 km offshore, corresponding to the 200 m and 400 m isobaths ranging from the equatorial regions to about 34 °S (Best 2001) and finally the Madagascan population which is found in the South West Indian Ocean, south and east of Madagascar and is not thought to extend as far as the coast of SA (Best, 2001). Bryde's whales in the Southeast Atlantic offshore population possess bite marks from the cookie cutter shark and are slightly larger than those in the inshore population and (Best, 1977; Penry 2009). Although all these populations were previously regarded to be populations of a Balaenoptera edeni, recent genetic analyses has suggested that the Southeast Atlantic population is actually Balaenoptera brydei and the inshore stock a closely related form of Balaenoptera brydei, possibly a sub-species (Penry 2009). Bryde's whales is the only large whale species in the study area which do not migrate to the Southern Ocean to forage, and the inshore population around Greater Dyer Island is believed to stay on the Agulhas Bank subject to minor local movements due to migration of prey (Best 2007). Penry et al. (2011) states that abundance of prey is most likely driving the factor of Bryde's whale presence in near-shore waters. The distribution of their main prey species (pilchard (Sardinops ocellata) and anchovy (Engraulis capensis) (Crawford 1980)), shift south and eastward in the summer (Crawford 1981, Coetzee et al. 2008). The Bryde's whales in the study area have occasionally been observed feeding (Chivell 2012) which can explain the main distribution in the summer and fall. This species is listed as data deficient by IUCN (IUCN 2001a).

1.5.4 INDIAN OCEAN HUMPBACK DOLPHINS

Four species of humpback dolphins are currently recognised; Indo-Pacific (*Sousa chinensis*), Indian Ocean (S. *plumbea*), Australian (*Sousa sahulensis*) and West African humpback dolphins (*S. teuszii*) (Jefferson and Rosenbaum 2014). The Indian Ocean and Indo-Pacific humpback dolphins were previously recognised as a single species (*S. chinenis*) with two forms (*plumbea* and *chinensis*) and thus much of the literature on humpback dolphins in South Africa refers to *S. chinenis*, but due to recent studies (Jefferson and Rosenbaum 2014) the more recently recognised nomenclature of *S. plumbea* is used in the present study for the species occurring in South Africa. The *Sousa plumbea* likely consists of fewer than 10,000 animals and with a discontinuous population, local subpopulations may be quite discrete from each other (Reeves et al., 2008) and the population in Algoa Bay was estimated at a minimum of 466 dolphins (Karczmarski et al. 1999) and fewer than 1000 individuals are thought to live in South Africa (Karczmarski 1996). The small populations and very coastal nature of their habitat makes the species particularly vulnerable to stressors or fatalities such as fishing by-catch, shark nets, human interference, habitat degradation and loss of key habitats, all of which are highest in the coastal habitat (Corkeron et al., 1997; Karczmarski et al., 2000; Reeves et al., 2008). The

FIGURE 6
Indian Ocean humpback dolphin (*Sousa chinensis*).

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FIGURE 7
Indo-Pacific bottlenose dolphin (*Tursiops aduncus*).

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ISABELLE DUPRÉ

humpback dolphins seem sensitive to disturbances caused by vessel traffic and unlike bottle-nose dolphins do not approach vessels to bow-ride (Karczmarski et al., 1997). The *S. chinenis* and the species is listed as "Near threatened" by IUCN red data list convention (IUCN 2001b) and is probably declining (Reeves et al., 2008).

1.5.5. INDO-PACIFIC BOTTLENOSE DOLPHINS

Two species of bottlenose dolphins are commonly found around the South African coast: the common bottlenose dolphin *Tursiops truncatus* and the Indo-Pacific bottlenose dolphin *Tursiops aduncus* (Best 2007). The common bottlenose dolphin is larger than the Indo-Pacific bottlenose dolphin and it generally occurs offshore except in Namibia where a small coastal population exists inshore (Best 2007). *Tursiops aduncus* are distinguished from common bottlenose dolphins by not being as robust as the common bottlenose dolphins, their longer beak, more uniform coloration, and freckled dark spots on the abdomen of some adults (Best 2007). *Tursiops aduncus* is found inshore to the east of Cape Town, throughout the Indian Ocean, and into the south western Pacific (Best 2007). This species is registered as "Data deficient" by the IUCN red data list convention (IUCN 2015).

1.6 Organisation of the report

The thesis is structured as a collection of four scientific articles produced during the PhD project, one article is already published, and parts of one is published, while the last two are still to be submitted. Each article is presented as a chapter and written as a manuscript prepared for submission. The reader will therefore find specific acknowledgements and a literature list at the end of each chapter.

Chapter 2 (is already published in Tourism In Marine Environments (TIME) "The use of Data from a Platform of Opportunity (Whale Watching) to study Coastal Cetaceans on the South West Coast of South Africa" (Vinding et al. 2015). This chapter is presented in a style consistent with the rest of the thesis and the final draft submitted to the journal as pre-page proofs, it has thus been subject to both co-author input, opponents, and peer-review. The final published version of the paper is available in Appendix 1.

Chapter 3 (Article 2), is titled "Cetacean Data Collection from Commercial Whale Watching Vessels: Consistency, Validity, and Value in Local Habitat Monitoring". This chapter is an analysis of the consistency and validity of the whale watching data from the local whale watching vessel. The main results were presented in a talk at the workshop "Marine Mammal Tourism" at the biennial conference at the Society for Marine Mammalogy in Dunedin, New Zealand, December 2013. A working group was established and the PhD student was encouraged to participate in the annual meeting in 2015 at the International Whaling Commission (IWC) and to submit parts of the results as a paper to the IWC. This paper was published as Vinding et al. (2014), "Data collection from commercial whale watching vessels: the need for international guidelines and systematic quality control" see Appendix 2. In June 2016, the PhD student was invited as a participant at the IWC whale watching subcommittee in Bleed, Slovenia.

Chapter 4 (Article 3) "Cetacean Multi-Species Survey in the Greater Dyer Island Area, South Africa: Behaviour, Spatial, and Temporal Distribution" and Chapter 5 (Article 4) "Passive Acoustic Monitoring of Southern Right Whales" will be submitted as papers in due course.

Two additional publications have been published during the PhD "Occurrence of vagrant leopard seals, *Hydrurga leptonyx*, along the South African coast" (Vinding et al. 2013), and

"Non-Offspring nursing in right whales" (Best et al. 2015). These publications can be found in Appendix 3 and 4 respectively. Data collection, data analysis, and article writing was provided by the PhD student for both article.

Appendix 5 contains posters which have been presented at four conferences.

Appendix 6 contains a sound propagation model of the area. The model was instigated by the PhD student and developed in collaboration with team from Seiche Limited; Guillermo Jimenez and Roy Wyatt. The PhD student provided acoustic recordings with humpback whale songs and visual observation positions of humpback whales from the study area.

The study was conducted under a series of permits issued to the Mammal Research Institute, Whale Unit, by the South African Department of Environmental Affairs "Environmental research permit for the purpose of a scientific investigation or practical experiment in terms of section 83 of the marine living resources act, 1998 (Act no. 18 of 1998)". Permit number: RES2011/24, RES2012/56, RES2013/58, and RES2014/73. Research ethics permission was granted by the "Animal use and care committee" University of Pretoria.

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2

2 The use of data from a platform of opportunity (whale watching) to study coastal cetaceans on the south west coast of South Africa

2.1 Abstract

Effective conservation management requires information on wildlife abundance and distribution. Platforms of opportunity, including whale-watching vessels (WWV) can provide inexpensive and valuable information particularly in data deficient areas. This study analysed over 5500 cetacean encounters from more than 2500 trips over 10 years conducted by a WWV in the Western Cape, South Africa. Results were two-fold; 1) discovering that there are five main cetacean species using the area (southern right (*Eubalaena australis*), humpback (*Megaptera novaeangliae*), and Bryde's whales (*Balaenoptera brydei*), Indo-Pacific bottlenose (*Tursiops aduncus*), and Indian Ocean humpback dolphins (*Sousa plumbea*) and providing spatial and temporal distribution patterns for these species as well as the first long-term, year round dataset for this area. 2) Showing that opportunistic data of cetacean encounters collected regularly from a WWV constitute an important source of baseline information of the wildlife abundance and distribution. Caveats and limitations of data from the WWV are discussed and advice regarding data collection from platforms of opportunities are provided. Particularly, the lack of basic data on search effort and of clearly defined behavioural categories is emphasised and standardisation of guidelines for data-collection methods worldwide is suggested.

2.2 Key words

Distribution, Dolphin, Eco-tourism, Guidelines, Seasonality, Whale.

2.3 Introduction

Southern Africa has a diverse cetacean fauna with 38 species known to occur (Findlay et al. 1992, Best 2007), including two endemic populations; Heaviside's dolphin (*Cephalorhynchus heavisidii*) found on the west coast and an isolated and endemic 'inshore' population of Bryde's whales (*Balaenoptera brydei*) (Best 2007). The high diversity is partly due to the varied oceanography around the coast with the warm south-westward flowing Agulhas current in the Indian Ocean passing along the south coast of South Africa and the cold northward flowing wind driven Benguela upwelling ocean current which forms the eastern portion of the South Atlantic Ocean gyre and runs along the Atlantic coast (Ansorge & Lutjeharms in Best, 2007). These currents creates three different ecosystems along the South African coast line; the subtropical east coast, the warm temperate south coast, and the cold temperate west coast (Emanuel et al. 1992). Different marine mammal fauna are associated with each ecosystem, the study area lies near the boundary of the west and south coast ecosystems (Findlay et al. 1992). Apart from information from museum-housed specimens and stranding records, long term research along this part of the coastline has targeted only the southern right whale (*Eubalaena australis*) (see Elwen et al. (2011) for review) identifying the right whale 'season' as June-December along the Cape south coast (Best and Scott 1993). Long term and year round studies are unavailable for the other cetacean species known to occur along this section of the South African coast and hence their seasonal and temporal distribution is unknown and if they are affected by human impacts. There are multiple anthropogenic threats to marine life along the southern African coast including physical changes to the coastline (Sink et al. 2012), pollution (Cockcroft et al. 1989, De Kock et al. 1994, Atkinson and Sink 2008, Braulik et al. 2015), potential establishment of additional nuclear power stations (Griffiths and Robinson 2011), effects of fisheries including depletion of prey (Atkinson and Sink 2008), entanglement in fishing gear (Atkinson and Sink 2008, Meÿer et al. 2011, van der Hoop et al. 2015), boat traffic including recreational, eco-tourism, and fishing vessels (Turpie et al. 2005, Waerebeek et al. 2006, Elwen and Leeney 2010, Meÿer et al. 2011), and tourism in a broader sense (Sink et al. 2012). Structured scientific studies rely on specialised and expensive staff, and intensive monitoring methods such as ship-based or aerial line transects, passive acoustic monitoring, or mark recapture studies (Hauser et al. 2007). Long term and consistent monitoring effort is also essential when determining patterns in spatial and seasonal distribution (Vigness-Raposa et al. 2009, Daniel et al. 2010). These factors make it challenging to obtain the baseline information needed to assess population health and impacts of environmental changes or anthropogenic threats to cetaceans. Baseline information is necessary to establish spatial and/or temporal management plans, and it is important to identify key areas, seasonal presence, and behaviours of cetaceans, to protection cetacean species (Hoyt 2011).

Observations from platforms of opportunity, such as whale-watching operations (Ingram et al. 2007), seismic survey vessels (de Boer 2010, Weir 2011), cruise ships (Williams et al. 2006), or ferries (Weir et al. 2004, Kiszka et al. 2007), have been used to provide alternative sources of data on cetaceans, especially in developing countries (Koslovsky et al. 2008), and information on spatial distribution, temporal patterns in abundance, and behaviour have been acquired (Hoyt 2001, Koslovsky et al. 2008). However, such data need to be interpreted with caution, especially given spatial or temporal biases in effort or variation in observer ability to correctly identify species (Evans and Hammond 2004, Hauser et al. 2007). In 1998, an estimated nine million participants took part in commercial whale watching activities in 87 countries. This number has increased annually by approximately 12.1% since 1991 (Hoyt 2001). By 2008, the industry had increased to an estimated 13 million whale watchers in 119 countries (O'Connor et al. 2009). This increase in numbers and geographic coverage broadens the potential scope for collection of scientific information from this type of platform.

In South Africa, commercial whale and dolphin watching has been permitted by government since 1998 (MLRA 2008), regulated by the Department of Environmental Affairs (DEA). Regulation began in 1998 when 20 license holder areas were designated along the approximately 3000 km coastline, increasing to 25 areas in 2002 (Turpie et al. 2005). Each license area has one to four (maximum) operating whale watching vessels (WWV). By law, the WWV may not approach cetaceans closer than 50 m, not spend more than 20 minutes at any encounter, nor spend time with cow-calf pairs, and operators must collect information on trip statistics including the species, number-, and behaviour of animals encountered, to submit to DEA. In the absence of other studies, observations from WWVs operating along the south-western Cape coast offer a potentially valuable source of information on cetacean presence, distribution, and seasonality. In this study, data collected from a single WWV for the period 2003-2012 were used to assess the distribution and seasonality of all observed cetacean species between Danger Point and Quoin Point in the south-western Cape, after assessing the veracity and consistency of the data. It is expected that there will be some caveats related to this type of data and based on the findings, recommendations will be provided as to how data collection from a WWV can be improved in the interests of providing valuable scientific information for cetacean research or monitoring.

Based on other studies it is expected that the southern right whale will be present in the area from June until December (Best 2007) and the dominant group compositions is likely to chance over the season or by area as cow-calf pairs are known to avoid areas and periods with social active groups (Elwen and Best 2004) and mainly occupy the near shore environments characterised by sheltered gently sloping sandy bays. It is unknown which other species of baleen whales frequent the area but it is hypothesised that species migrating or foraging close to shore can be found in the area. Such species could be humpback whales (*Megaptera novaeangliae*), Bryde's whales, and dwarf minke whales (*Balaenoptera acutorostrata* subsp.) (Best 2007). It is also hypothesised that near shore delphinid species are found in the area, such as the two most common inshore species along the South African coast line; the Indian Ocean humpback dolphins (*Sousa plumbea*) (Findlay et al. 1992, Braulik et al. 2015, James et al. 2015), and the Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) (Findlay et al. 1992, Best 2007). Other dolphin species which might frequent the area could include the long-beaked common dolphin (*Delphinus capensis*) (Findlay et al. 1992). Dolphin species, for example the dusky dolphins (*Lagenorhynchus obscurus*), killer whales (*Orcinus orca*), and the Heaviside's dolphins are unlikely to occur in the study area based on their known distribution patterns. (Findlay et al. 1992, Best 2007).

2.4 The study

2.4.1 STUDY AREA

The study area, from Danger Point in the west to Quoin Point in the east (Figure 1), is identified as whale watching license area 10 (Turpie et al. 2005), where the company 'Dyer Island Cruises' (DIC) has been the sole license-holder since 2000, until 2010 when "Geyser Rock Tours" (GRT) started as the second whale-watching company. GRT conducted similar tours but operated far less frequent and stopped in 2013. Data from GRT have not been included in this study. DIC conducted trips year-round from year 2003.

The study area consists of two main bays with sandy beaches, namely Franskraal and Pearly Beach, which are separated by a rocky, kelp covered reef extending out to Dyer Island and Geyser Rock, approximately 10 km offshore. Both bays are characterised by a mixture of sandy gently sloping bottoms, a few shallow reefs, and kelp forests. Water depth in the study area does not exceed 100 m and the most frequently visited area is less than 30 m deep. Two small rivers flow into each of the main bays, Pearly Beach Bay (Pearly Creek) and Franskraal Bay (Uilkraal estuary). Pearly Creek is the smaller of the two, and is only open in the summer period. Since 2009, closure of the mouth of the Uilkraal estuary occurred periodically (Anchor-Environmental 2010). The estuary was closed during the following periods: January - July 2009, December 2009 - October 2010, December 2010 - July 2011 and October 2011 - June 2012 and was manually opened each time (Anchor-Environmental 2010).

Sea surface temperature in the study area has been described by Towner et al. (2013) who showed that the annual mean SST was 14.9 °C (mean monthly temperatures ranging from 13.5 – 16.2

°C) without any strong seasonal patterns, but with short periods of cold water fluctuation due to upwelling in summer driven by the south-easterly winds (Roberts 2005). The prevailing wind direction shifts throughout the year: in December – February (summer) winds are predominantly southerly or south-easterly, in March – May (autumn) they are southerly, south-easterly or north-westerly, in June – August (winter) they are north-westerly, south-easterly or south-westerly, and in September – November (spring) they are south-easterly, southerly or south-westerly (Law 1999). The study area is situated inshore of the Agulhas Bank which forms the southern boundary of the Benguela upwelling system and displays characteristics of both an upwelling system and a temperate shallow shelf system (Hutchings et al. 2009).

2.4.2 DATA COLLECTION AND VALIDATION

Throughout the 13 years of observations from the WWV (2000-2012), 14 persons were responsible for data collection as either skippers or biologists/guides on board (see acknowledgments). In 2000 there were whale-watching trips only during October – December and in 2001-2002 only during July – October, whereas trips were conducted year-round from 2003-2012. For consistency, only 10 years of data from 2003-2012 were included in this study (see Chapter 3).

On each trip, the following data were collected: date, daily trip number, departure time and weather conditions including wind speed, wind direction and sea state or category. When cetaceans were encountered, the location (latitude and longitude), species, number of groups and individuals, presence of calves, animal behaviour, and photo documentation were recorded.

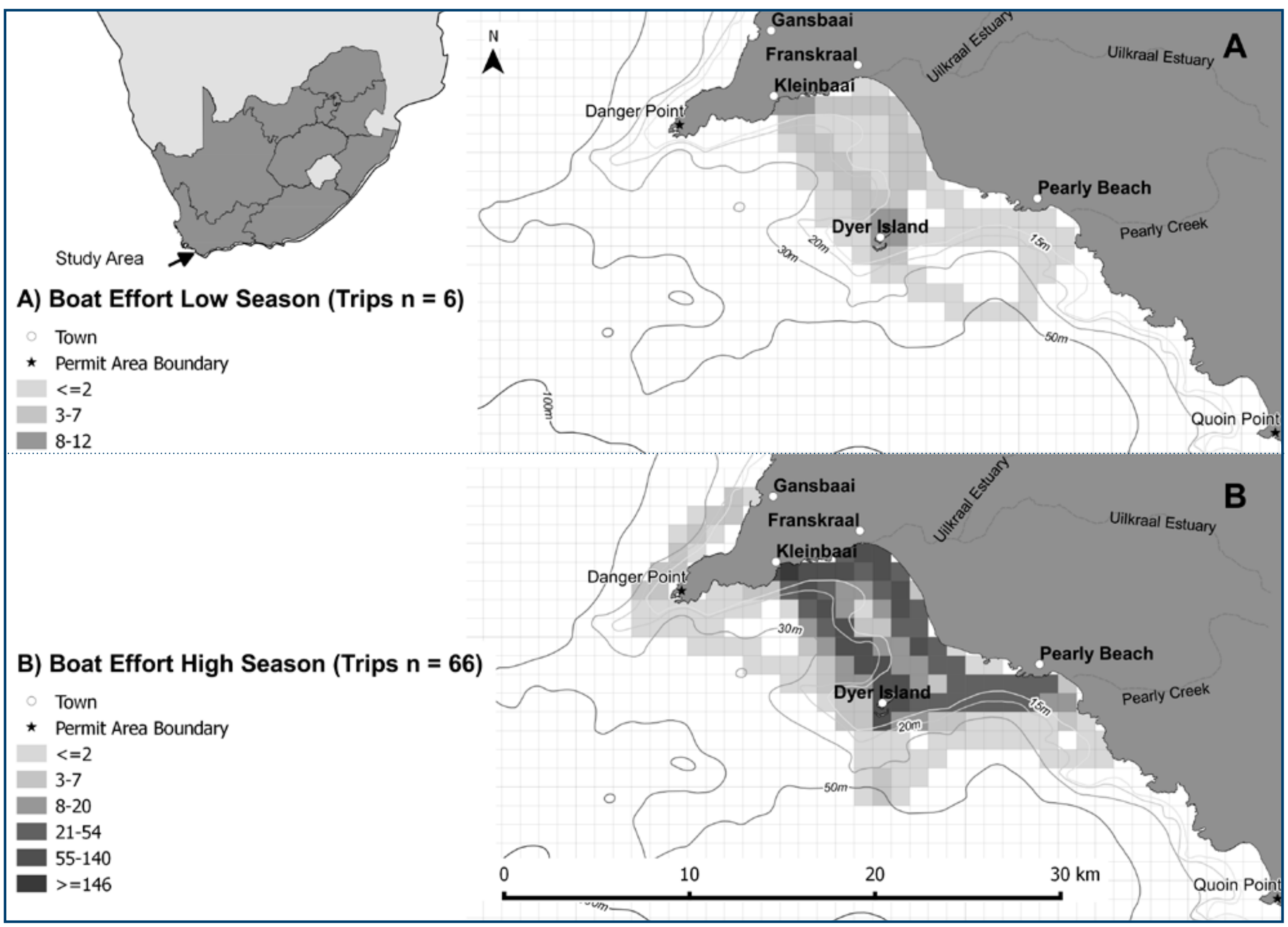


FIGURE 1
Map of the study area between Danger Point and Quoin Point, Western Cape, South Africa showing spatial effort of the WWV based on GPS tracks in the low season (A) and in the high season (B) collected between September 2011 and September 2012.

Grid cell size is 1km x 1km and colours represent the number of times the WWV track passed through each grid cell.

The probability of sighting a cetacean at sea is reduced with increased sea state (Redfern et al. 2008, Bailey et al. 2013). Whereas for larger whales it is possible to conduct scientific surveys in up to sea state 5 (Thiele et al. 2000) for dolphins a sea state of <3 is recommended (Reeves and Brownell 2009). The WWV trips in this study occurred in a wider range of weather conditions than those normally considered suitable for scientific surveys. Only a single value of sea state was recorded per trip often with insufficient record of wind strength or direction (see Chapter 3), thus it was not possible to account for variation in sighting conditions within a trip. Sea state conditions within the study area can vary owing to location and prevailing wind direction, thus sheltered areas can have calm seas at the same time as the exposed locations undergo rough seas. For instance, Pearly Beach is exposed to the southerly winds and fairly protected from the northerly winds while the waters around Dyer Island are exposed to all wind directions.

The relationship between weather conditions and number of encounters for each of the five main species was investigated by comparing the number of encounters of each species at each sea state from Beaufort ≤ 2 up to Beaufort = 5 (Table 1). It was not possible to obtain a Beaufort scale measure for the categories 'calm', 'choppy', and 'rough' but based on the description of the Beaufort scale it was presumed that the category 'calm' equaled Beaufort ≤ 2 and 'choppy' equaled Beaufort = 3 and 'rough' equaled Beaufort ≥ 4. The categories 'calm' and 'choppy' was grouped together in the Beaufort analysis in order to investigate the percentage of encounters recorded at each Beaufort sea state and the category rough was not included in the analysis because the number of encounters was extremely low. The first column in Table 1 "encounters at sea state ≤ 2 and calm, choppy" show the total number of encounters of each species. the next three columns show the number of new encounters as the sea state changes. The number of encounters decreased as the sea state increased. Three of the species were encountered more than 25% at sea state 3, calm, choppy, this also included inshore dolphin species, whereas new sightings dropped below 25% once sea state was above sea state 4, indicating as expected that there were fewer encounters in rougher sea conditions. Therefore, all trips in conditions of Beaufort ≥ 4, or described as 'rough' on the simpler scale, were removed to reduce the influence of sea conditions on sighting probability. Trips and encounters for which weather data or trip date were missing were also removed. Not only wind strength (affecting sea state) but also wind direction to some extent affects the sightability of dolphins and could influence seasonal differences in encounters. Wind direction was infrequently recorded (see Chapter 2) and the data available were not considered reliable, thus the potential effects of wind direction could not be determined retrospectively. However, the two seasons of the year for which results are presented separately (see Data analysis) based on the availability of right whales are broadly different in terms of the prevailing wind directions. Low season, which generally coincides with summer-autumn (January - June), is

TABLE 1 NUMBER OF ENCOUNTERS FOR THE FIVE MOST FREQUENTLY ENCOUNTERED CETACEAN SPECIES UNDER DIFFERENT SEA CONDITIONS. TWO DIFFERENT CATEGORIES FOR SEA CONDITIONS WERE USED DURING THE DATA COLLECTION; THE BEAUFORT SCALE AND A SIMPLER SCALE (CALM, CHOPPY AND ROUGH). DATA COLLECTED AT SEA STATE 3, CALM, CHOPPY WAS INCLUDED IN THE ANALYSIS.

Sea conditions	Calm, choppy & sea state ≤ 2	Calm, choppy & sea state = 3		Calm, choppy & sea state = 4		Calm, choppy & sea state = 5	
	Total encounter	Total new encounters	% of new encounters	Total new encounters	% of new encounters	Total new encounters	% of new encounters
Humpback whales	93	9	9.6%	5	5%	1	1%
Bryde's whales	93	8	8.6%	4	4%	1	1%
Indian Ocean humpback dolphins	269	76	28.2%	38	14%	11	4%
Indo-Pacific bottlenose dolphins	153	52	34%	27	18%	4	3%
Southern right whales	3534	1138	32%	791	22%	188	5%

characterised by southerly or south-easterly winds with an increase in north-westerlies towards the end of the period, whereas the prevalence of north-westerly and south-westerly winds increases during winter and spring (July to December). Seasonal differences reported in the encounters of the different species may therefore be affected by differences in prevailing wind direction, wind strength (represented by sea state), behaviour of animals including seasonal migrations, and different routes of the WWV between seasons.

Recorded GPS positions of encounters were vetted by mapping them using ArcGIS 9.3 (ESRI), projection UTM 34S, datum WGS84. Of 5431 available encounter positions 118 (1.5%) occurred either on land or well outside of the permit area. All these records were cross checked against the original data sheets; those that could not be corrected were likely caused by clerical errors during initial recording at sea. Records containing these obvious errors were discarded, with no further attempt at correcting them, and encounters that lacked latitude and longitude positions were excluded from the spatial analyses (but included in the temporal analyses).

Species identification was validated by comparing written field records with photographs taken during a number of different encounters of each species: 80 encounters with southern right whales 21 with humpback whales, 5 with Bryde's whales, 65 with Indian Ocean humpback dolphins, 187 with Indo-Pacific bottlenose dolphins, 7 with common dolphins, a single encounter with Heaviside's dolphins (*Cephalorhynchus heavisidii*), and 2 encounters with killer whales (*Orcinus orca*). For all encounters there was 100% agreement between the field identification and associated photographs.

Where the number of animals in a group was recorded as a range, a conservative approach was used for analysis and only the minimum was considered. Cow-calf pairs of southern right whales were regularly approached by the WWV because calves were difficult to see from a distance, cow-calf pairs are therefore present in the observation sheets. Behaviour data were not included in the analysis due to subjectivity in the categories and inconsistency in then data collection. Many of the 25 pre-defined behavioural categories provided from the government in the data-forms were subjective and difficult to distinguish. For example, "tail slapping" was only defined within the main category "Aggressive behaviour" and would hence only be categorised as aggressive behaviour. Another main category was "Attraction/interactive behaviour" with a sub-category "relaxed behaviour" whereas a similar sub-category "relaxed, no approach" was categorised in another main category "Calm/undisturbed behaviour". Also in addition to the pre-defined categories, there were more than 50 different descriptions of behaviours recorded in the completed forms, many of which were impossible to categorise or re-categorise into simpler, more functional categories such as *"resting, travelling, socialising, and feeding"* (Lusseau 2004).

2.4.3 DATA ANALYSIS

When determining patterns of seasonal or spatial distribution of populations, it is essential that any spatial or temporal variation in search effort be taken into account (Vigness-Raposa et al. 2009, Daniel et al. 2010). The South African government does not require WWVs to record or report trip routes and search effort, hence no direct measure of spatial and temporal search effort was available for the dataset.

Temporal search effort, i.e. trip duration, was only recorded intermittently by the WWV (see Chapter 3), therefore records held by the local harbour master for 1007 trips conducted between 2010-2012 were used to estimate a standard trip duration (see Results). Difference in trip duration led to a division of the dataset into high (July to December) and low seasons (January to June), and data is presented separately in the analyses as encounters per trip (number of groups encountered per trip). Temporal patterns in encounters per trip were investigated for both years and months.

To provide an index of spatial search effort by the WWV, the tracks of 72 trips between September 2011 and September 2012 were recorded. Track data were collected using a Garmin Dakota 20 GPS receiver recording at 1-minute intervals, downloaded to computer, converted to a polyline and overlaid on a 1km x 1km grid (NOAA 2006, Koslovsky et al. 2008) using QGIS 2.1.0, projection UTM 34S, datum WGS84. The tracks were separated in low and high season and number of tracks in each grid cell was calculated and used as indications of the spatial effort of the WWV. These tracks were typical of the routes followed since 2003 according to co-author and owner of the WWV company since its inception in 2000; Wilfred Chivell. The routes of the trips were influenced by local experience of the availability and distribution of the cetacean species, the time constraints of the trips (cost efficiency and back-to-back trips), and the distributions of other attractions including seabirds for example the African penguins (*Spheniscus demersus*), Cape fur seals (*Arctocephalus pusillus*), and great white sharks (*Carcharodon carcharias*), which may vary between seasons.

Species encountered less than 20 times during the 10-year period was regarded as rare species and further analysis of group structure was not conducted. This measure of 20 encounters was set as a cut off based on the logic that animals has to be encountered more often to be regarded as regular species of an area. For species with more than 20 encounters, groups containing calves were included in the overall encounters per trip but also presented separately. Southern right whales were the species with the most encounters out of all the species and due to the extensive data available, the data set was further subdivided into cow-calf pairs, single individuals, two adults, and three or more adults. The presence of mating groups or Surface Active Groups (SAG) was recorded in some data sheets, but it was not possible to determine from the data sheets if this category was recorded consistently by all observers, so they were not included distinctively, and hence form part of the groups of three or more right whales. SAGs are defined as groups with high levels of social interaction at the surface with physical interaction between individuals, where most attention is directed towards a focal animal (or animals) (Kraus and Hatch 2001, Best et al. 2003).

2.5 Results

2.5.1 SEARCH EFFORT

From 2003-2012 Dyer Island Cruises (DIC) conducted 3914 trips. Cetaceans were encountered on 3390 trips (524 trips without encounters) and 7492 cetacean encounters were recorded in total. After exclusion of trips and encounters that occurred under poor weather conditions, there were 5920 encounters during 2876 trips (475 trips without encounters) available for analysis. All data were suitable for temporal analysis and 5838 encounters were suitable for spatial analysis (82 encounters were discarded because of missing or invalid positions), the number of trips varied between the seasons; during the low season January – June, 708 trips (mean = 118 per year *SD* = 41.8) were conducted and 2168 were conducted during the high season from July – December (mean per year = 361.3 *SD* = 127.3) (Figure 2). Typical search effort is shown in Figure 1 as the number of times the WWV track passed through each grid cell with high and low season presented separately. Trip duration was significantly longer (Students t-test $t_{df} = 1287$, $p > 0.001$) in high season (July to December; mean =145.4 minutes ± 14.6 *SD*) than low season (January to June; mean = 99.2 minutes ± 14.8 *SD*) based on the records from the local harbour master.

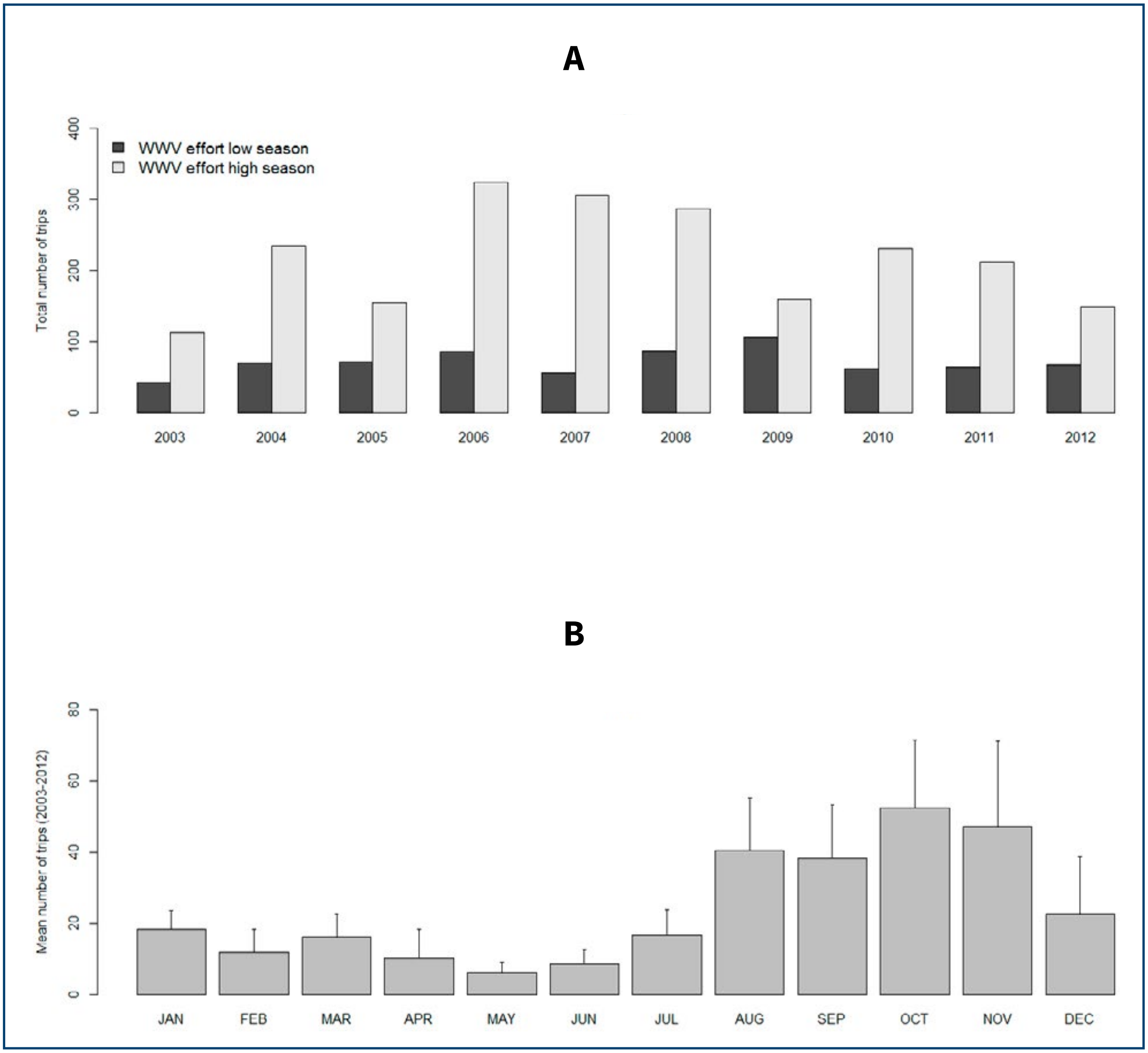
The spatial search effort differed between low and high seasons, with effort during low season focusing mainly in the Franskraal area with only rare visits to the Pearly Beach area or the deeper waters beyond Dyer Island (Figure 1). During the high season, the typical route included Pearly Beach more frequently. Visits to water deeper than 30 m and to west of Dyer Island were rare and with no predictable pattern. There were no records of trips to the southernmost area, Quoin Point. Trips starting from Gansbaai harbour only happened when the tide was too low for boat launching from Kleinbaai harbour, this area is beyond the permit area and approaches were therefore not allowed.

2.5.2 CETACEAN OCCURRENCE AND SEASONAL DISTRIBUTION

Five species of whales and dolphins were encountered regularly: southern right whales, humpback whales, Bryde's whales, Indian Ocean humpback dolphins, and Indo-Pacific bottlenose dolphins. Three additional species were seen on fewer than 20 occasions: two encounters of killer whales, two of Heaviside´s dolphin and 14 of common dolphins.

The southern right whale was, as expected, present in high numbers in the area with a clear seasonality and different group compositions were found in the area. Humpback whales and

FIGURE 2
Total number of trips per year (A) and mean number of trips per month (B), conducted by the whale-watching vessel for the period 2003–2012. Error bars indicate the standard deviation of the mean value.



Southern right whale.

PHOTO CREDIT
KATJA VINDING PETERSEN

Bruyde's whales were also encountered regularly, although much less frequently than southern right whales The two more frequently encountered delphinid species found were the Indian Ocean humpback and the Indo-Pacific bottlenose dolphins. The occasionally encountered species were hypothesised to be species which are known to use the areas in the vicinity of the research area and all hypothesised species except the Dusky dolphin was found in the area. No off shore species were found in the area as it was hypothesised.

2.5.3 TEMPORAL PATTERNS

Annual encounters of the five main cetacean species varied considerably between years and among the species (Figure 3), while monthly encounters showed more consistent trends across years (Figure 4B and 5).

Bryde's whales were encountered on 101 occasions (145 individuals of which 125 were adults and 20 calves). Most encounters were of solitary animals (mode = 1). This species was most frequently encountered (74 times) in low season, with the highest encounters between March and May (Figure 5), and rarely (27 times) during high season. Bryde's whale calves were encountered year round. Bryde's whales were observed in all years, except 2006. The highest number of encounters occurred during 2003 (n= 25), dropping to 0 in 2006 and then slowly increased at 1% per annum after 2006 (Figure 3).

Humpback whales were encountered on 102 occasions (233 individuals of which 218 were adults and 15 calves). The modal group size encountered was one, the maximum was 10, and from the 102 encounters 73% were either solitary individuals or groups of two or three individuals. Humpback whales showed two peaks in seasonality; the majority of animals were encountered in June (last month of low season), July and August, with a much smaller peak in late November and December (Figure 5). Most encounters with humpback whale cow-calf pairs occurred during October – December. Humpback whale encounters varied considerably from year to year, with most encounters in 2008 (n= 28), 2011 (n= 15), and 2012 (n=12) (Figure 3), but showed a slow average increase at 0.4% per annum.

Southern right whales were encountered on 4672 occasions (13 091 individuals of which 10 154 were adults and 2 937 calves). Numbers peaked consistently between June and January (Figure 4B) each year and only a single encounter was recorded between 31 January and 26 May (two animals on 18 March 2011) in the entire dataset. The results show that the season extended until January when predominantly cow-calf pairs were encountered (Figure 4) which is longer than expected. Single right whales were more commonly encountered at the beginning of high season (June – September) while groups of two or more were most commonly encountered in the middle of the season (July – September) and the modal group size was two. Cow-calf pairs were encountered most frequently late in the season with highest encounters in October – December (Figure 4B). The earliest observation of a cow-calf pair was on 26 June (2011) and only a total of six cow-calf pairs were observed during July throughout the study. The latest encounter of a cow-calf pair was on 26 January (2009). Annual trends in encounters varied considerably between social categories. Encounters of all non-cow-calf groups showed a decrease over the duration of the study period (single = -9.8% pa, pairs = -11.8 % pa, > 3 = -11.1 % pa.) (Figure 4A). Conversely, the encounters of cow-calf pairs increased almost linearly between 2003 and 2010 at 9.9 % pa, but declined substantially in the last 2 years of the study. This trend is evident in all months of the year, although there is some indication of an earlier shift in the timing of cow-calf pairs, with encounters peaking in November/December from 2004-2009 and in October from 2010-2011 (and 2003); data for comparison were not available for November and December 2012 (Figure 3).

Indian Ocean humpback dolphins were encountered on 345 occasions (1,521 individuals of which 1,386 were adults and 135 calves). Humpback dolphin groups ranged from one to 12 individuals (mode = 1, mean = 4). Encounters were more frequent during summer months

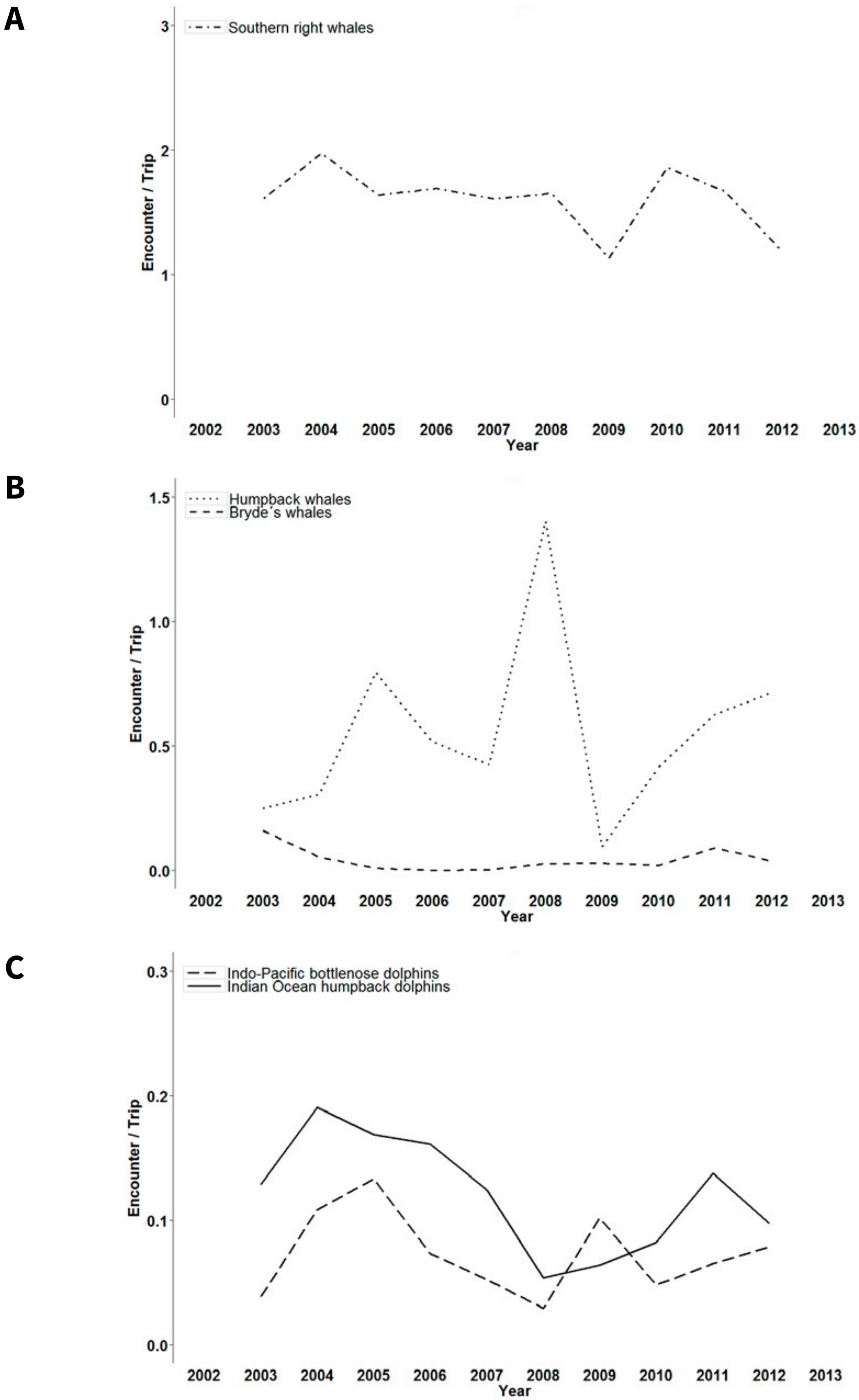
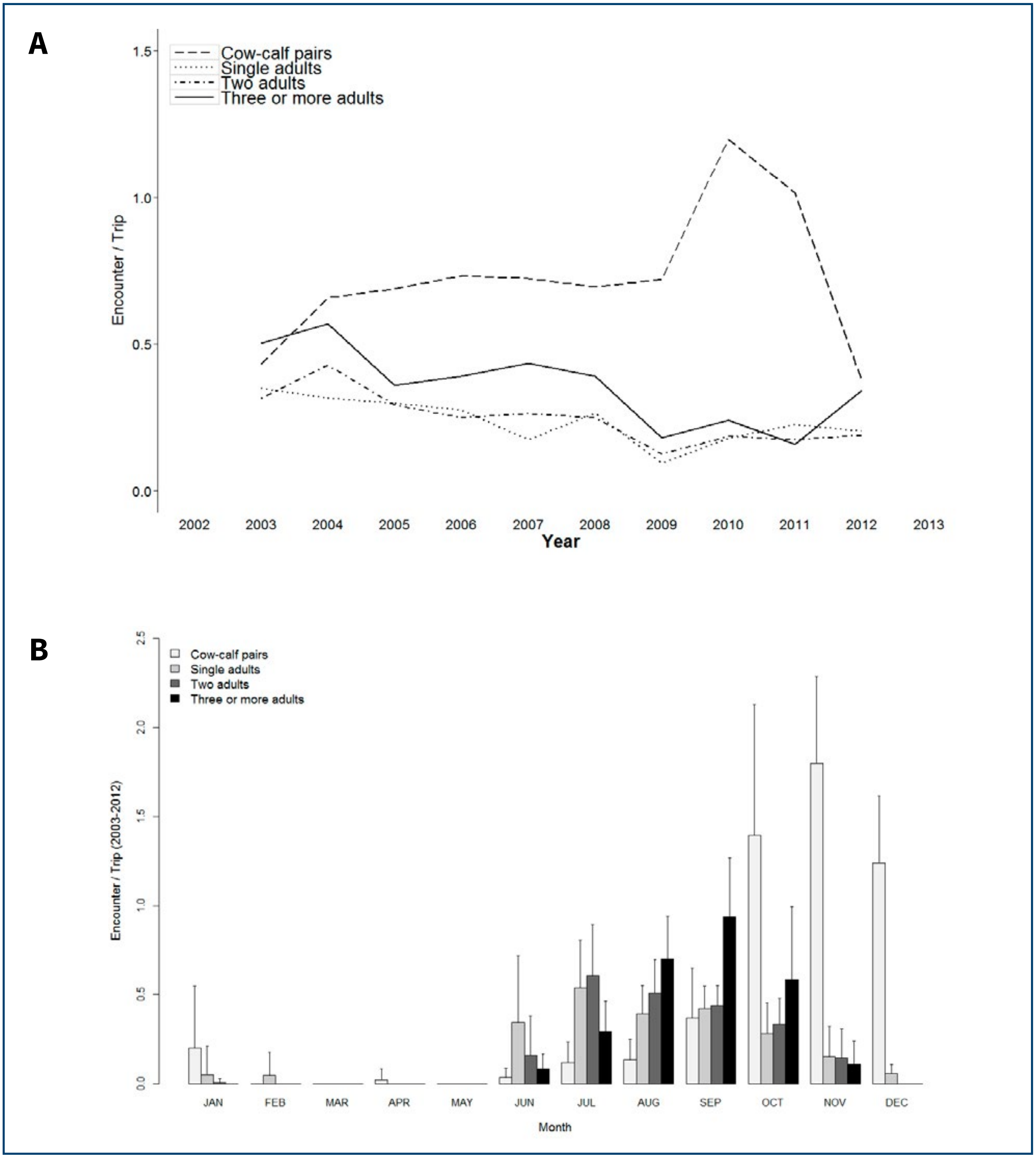


FIGURE 3
Annual mean encounter rate of Southern right whales (A) and baleen whales (B, C) and dolphins (D, E) per year by the whale-watching vessel operating from Kleinbaai harbour, South Africa.

Notice the higher Y-axis for Southern right whales and Bryde's whales, due to the high sighting rate of this species in the area. Error bars indicate the standard deviation of the mean value.

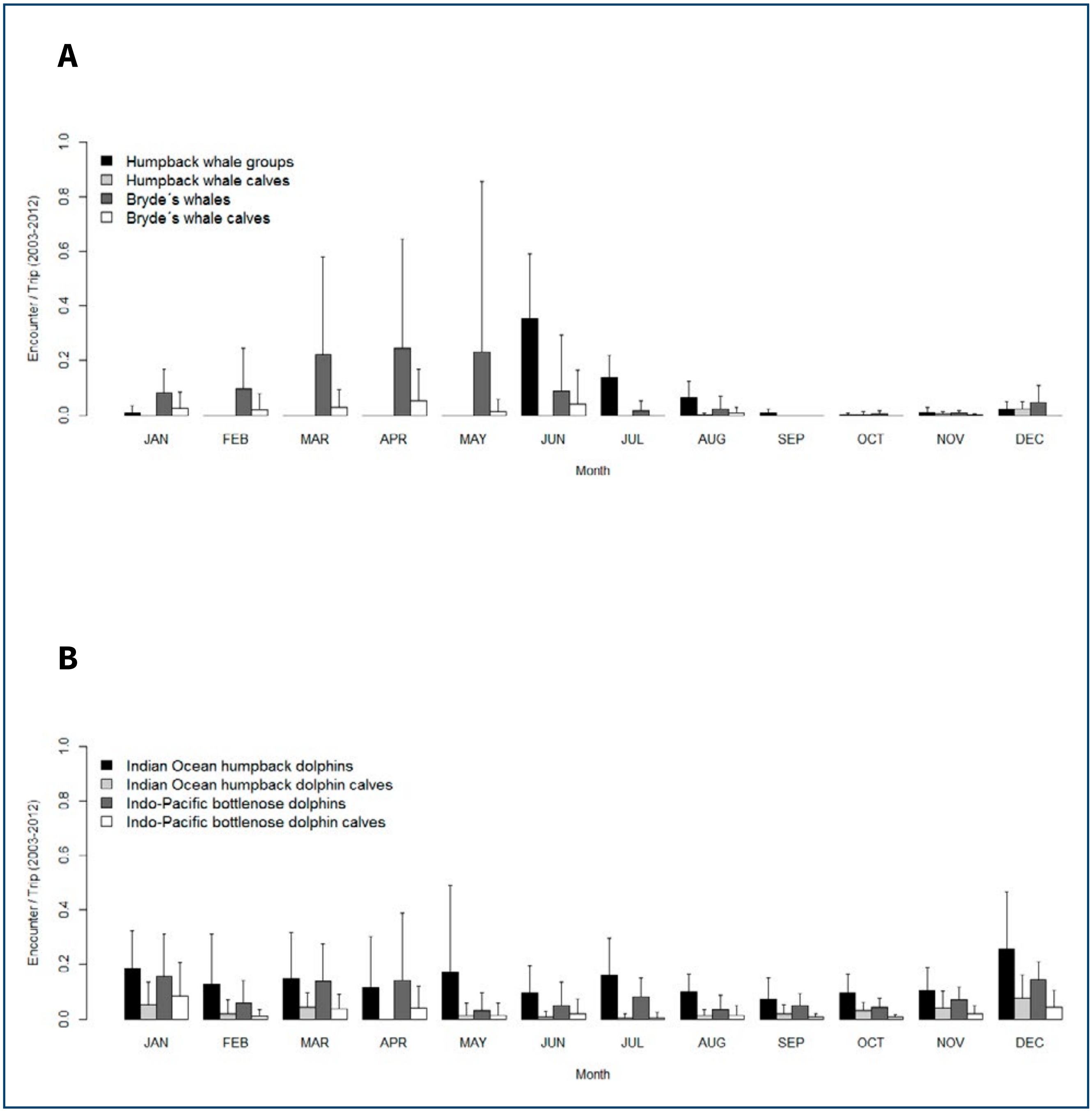
(Figure 5), and most encounters occurred in 2003-2007 and in 2011 (Figure 3), a slightly negative annual trend existed (0.9%). Calves were recorded in 97 encounters with most calf encounters occurring in December (n = 25) and January (n = 12) (Figure 5); a maximum of three calves in a group was noted.

FIGURE 4
Mean monthly sighting rates (sightings per trip) of different southern right whale group types. Error bars indicate the standard deviation of the mean value.



Indo-Pacific bottlenose dolphins were encountered on 205 occasions (4 271 individuals, of which 4085 were adults and 186 calves). Group size ranged from one to 200 individuals (mode = 10, mean = 20). Group sizes larger than 40 individuals were only encountered 28 times. A clear seasonal peak occurred from December to April (Figure 5) and most encounters occurred in 2004-2006 and in 2009 (Figure 3) with a slightly negative annual trend over time (0.2%). Calves were observed in groups on 109 occasions, with 10 being the highest recorded number of calves in any group. Seasonality of calves followed the same pattern of as adults.

FIGURE 5
Mean monthly sighting rate (sightings per trip) of humpback and Bryde's whales (A) and Indo-Pacific bottlenose dolphins and Indo-Pacific humpback dolphins (B). Error bars indicate the standard deviation of the mean value.



2.5.4 SPATIAL PATTERNS

Bryde's whales were observed in predominantly deeper waters throughout the surveyed area with most encounters occurring between Dyer Island and the Kleinbaai harbour (Figure 6). The farthest observed Bryde's whale was 9.3 km from shore, and only a single encounter occurred within 1 km of shore. Cow-calf pairs were observed in the same areas as adult-only groups and single individuals. Most of the encounters occurred between 20m and 30m water depth.

Humpback whales were observed throughout the study area, with most sightings around Dyer Island and in the bay at Franskraal, which coincides with the most frequently searched areas (Figure 6). The furthest from shore that a humpback whale was encountered was 8.3 km. Animals were observed less than 1 km from the shore during the high season. Cow-calf pairs were observed in the same areas as adult-only groups and single individuals. Most of the encounters in low season occurred between 15 m and 50 m water depth. Encounters in high season were similar to low season, but covering a larger area with some encounters close to shore.

Southern right whales were seen throughout the license area, although the majority of encounters occurred in near-shore waters and bay area's mainly in less than 20 m depth of water (Figure 6). Cow-calf pairs and groups of animals were found close to shore and always in less than 30 m of

Southern right whale.

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FIGURE 6

Spatial distribution of encounters of Bryde's whales, humpback whales, and southern right whales by the whale watching vessel operating from Kleinbaai Harbour, South Africa. Size of circles represents numbers of encounters per 1 km × 1 km grid square.

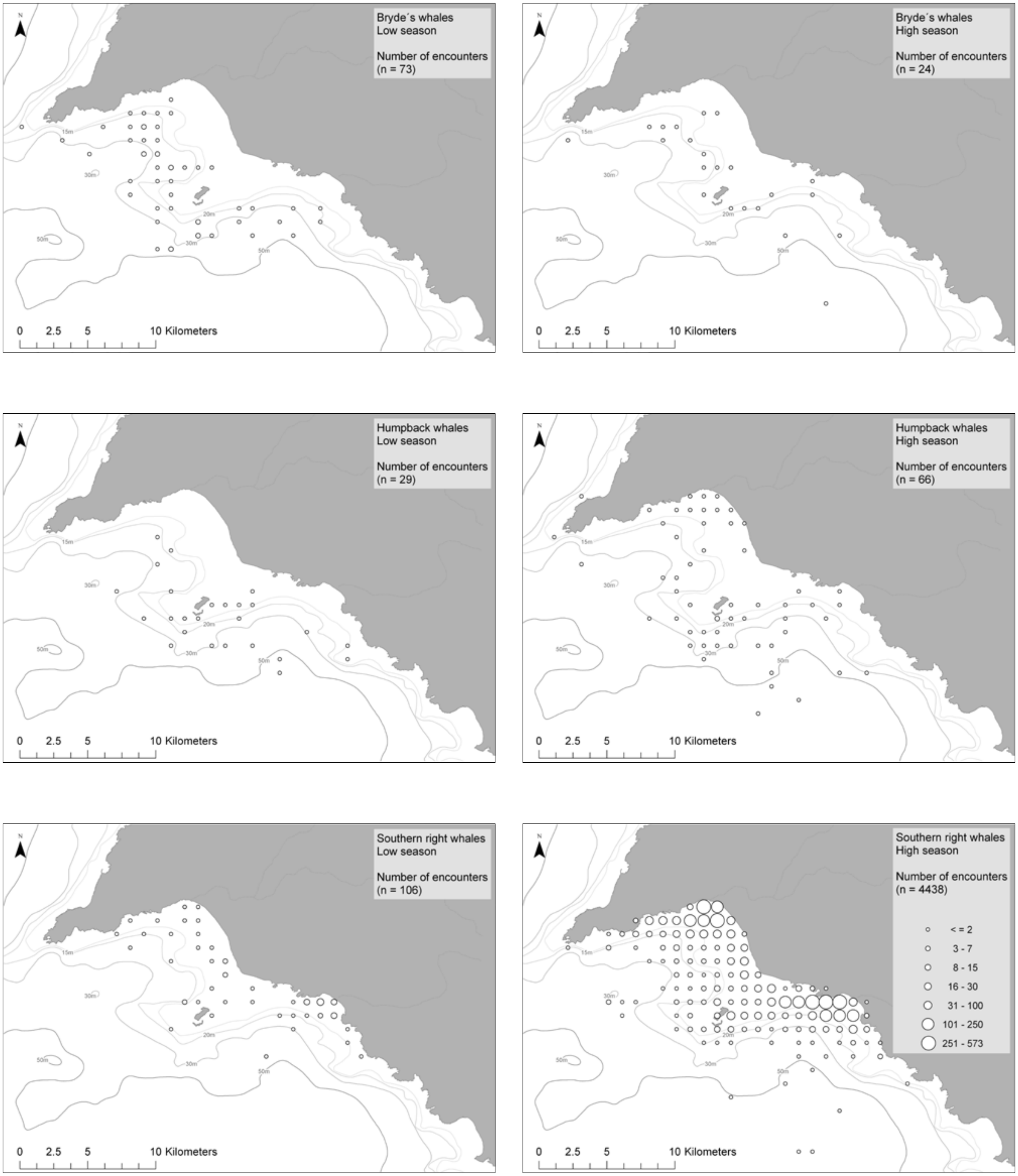
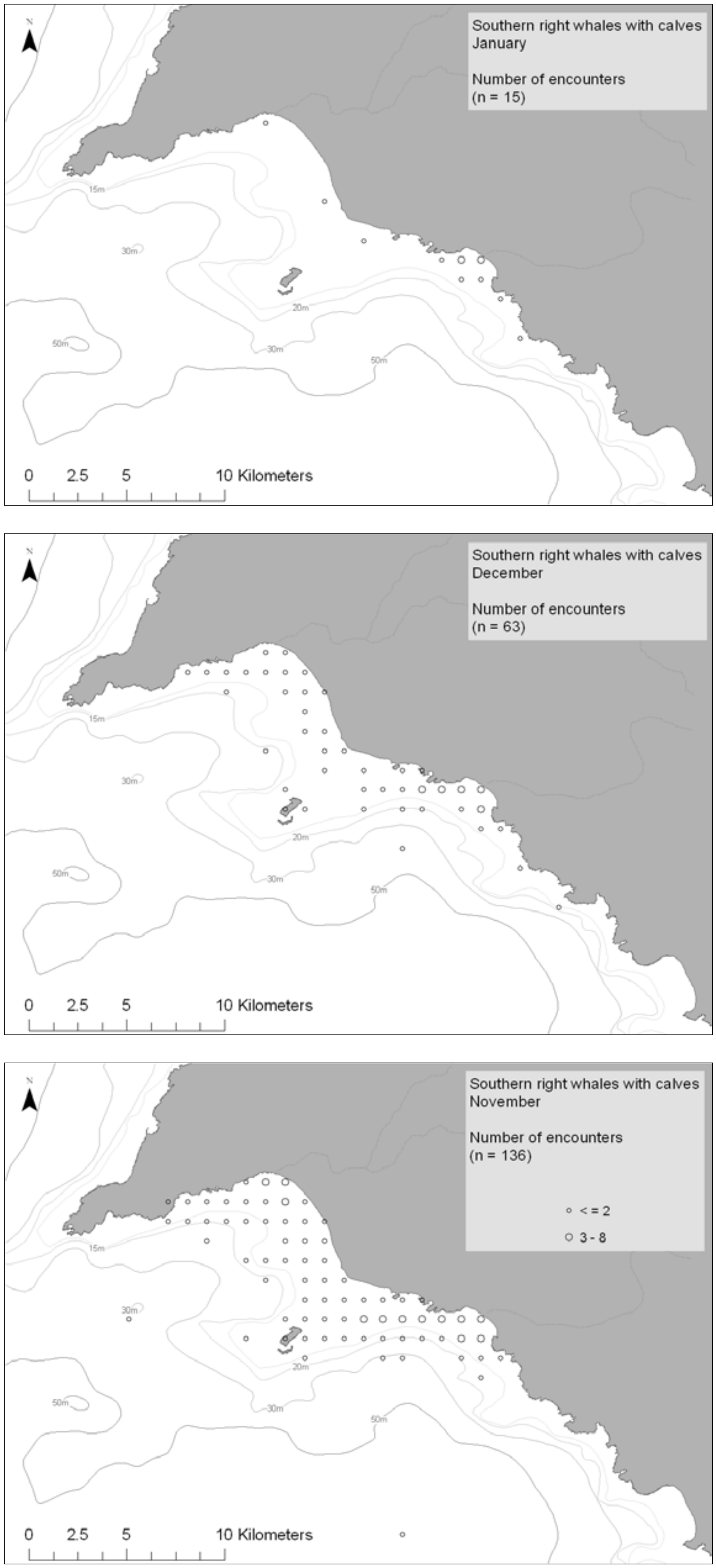


FIGURE 7
Encounters of southern right whale cow–calf pairs (2003–2012) in January, December, and November. Size of circles represents numbers of encounters per 1 km × 1 km grid square.



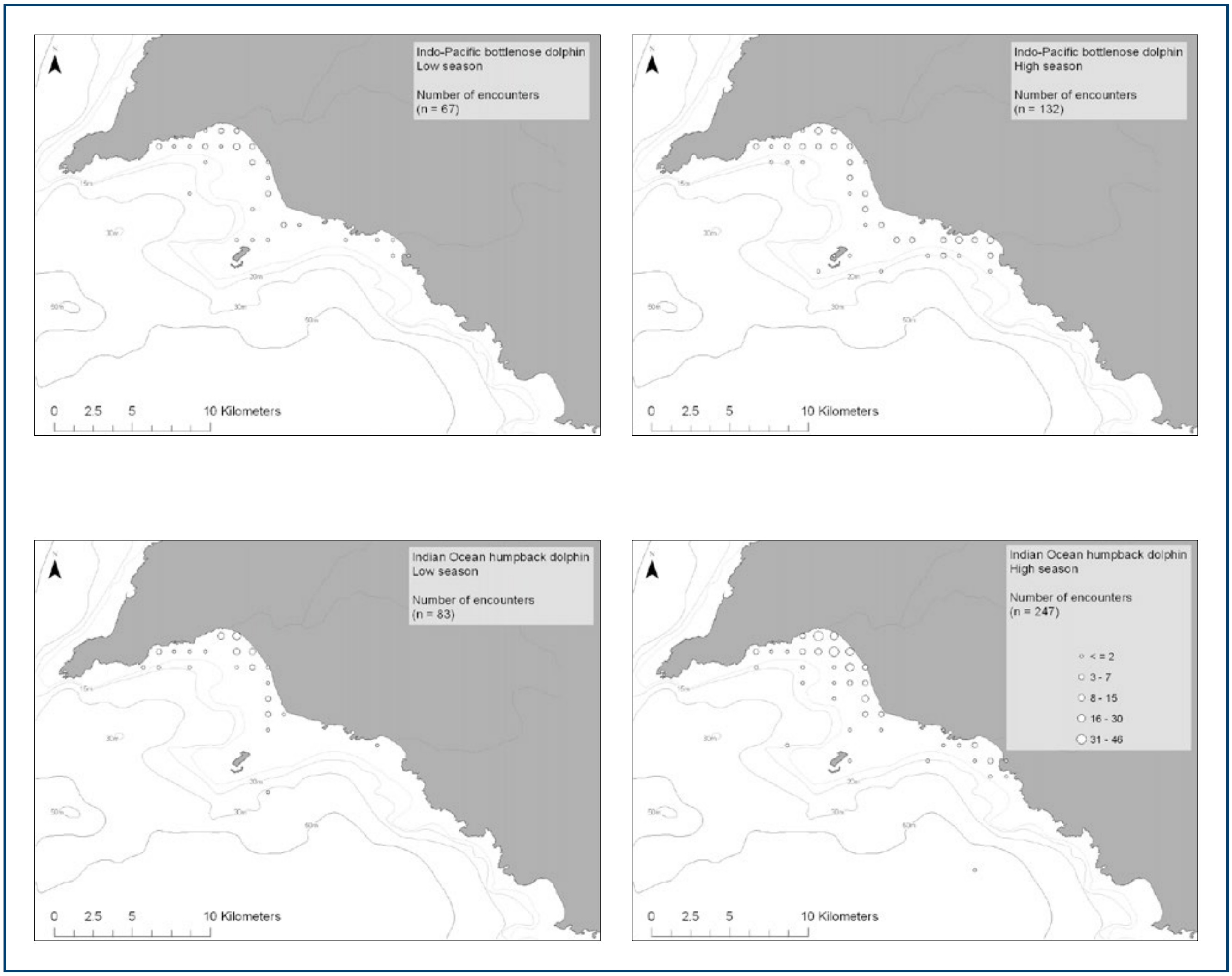
depth. Most encounters were less than two km from shore. The furthest from shore that southern right whales were recorded was 9.3 km. Encounters of the first and last animals in June and December were mainly recorded in Pearly Beach and in the months of December and January cow-calf-pairs were most frequently observed in the Pearly Beach area (Fig. 7).

Indian Ocean humpback dolphin distribution was restricted to very shallow water (Figure 8). Encounters were most regular along the sandy beaches in the vicinity of the well searched areas of Uilkraal estuary in less than 15 m of water with fewer encounters in other highly searched coastal areas, although a few encounters were recorded near Dyer Island and up to 5.9 km off shore at a depth of more than 50 m. They were commonly observed less than 1 km from shore. No spatial difference was observed in the patterns for low and high season.

Indo-Pacific bottlenose dolphins were predominantly encountered in waters less than 15 m deep. Most encounters were observed less than 2 km from the coast, with a maximum distance of 5.8 km from the coast (Figure 8). Encounters were most frequent in both of the sandy beach areas near Franskraal and Pearly Beach. No spatial difference was observed in the patterns for low and high season.

FIGURE 8
Spatial distribution of encounters of the two main dolphin species.

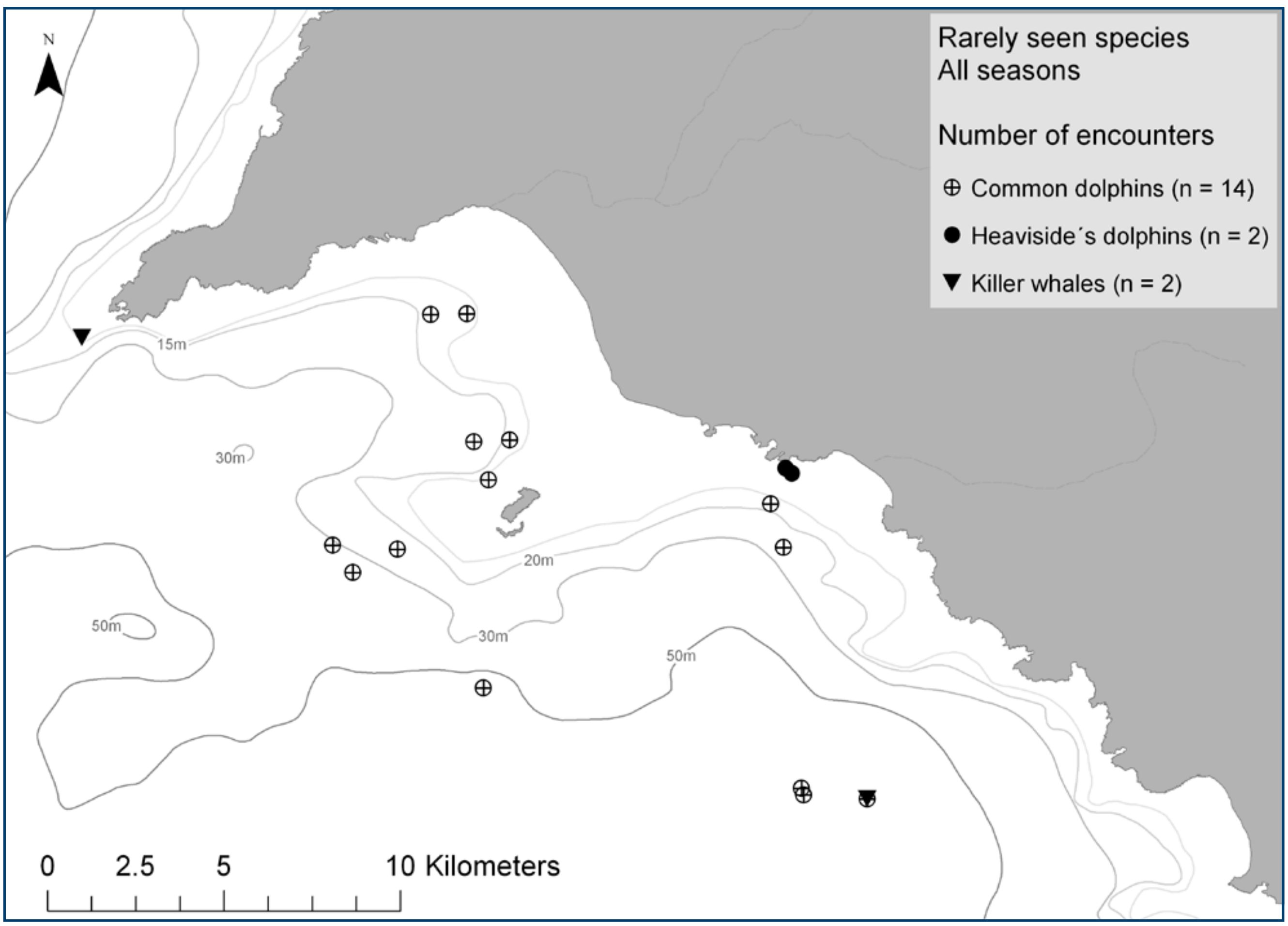
Size of circles represents numbers of encounters per 1 km × 1 km grid square.



2.5.5 OBSERVED ON RARE OCCASIONS

The locations of common dolphin, killer whale, and Heaviside's dolphin encounters are shown in Figure 9. Common dolphins were encountered on 15 occasions, in October (n = 4), September (n = 2), April (n = 1), June (n = 1), July (n = 2), August (n = 4), and January (n = 1). Their group sizes ranged from six to 1000 individuals (mode = 200), the largest group size for any of the cetacean species observed in the area. Common dolphins were encountered at depths from 15 m and beyond with four encounters beyond 50 m of water depth. Killer whales were only observed twice. In April 2011 two animals were encountered to the west of the Danger Point peninsula, at the western boundary of the permitted area. On 24 August 2012, six killer whales, including at least one calf, were observed hunting a school of approximately 1000 common dolphins. Heaviside's dolphins were also observed on two occasions within size hours on 23 November 2007, both encounters were very close to shore at Pearly Beach.

FIGURE 9
Spatial distribution of rare species in the research area.



2.6 Discussion

2.6.1 SEASONALITY AND DISTRIBUTION OF CETACEAN SPECIES

Southern right whales were the most frequently encountered cetacean species in the study area and the majority of encounters occurred within 2 km of shore in the two sheltered, sandy-bottomed bays of Franskraal and Pearly Beach. Changes in group composition throughout the season were consistent with the seasonal patterns previously described for right whales in South Africa by Best et al. (2003) and as hypothesised for this area. An unexpected extension of the season (until January) was found, when predominantly cow-calf pairs were encountered. This extended season could indicate that the area serves as an important area for cows with late born or small calves (Elwen and Best 2004) before conducting the migration to the feeding grounds. Most southern right whales leave by the end of November but the specific cues for what triggers the migration is still unknown (Mate et al. 2011). The results finally indicate a possible shift in distribution between the bays (Figure 7). Several changes in the encounters of different social categories were detected over the study period. The proportion of encounters of adults without calves (single, pairs, and groups of more than 3 including SAGs) declined almost linearly over the study period, while the proportions of encounters of cow-calf pairs showed a general increase, at least until 2010. This corresponds with a decrease in adult only groups of right whales along the southern Cape coast that has been observed in annual aerial surveys since 2009 (Roux et al. 2013). These trends may be related to increased use of the historical feeding ground and off Saldanha and St Helene Bays on the South African west coast since at least 2000, and increased use of the Namibian coast to the north of this (Peters et al. 2011, Roux et al. 2013, Barendse and Best 2014).

The sighting rate of Bryde's whales in this study (145 individuals during 3914 trips in 10 years of which 20 were calves) was considerably lower than that reported by Penry et al. (2011) for Plettenberg Bay (146 individuals during 330 trips in four years of which 38 were calves) during a study that also used WWV as the observation platform. Seasonality was similar in both study sites with most encounters occurring in autumn (March – May), peaking in April, and the highest encounter of calves also occurring in this season. The drop in Bryde's whale numbers in the study area after May could be linked to the increased sightings of this species during winter on the east coast, where at least some animals are known to follow the 'sardine run' and are regularly seen feeding in association with common dolphins and Cape gannets (*Morus capensis*) (Best et al. 1984, Best 2001, O´Donoghue et al. 2010).

The peak in abundance of humpback whales in the study area during winter was coincident with the timing of the northward migrations of humpback whales up the east and west coasts of South Africa. The population migrating up the east coast is *en route* to breeding grounds referred to as Breeding Stock C (BSC1) by the IWC (Best et al. 1998), while those passing the west coast are part of Breeding Stock B (BSB), which consists of a large breeding population (BSB1) off tropical West Africa, and a much smaller sub-stock BSB2 (estimated at approximately 500 individuals in 2010) (Barendse et al. 2011), which feeds off west South Africa in spring and summer (Barendse et al. 2010). The study area is located between the western most area predicted to be used by BSC whales, namely Cape Agulhas (Cerchio et al. 2008), and the south-eastern most location where BSB humpback whales have been identified, namely Cape Point (Barendse et al. 2011), therefore the affinity of the humpback whales sighted in the study area is uncertain and evidence from genetic, acoustic, or photographic matches is needed. Certainly the low overall number of sightings in the current study (233 individuals over 10 years) suggest that the study area is not part of a main migration route (c.f. Findlay et al. 2011), and the whales sighted may have miscued their point of arrival at the continent on their northward migration. There were relatively few encounters from September to January during the expected southward migration period. This likely reflects the tendency of humpback whales from both BSB and BSC to migrate fairly directly, rather than coast-wise, between their breeding grounds and sub-Antarctic feeding grounds (Fossette et al. 2014, Rosenbaum et al. 2014), except for the small group that uses a more coastal route from tropical

West Africa which forms BSB2 (Carvalho et al. 2014, Elwen et al. 2014). Those that were encountered late in the year were mainly cows with calves, corresponding with the findings of Banks (2013) at Plettenberg Bay and Knysna for this period (460 km to the east of Kleinbaai). The increase in humpback whale encounters over the study period, albeit only slight, was not unexpected given the recovering trend of this species from past overexploitation (IWC 2012).

Throughout their range humpback dolphins are known to prefer highly coastal habitats and are usually found within one kilometre of the shore (Saayman and Tayler 1979, Findlay et al. 1992, Braulik et al. 2015). This was the case in this study where they were only encountered close to shore. The small group sizes (maximum 12 individuals) and the seasonality of encounters were similar to findings of Karczmarski and Cockcroft (1999) at Algoa Bay on the south east coast. Habitat preference of this species seems to change with environment; off KwaZulu-Natal they prefer estuarine areas (Atkins et al. 2004) whereas in Algoa Bay they prefer rocky reef areas (Saayman and Tayler 1979, Karczmarski et al. 2000). The majority of encounters in this study occurred near the frequently searched sandy beach regions of Franskraal and the mouth of the Uilkraal estuary (the largest river within the study area). Encounters dropped during the low season in 2010, 2011, and 2012, corresponding with three out of four summer periods during the years 2009-2012, when the estuary mouth was closed (Anchor-Environmental 2010). These patterns suggest a preference for sandy substrates and brackish wasters related to river mouths similar to what has been reported for humpback dolphins in KwaZulu-Natal (Atkins et al. 2004) but further research is needed to confirm or reject this suggestion. Annual encounters showed a slight decrease since 2007 (peak year). Concern has been expressed regarding the conservation status of this species especially considering the diverse anthropogenic threats associated with its inshore habitat (Braulik et al. 2015) and in the Plettenberg Bay area the provisional results of a population study indicates a considerable decline in numbers over a ten year period (P.A.Pistorius (2015) pers comm.). Indeed, a recent reassessment of the species during the South African National Red list assessment reduced its conservation status from Vulnerable to Endangered due to the small population, indications of population decrease, increased habitat loss, and unknown levels of interchange between existing sites from which abundance levels are available (Atkins et al. *in press*).

Indo-Pacific bottlenose dolphin adults and calves showed no obvious peaks in seasonality, suggesting a year round residency in the area despite the proximity to the western end of the species range (Findlay et al. 1992), and relatively high seasonal variation in water temperature (Rouault et al. 2010). However, group sizes were considerably smaller (mean = 20), than the mean size previously recorded for this species in Tsitsikamma National Park, South Africa, i.e. 76,2 (±*SD* = 84.98) (Findlay et al. 1992). The largest group of any cetacean species encountered was of common dolphins with a group of approximately 1000 animals recorded. This species was primarily observed in offshore waters (> 15 km from shore) but it was not possible to determine their seasonal distribution because encounters were too few.

A rare encounter of a group of 6-8 killer whales hunting a pod of common dolphins was the first record for this event in the study area. Around the coast of South Africa, killer whales are present year round in low numbers. They are more common in offshore waters and mainly feed on marine mammals including common dolphins (Findlay et al. 1992, Best et al. 2010). Two Heaviside's dolphins were encountered twice on a single day during the study period, and therefore these animals must be considered vagrants. The species is endemic to the cold waters of the Benguela ecosystem between Cape Point and southern Angola (Elwen et al. 2006), and the only other record to the east of Cape Point was a single sighting in Plettenberg Bay (Best 2007).

2.6.2 CAVEATS AND RECOMMENDATIONS

When using data collected from commercial WWVs there are several biases which need to be considered. An inherent problem with WWV data is the unavoidable interaction between the vessel and the cetaceans, where for example underwater noise from time spent in close proximity to animals and number of vessels (Bejder et al. 2006b) can result in an anti-predator type response from the cetaceans including change in the type of behaviours observed and avoidance of high vessel impact areas (Bejder et al. 2006a, Bejder et al. 2006b). Such responses have been documented to have both short and long-term effects (Bejder et al. 2006b, Lundquist et al. 2013) in the form of measurable changes in ecology and behaviour (Stensland and Berggren 2007, Christiansen and Lusseau 2014). Thus the collected data have the potential of being biased particularly with respect to avoidance of high vessel impact areas. It is therefore important when interpreting WWV data to consider information regarding the specific local legislation and WWV conditions. The data used in this study were collected from a single vessel operating under South Africa´s fairly strict laws, which currently allow for limited vessels per license area, restrictions to the approach distance and time allowed with animals, specifically to minimise impacts. Enforcement of these laws currently depends on public complaints to DEA, as no *in situ* enforcement from DEA exist.

Another challenge is the influence of sea state and wind direction on the sightability, distribution and behaviour of cetaceans. Wind direction can affect the presence of cetaceans, with indications that feeding dolphins (Elwen et al. 2009) and southern right whale cow-calf pairs in particular are affected (Elwen and Best 2004*a*, Elwen and Best 2004*b*). The WWV data on wind direction were only collected once per trip so it was not possible to filter out sightings or periods within trips where conditions were too poor for reliable observations. However entire trips were removed from the analysis when sea state conditions exceeded Beaufort 4. Furthermore, the separation of results into two seasons (low and high) based on changes in trip duration associated with the availability of southern right whales, coincidently distinguished two periods within each of which the wind patterns were generally consistent. It is recommended for future efforts that wind direction and sea state information is collected for each encounter and not only per trip.

A lack of spatial and temporal effort data complicated the analysis to some extent. Temporal and spatial effort information was not adequately recorded by the WWV, because it is not currently a requirement for data entry. This issue was addressed by obtaining information from the harbour master's office (trip duration), and an index of spatial search effort from 72 representative trips. Recording of trip duration, animal encounter times and duration, and vessel track data through GPS tracking or vessel monitoring systems (VMS), would improve the accuracy of results. It is recommended that such effort data are part of a basic standard for data collection from any type of platform of opportunity such as sea, land, and air. Equipping WWV with VMS would also assist government in monitoring and regulating the behaviour and spatial use of restricted areas by WWV.

Another challenge when describing seasonality and space use patterns is that low density areas are likely to be underrepresented and encounters are likely to be skewed in favour of species that are easiest to locate or are of greatest interest to the tourists. The main problem arising from this lack of structured search effort and lack of collection of effort is an uneven and non-documented effort, which complicates and in some cases exclude a comparison of the sighted species. In the study area, southern right whales are the main target species of commercial operators due to their regular and predictable occurrence close to shore (Turpie et al. 2005), their preference for protected waters (Elwen and Best 2004*a*, Elwen and Best 2004*b*), near shore distribution and slow movements along the coast (Mate et al. 2011) and relatively "boat-friendly" behaviour. Thus, during high season which largely coincides with the presence of southern right whales in vast numbers, encounters by WWVs are potentially skewed towards this species at the expense of all other species. Taking in to account the time constrains, cost, and costumer interest and level of satisfactory related to each WWV tour, it is unlikely that the WWV will spend excessive amount of time searching for additional species and moreover, if suitable animals were encountered early in a trip, there would be no motivation for the WWV to survey the entire license area. Despite this potential bias, seasonal trends in occurrence were clear for several species in the study area and the seasonality of humpback whales and Bryde's whales corresponded with what has been observed in other areas for these species, but further studies are required to establish if the drop in Bryde's whale encounters during the high season is related to a change in the behaviour of the WWV or actual absence of Bryde's whales. Likewise the presence of dolphin species may be under represented during the high whale seasons. The lack of annual trends in right whale encounters in the study area could be masked by several factors. During the high season the number of right whales in the license area is sufficient that encounters per trip would reach a saturation level of between 2 and 3 encounters in a 2 hours trip. Re-sightings of animals during the same trip, especially during periods of lower numbers June, July, and December, January would result in overestimation of animals, which could positively bias numbers. Additionally, the Pearly Beach area has the characteristics of a preferred habitat for right whales (Elwen and Best 2004*a*, Elwen and Best 2004*b*) and numbers in the area may effectively be saturated during high season and therefore not changing correspondingly with the growth rate of the population as the whole. The lack of a pronounced positive annual trend in humpback whale encounters likely reflects the license area's location between the migration paths of the east (BSC) and west (BSB) coast populations, with most whales encountered being at the border of their known range.

The collection of photographic material of a sufficient quality to allow for identification of individual animals would increase the number of questions that could be asked from this type of opportunistic data, including matching the encounters within and between trips and reducing the number of re-encounters within a dataset. However, this would be dependent upon complete coverage of the groups encountered which is generally impracticable for WWV personnel to achieve, given the required high level of simultaneous interaction with clients, the relatively high staff turnover, issues of data storage and management, and allowable approach distances to animals. Therefore, WWV's are not an optimal platform for collecting individual photographic identification data, unless there is at least one person aboard dedicated to this task (e.g. scientist or trained volunteer). Apart from individual recognition, collection of photographic images can be extremely useful for species identification and recording of rare species, behaviours or other events (e.g. injuries or entanglements), and is thus encouraged.

Finally, one of the most difficult tasks for observers is to objectively assess the behaviour of animals, which may itself be altered by the presence of the WWV. To obtain reliable data it is necessary to define behaviour into clear, mutually exclusive categories. The behavioural data collected from the WWV in this study were not analysed due to inconsistencies within the dataset. It is recommended that future log sheets consist of restricted and simple tick boxes with only a few main behaviour types (depending on the main species of interest), e.g. socialising, feeding, travelling, and resting (Lusseau 2004) with clear descriptions of typical behaviours observed in each category and a comment box for further details.

The whale watching industry is increasing worldwide (Hoyt 2001), and potentially also in South Africa, and it is strongly recommended that guidelines at a regional and/or worldwide level are developed to secure the collection of high quality data from different categories of platforms of opportunity. Consistency of countrywide or even worldwide data collection methods (Robbins and Frost 2009) would generate a powerful and versatile dataset for a broad scale comparison of results. Data collection is mandatory for South African WWV, and while crew members may make concerted efforts to follow the rules, it becomes a futile exercise for them, and any officials processing the data, if the collected data are not consistent, useful, or logical. In order to maximise the usefulness of the data, the structure of the data log sheets must enable behavioural, temporal, and spatial distribution analyses (Vinding et al. 2014). The lack of systematic sampling of data or sampling of spatial and temporal effort complicated the analysis in the present study. Currently in South Africa there is a lack of any enforcement regarding the compliance to the data collection; it is highly recommended that the boats are either inspected or dedicated observers are placed on board the WWVs for the benefit of better quality and reliability of collected data.

2.7 Conclusion

The dataset used in this study provides a unique insight into the presence, seasonality, and distribution of cetaceans in an area of the southwestern Cape. The data showed that cetacean species are distributed throughout the study area and present year round, although there was clear seasonality in both species presence and group composition. The baseline provided may enable early recognition of adverse effects from human impacts on cetaceans or natural changes in the measured parameters, for example the different patterns in annual trends observed here for cow-calf pairs and non-calf groups of right whales in the study area. Moreover, at least within the extent of the area surveyed, the data are potentially useful for informing of spatial management measures, e.g. in prioritising areas or times for protection or more detailed research. However, certain shortcomings of this type of data were expected and identified in the data collection methods, which had impacts upon analysis and interpretability of the data. Changes to data collection protocols to secure efficient and precise data collection from WWV are recommended and the development of regional and/or worldwide guidelines are strongly encouraged.

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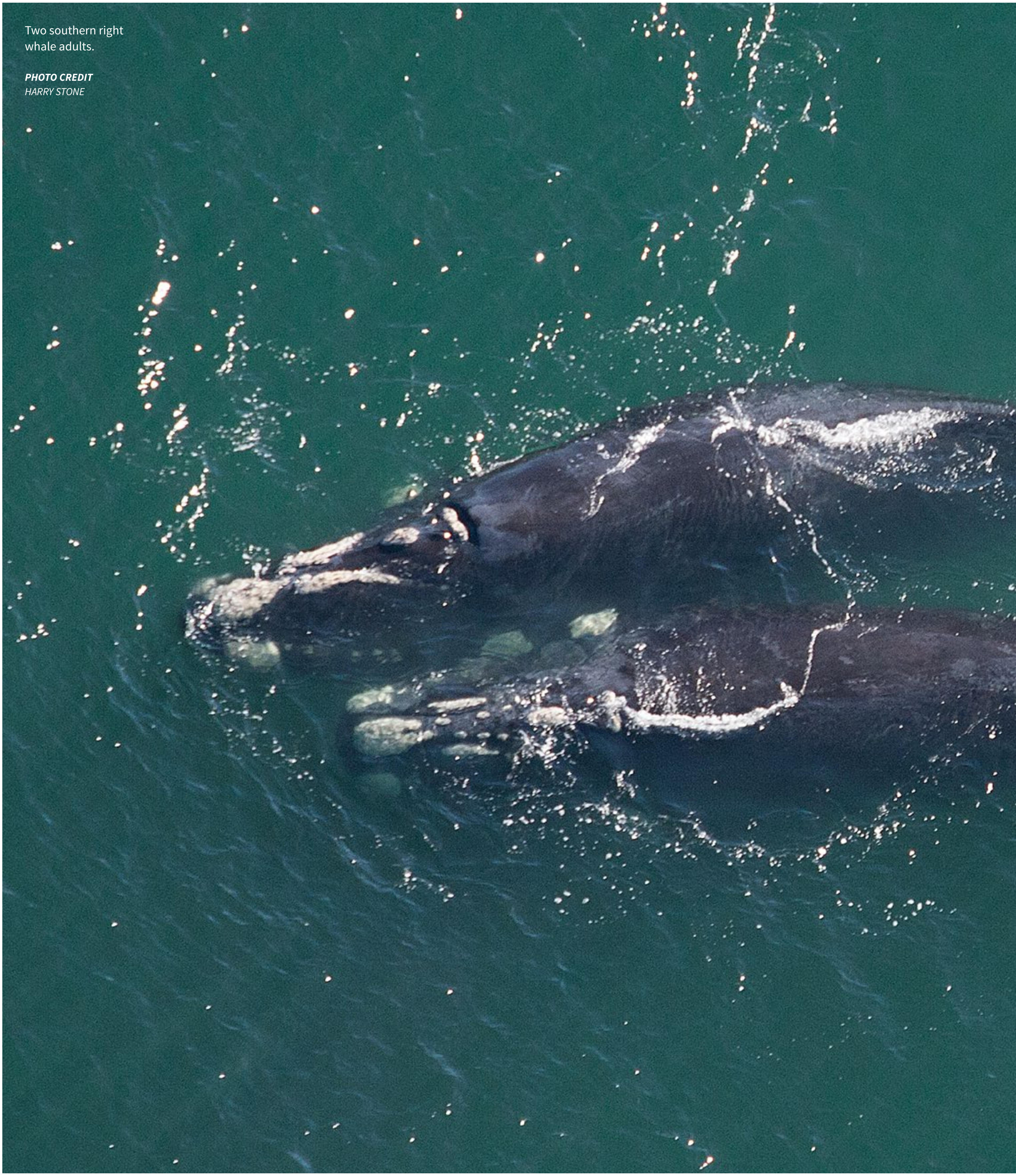

Two southern right whale adults.

PHOTO CREDIT
HARRY STONE

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3

3 Cetacean data collection from commercial whale watching vessels: Consistency, validity, and value in local habitat monitoring

3.1 Abstract

Whale watching vessels (WWVs) can constitute an important platform of opportunity for collection of information on cetacean species presence, distribution, population size, group composition, and behaviour. In South Africa, licensed WWVs are required to submit trip summary data, including information on cetaceans encountered, to the responsible government agency, the South African Department of Environmental Affairs, Oceans and Coasts (O&C). This study analyses the consistency and validity of data collected from thirteen years of observations (2000 – 2012) from the Dyer Island Cruises WWV operating between Danger Point and Quoin Point, Western Cape, South Africa. The Consistency Index (CI) was defined as the proportion of times a data field was recorded per total number of trips during all years. The validity of the data were assessed to determine accuracy of the data for, the fields of location, species identification and sea surface temperature (SST). Data fields varied considerably in their consistency of collection with date, skipper and guide ID were having a CI of >90% while, those for weather and oceanographic information were much lower (from 12% consistency for water depth to 88% for sea state). The trip duration and route was recorded in less than 5% of cases, making analysis of temporal and spatial patterns difficult. The validity of species identification was excellent with 100% agreement between observer records and photographic documentation in 152 encounters of seven cetacean species. The recorded location of encounters was very good with only 1.5% of cases. Behavioural data were described in overly subjective terms, thus not allowing for any analysis of patterns. The number of steps involved in the data collection and the complexity of the required data allows room for error and lack of data. To secure collection of useful and precise data from WWV the development of worldwide or at least, regional standards are encouraged (guideline and protocol), which should address different levels and scenarios of data collection from WWV, and include log sheet key criteria, online data entry, and recommended data analysis approaches. Formal guidelines and protocols could increase consistency and would also enable and encourage a worldwide comparison of data.

3.2 Key words

Cetaceans, data deficient areas, spatial and temporal effort, quality control, wildlife management.

3.3 Introduction

Effective conservation of species and ecosystems rely on knowledge of the abundance of animals, their distribution, genetic variability, and behaviour (Caughley and Sinclair 1994). But it can be difficult and expensive to obtain the necessary abundance, distribution, and behaviour data, (Redfern et al. 2006), that are essential to apply an efficient conservation effort (Perrin et al. 2007). Observations from platforms of opportunity, such as whale-watching operations (Ingram et al. 2007), seismic survey vessels (de Boer 2010, Weir 2011), cruise ships (Williams et al. 2006), or ferries (Weir et al. 2004, Kiszka et al. 2007), can provide alternative and potential supplement to scientifically conducted research, especially in developing countries (Hauser et al. 2007, Koslovsky et al. 2008). Such platforms of opportunity have been used successfully at a number of locations to obtain abundance and distribution data of marine mammals (Weinrich et al. 1997, Macleod et al. 2004, Ingram et al. 2007, Koslovsky et al. 2008) and for example Hauser et al. (2007) study which show that the whale watching vessel (WWV) can provide accurate positions of killer whales but identification of pods were less reliable.

Whale watching has become an increasingly popular activity and has often led to local economic upliftment (Higham et al. 2014). The whale watching industry is fast-growing with a global increase in activity of 12.1% annually since 1991 (Hoyt 2001, O'Connor et al. 2009). The industry was established in 87 countries worldwide by 1998 (Hoyt 2001) and this number has increased to 119 countries by 2008, (O'Connor et al. 2009). Opportunistic data from whale watching vessels (WWV) are collected world-wide and in 2004 there were at least 80 projects which were either ongoing or finalized (Palazzo et al. 2004). For example the study of Ritter et al. (2011) in La Gomera (Canary Island, Spain) established that at least 23 cetacean species use the area based on 15 years of whale watching data and Scheidat et al. (2000) photo-ID study of humpback whales (*Megaptera novaeangliae*) in Ecuador found an increase in reproductive behaviour, number of calves, and relative abundance and concluded that the Machalilla National Park constitute a reproductive area for humpback whales. Data collected from opportunistic platforms can constitute a very useful source of information on the presence and distribution of cetacean species (Hauser et al. 2007, Vinding et al. 2015b), but certain caveats and precautions are important to take into account when using such data sources. From a research point of view, the collected data must be valid and consistent to be useful. Hauser et al. (2007) recommend that a proper evaluation and understanding of the limitations of the dataset is conducted before a spatial analysis can be applied.

The purpose of the present study was to conduct an in-depth analysis of the quality of data from a WWV data, with respect to consistency in reporting and validity of data. Data was obtained from a commercial WWV licensed to operate between Danger Point and Quoin Point, Western Cape, South Africa in the period 2000 – 2012. The analysis seeks to establish to what extend such data is useful and what the pitfalls are when using such data. In South Africa, commercial whale and dolphin watching has been permitted and regulated since 1998 (MLRA 2008). The regulatory body is the Department of Environmental Affairs (DEA), Oceans and Coast (O&C). Initially 20 license holder areas were designated along the approximately 3000 km coastline, and this number increased to 25 in 2002 (Turpie et al. 2005). Each license area has between one and three (maximum) operating whale watching vessels (WWV). By law, the WWV may not approach closer than 50 m to large whales, stay with animals for maximum 20 minutes, and not approach cow-calf pairs, the operators must collect information on trip statistics including the species, number of individuals, and behaviour of animals encountered, to be submitted to DEA. The data are recorded on board the vessel on paper observation sheets, manually entered into spreadsheets and submitted electronically to O&C.

It is hypothesised that data from the WWV can be useful as a guideline for cetacean distribution, particularly in otherwise data deficient areas. It is also hypothesised that the data from the WWV have certain caveats, which will limit the level of scientific outcome, particularly with respect to spatial and temporal distribution of cetaceans, under- and overestimation of species depending on sightability and seasonality, inconsistency in data reporting, species recognition, and behaviour categorisation. Finally, it is hypothesised that some of the data types are unnecessarily collected while other types could be collected more efficiently and based on a data analysis and management plan.

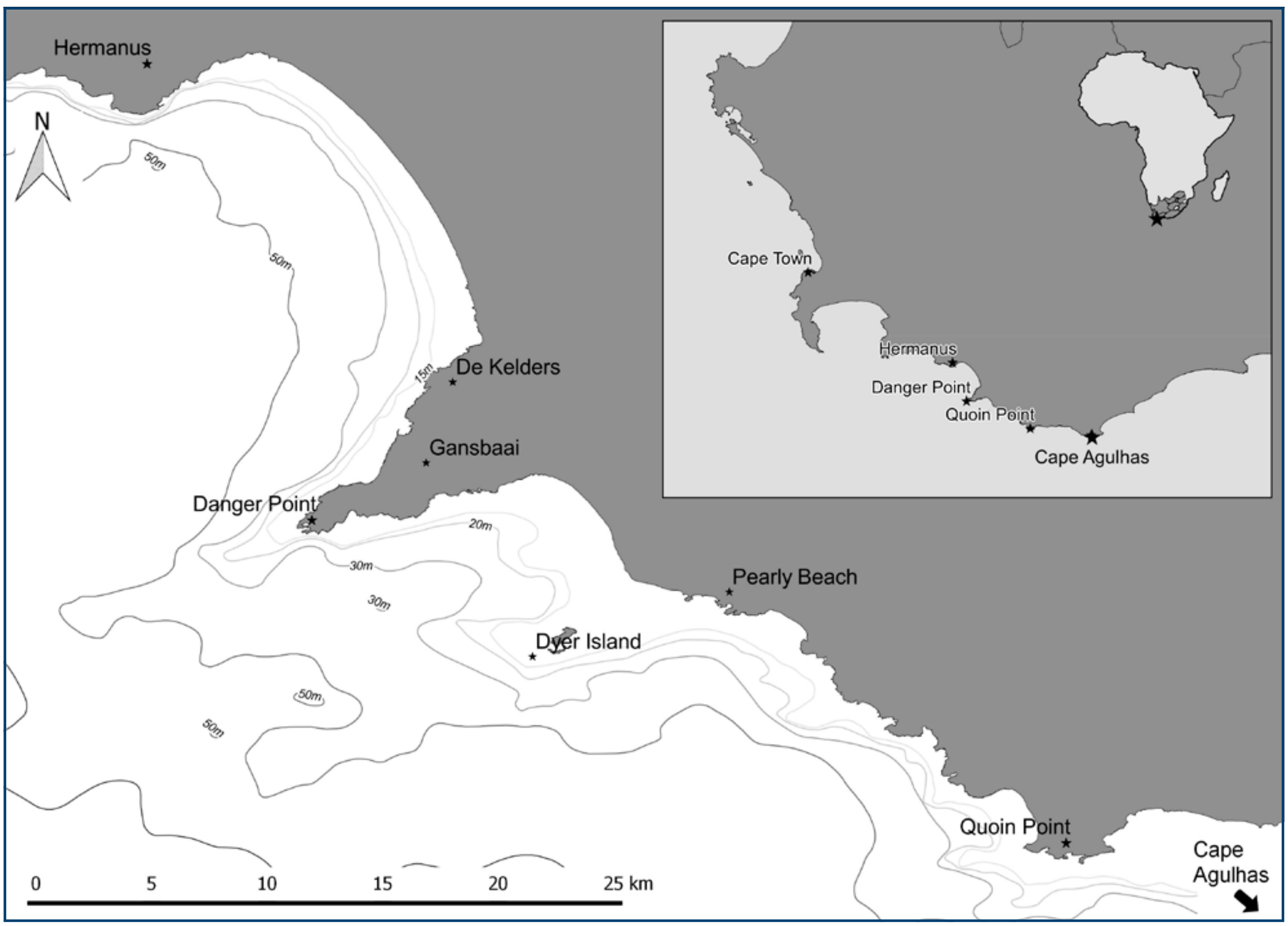
The findings are used to suggest improvements in data reporting requirements and organisation, and finally, the potential of world-wide guidelines and protocols for data collection from WWVs to support conservation efforts for cetaceans is discussed. Parts of this work have been published in the International Whaling Commissions´ Journal of cetacean research and management, Vinding et al. (2014).

3.4 Materials and methods

3.4.1 STUDY AREA

The study area stretches from Danger Point to Quoin Point (20 km x 10 km). The Western boundary is a line due south of Danger Point lighthouse (34°37.769'S 19°18.133'E), the Eastern boundary, a line due south of Quoin Point lighthouse (34°46.802'S 19°38.384E) (Figure 1).

FIGURE 1
Overview of the whale watching vessel permit area between Danger Point and Quoin Point.



3.4.2 DATA

Since 2000 the company Dyer Island Cruises (DIC) (Figure 2) has operated between Danger Point and Quoin Point, and has systematically collected data on conducted trips and encountered species as required by South African law (MLRA 2008). Either a biologist or an experienced skipper on board the WWV recorded the data. Throughout the thirteen years of data collection, 21 different data types were required to be collected on a hard copy log sheet at sea (Table 1). Spatial and temporal patterns of cetacean spatial and temporal distribution have been analysed from a subset of this dataset (2003 – 2012) (Vinding et al. 2015b).

The information from hard copy log sheets from the WWV was regularly transferred to an electronic database on land. Hard copies of log sheets and the electronic database were submitted to O&C regularly throughout the year. An example of a log sheet from 2006 and 2011 is presented in Figure 3. In the present study the electronic records were checked against original log sheets and typing mistakes, and other clerical discrepancies were corrected if possible. Where discrepancies were found, information on the original hard copy log sheet took precedence. Some periods were clearly data deficient and missing data were obtained from a copy of the hard copy log sheets originally submitted to O&C, where present. Data from 2000, 2001, and 2002 was only available as digital material. A few months of data were impossible to locate and were completely absent: 2007; February. 2008; December. 2009; June and July. 2012; November and December.

Temporal effort in the format of trip-duration (start and end time) was required from two sources; firstly, the total number of trips (including trips with no cetacean sightings) was calculated and secondly the logbooks of Kleinbaai's harbour master covering the period 2007 – 2012. These logbooks were analysed to obtain the start and end time of the WWV trips and the entire duration of each trip.

South African regulations never required spatial effort to be recorded. However, two initiatives were taken to obtain reference of the spatial search effort of the WWV; firstly, the DIC log sheet from September 2011 was modified and included tick boxes (Figure 3) reflecting visits to three main local areas of interest; Franskraal, Pearly Beach Bay, and Dyer Island. Secondly, 72 tracks were collected between September 2011 and September 2012 using a Garmin Dakota 20 GPS receiver recording at 1-minute intervals.

3.4.3 DATA ANALYSIS

The collected data were analysed with respect to consistency in reporting and validity of the reported data (see definitions below). It was possible to assess consistency for all data types except the registration of calves. It was possible to validate; latitude and longitude position, SST, water depth, species, and behaviour comments. While it was not possible to validate; data, trip number, skipper, guide, other crew, photographer, videographer, weather category, time of encounter, number of adults, number of calves, if the animals moved or not from the vessel, departure time, and all photos taken. These data types were impossible to validate because there was no reference or source of data which could verify if the collected data was valuable, for example; it was impossible to validate the weather data because the only available meteorological data were from an automatic weather station positioned on top of a mountain close to Hermanus, Overstrand Municipality. The available spatial and temporal effort data of the WWV was analysed to assess if it was possible to obtain a reference of the search effort.

3.4.3.1 Consistency

Consistency is a measure of the certainty with which each data point was recorded on each trip. A Consistency Index (CI) classified the consistency of the reporting of data. CI was calculated as; the number of times where a parameter was recorded per total number of trips during all years. For encounter specific statistics, CI was defined as; number of registrations per number of total encounters during all years. Data were regarded as consistent when more than 95% of the expected data were present. This cut off level was chosen as an acceptable limit since a lack in

FIGURE 2
The local whale-watching vessel "The Whale Whisperer" from Dyer Island Cruises, from which the data was collected between 2000 – 2012.

PHOTO CREDIT
HARRY STONE

TABLE 1 THROUGHOUT THE THIRTEEN YEARS THE FOLLOWING DATA WERE REQUITED TO BE COLLECTED ON A HARD COPY DATA SHEET AT SEA

Per trip:	Per encounter:
1 Date	**10** Time of encounter
2 Trip number	**11** Latitude position
3 Skipper	**12** Longitude position
4 Guide	**13** Water temperature
5 Other crew	**14** Water depth
6 Photographer	**15** Species
7 Videographer	**16** Number of adults
8 Weather category (Calm, Choppy, Rough)	**17** Number of calves
9 Wind category (Wind speed index, Wind speed, Wind direction)	**18** If the animals moved or not from the vessel
	19 Departure time
	20 Photographs taken
	21 Behaviour comments

MARINE AND COASTAL MANAGEMENT WHALE WATCHING LOG

A

Trip information					Sighting information (whale and dolphins)							
dd / mm / yyyy	Trip no	No of passengers			Time	Species code	Position GPS ddºmm. mmm'	No of adults	No of calves	Moved off Y/NO	Depart time	Comments behaviour/ markings
		Local	National	International								
Vessel		Sea state										
		Calm	Choppy	Rough								
Skipper		Film	Frame	Sight #								
Guide		Wind direction										
		Wind speed (knots)										

B

Date		**# PASSENGERS**			**EFFORT** (Where you DID go: Franskraal/Pearly Beach bay/D. Island)			**ABBREVIATIONS FOR OBSERVATIONS**				
Trip Nr.		Local	International	Int'l	Franskraal	PB bay	Dyer Island	Time	First time encounter at each sighting			
Vessel								Species	See abreviations on the observation note board			
Skipper		**WEATHER** (see Beaufort scal on observation note board)			**EFFORT / From harbour**			Temp and depth. GPS	Look at GPS on the boat and note it down			
Guide		Sea state	Wind direction	Wind speed	Start time		End time	Moved off	Did the animal move away from the boat?			
Other crew								Depart time	**NOTE** Time when the whale boat left the sighting			
Photo-grapher		Calm (1)	Choppy (2)	Rough (3)				Behaviour	See abbreviations on the observation note board			
Video-grapher								Pictures	**NOTE** which pics taken of individuals. Remember blanks!			

OBSERVATIONS

Time	Water temp.	Water depth	Species	GPS (position)	# Adult	# Calves	# Juvenile	Moved off	Depart time	Behaviour	Camera pics nr	Comments

FIGURE 3
Examples of data sheets from the wwv. a) data sheet from 2006 b) data sheet from 2011 with modification including effort, water depth, sst, and photography notes.

data recordings were to be expected within the opportunistic collected data set and even though not optimal, a data set covering more than 10 years with 95% of each data type present can be regarded as an opportunistic data set of useful and good standard.

It was possible to calculate CI for all data types except the registration of calves. Calves were only recorded when they were present and hence impossible to tease out if the lack of data reflects that the data was not recorded or if there were no calves observed. The calculated CI provides information on the probability of a data point being reported, but it also reflects the efficiency and usability of the log sheet design.

3.4.3.2 Validity

Validity is an assessment of how trustworthy the data are, e.g. whether reported species identification is correct, or whether the recorded sea surface temperature (SST) is correct. Given the post-hoc nature of this analysis, it was only possible to validate records on latitude and longitude position, SST, water depth, species, and behaviour comments. These data types were validated in the following manner:

11. and 12. Latitude and longitude position

GPS positions were validated by plotting the encounters in ArcGIS 9.3, projection WGS 1984, and assessing the number of clearly deviant records.

13. SST

One source of data was used to validate the recorded SST values. One hundred data recordings of SST from the WWV were chosen between 2003 and 2012 and compared with SST obtained from satellite images from Afro-Seas (2014) from the area during cloud free days. A Pearson product-moment correlation test was conducted to test for the correlation between the SST measured on the WWV and SST obtained from the satellite images.

14. Water depth

Water depth data were compared to the bathymetry of the area. The local bathymetry shape file was plotted as a raster layer using QGIS 2.8.3 (www.qgis.org) and ArcGIS 9.8 (www.arcgis.com), projection UTM 34S, datum WGS84, and the encounters were grouped in water depth categories of 0 – 15 m, 15 – 20 m, 20 – 30 m, 30 – 50 m, and 50 – 100 m and overlaid as shape files.

15. Species

The species identification was validated by comparing the recorded species in the log sheets with photographic material from a number of encounters. Not all encounters were validated, since photographic material was opportunistically collected and did not exist for all encounters nor was all of the material categorised and matched with specific sightings. It was possible to use the following number of photos which was matched with encounters; 80 southern right whales, 21 humpback whales, 5 Bryde’s whales, 65 Indian Ocean humpback dolphins, 187 Indo-Pacific bottlenose dolphins, 7 common dolphins, a single encounter with Heaviside’s dolphins, and 2 encounters with killer whales.

21. Behaviour comments

Behaviour comments collected from the WWV were analysed for consistency and validity. The validity of the behaviour codes (supplied by O&C, Table 2) were compared with the categories from species relevant literature from Lusseau (2004), Lundquist et al. (2012) (Table 3).

TABLE 2 BEHAVIOUR CODES SUPPLIED BY O&C

1. Aggresive behaviour
a) Tail slap
b) Flipper slap
c) Head lunge
d) Aggressive approach
e) Fluke swirl (slash)

2. Calm / undisturbed behaviour
a) Sailing
b) Spy hopping
c) Feeding
d) Mating
e) Relaxed, no approach
f) Flipper wave
g) Fluke wave
h) Relaxed roll

3. Attraction / interactive behaviour
a) Relaxed behaviour
b) Relaxed diving to vessel
c) Relaxed alongside the vessel
d) Rubbing on bottom of the vessel
e) Relaxed lift vessel up
f) Dolphins or sub group bow ride the vessel

4. Social behaviour
a) Several whales/dolphins apparently socializing

5. Avoidance behaviour
a) Behavioural change from relaxed behaviour to swimming/diving away from the vessel
b) Relaxed diving to vessel

6. Unidentified behaviour
a) Arch

7. Other: e.g. breech
a) State behaviour, using back of page if necessary
b) Accidential approach

If attracted to vessel please state how close whale / dolphin approached vessel.

Effort

Data on spatial and temporal effort was scarce and four data sources was analysed in an attempt to establish a reference of the effort of the WWV.

1. Total number of trips conducted including trips with no cetacean sightings was calculated based on trip numbers.

2. Temporal effort from 2007 – 2012 from logbooks of Kleinbaai's harbour was calculated based on the start and end time of trips.

3. Spatial effort from the modified log sheets between September 2011 and October 2012 with key areas; Franskraal, Pearly Beach Bay, and Dyer Island. Potential spatial effort patterns were investigated based on the marked areas and CI was calculated as number of registrations per total number of trips during the selected period.

4. Spatial effort based on 72 collected tracks were converted to one polyline and overlaid on a 1 km x 1 km grid (NOAA 2006, Koslovsky et al. 2008) using QGIS 2.1.0, projection UTM 34S, datum WGS84. The tracks were separated in low and high season (based on the results from the temporal effort data) and number of tracks in each grid cell was calculated and used as indications of the spatial effort of the WWV.

TABLE 3 BEHAVIOURAL CATEGORIES USED IN SCIENTIFIC STUDIES FOR DOLPHINS (LUSSEAU ET AL. 2006) AND RIGHT WHALES (LUNDQUIST ET AL. 2013)

Behaviour categories of dolphins from Lusseau et al. (2006)	Behaviour categories of right whales from Lundquist et al. (2013)
Traveling Group is moving steadily in a constant direction more quickly than the idle speed of the observing vessel. Swimming with short, relatively constant dive intervals. Group spacing varies.	**Traveling** Whale is moving from location to location, leaving visible surface swirls ("footprint") behind in its path.
Resting Group is moving steadily in a constant direction more slowly than the idle speed of the observing vessel. Swimming with short, relatively constant, synchronous dive intervals. Individuals are tightly grouped.	**Resting** Whale is motionless and horizontal at surface of water; may also be drifting or slightly below water, surfacing only to breathe.
Milling No net movement. Individuals are surfacing in different directions. The group often changes direction as well. Dive intervals are variable but short. Group spacing varies.	**Not available**
Diving Direction of movement varies. Group dives synchronously for long intervals. All individuals perform "steep dives," arching their backs at the surface to increase their speed of descent. Group spacing varies. Diving most likely represented the "feeding" category in other studies (Shane 1990).	**Not available**
Socializing Many diverse interactive behavioural events are observed, such as body contacts, pouncing, genital inspections, and hitting with tail. Individuals often change position in the group. The group is split in small subgroups that are spread over a large area. Dive intervals vary.	**Social** Whale is actively rubbing, touching, or circling around another whale.
Not applicable	**Surface Active** Whale is causing whitewater at the surface by rolling, breaching, tail- or flipperslapping.

3.5 Results

In the period 2000 – 2012, a total of 4323 trips were conducted by the WWV. The main whale-watching season, the peak season, extends from June to December, when southern right whales are present at the South African coast line (Best 2007). The peak season where most southern right whales are present in the area is between August and November (Vinding et al. 2015a). From 2000 – 2002, the WWV only operated during the southern right whale season. Trip numbers increased to include all months of the year from 2003. However, number of trips were still markedly higher in the high season, (Table 4). The results of the consistency and validity analysis are shown in Figure 4.

3.5.1 CONSISTENCY

3.5.1.1 Trip data

The only data-type with a CI at 100% was "Date". The registration of trip ID-number was 80% and the registration of ID of the skipper and the guide was 90% or above. In the study period, a total of 14 different persons were involved in data collection and from 2004, a permanent whale spotter was part of the crew (data not shown). It was generally impossible to identify the responsible data recorder, as many trips had up to five persons on board (skippers, guides, biologists, videographers and photographers), who might have undertaken the data collection, and it was not clearly defined who was responsible. Other crewmembers, and videographers were rarely (less than 10% of trips) identified by name. The registration of the trip number had a CI = 76,6%. "Weather category" had a higher CI (83,2%) than "wind category" (64,7%).

3.5.1.2 Encounter data

None of the data fields for encounter data-types had a CI of 100%. The data-types with CI above 95% were: Time, latitude and longitude, species, and number of adults. Recording of departure time occurred significantly less than arrival time (Students t-test $t = 0.015$, $p > 0.001$) with a CI of 82,8% for departure time. Only 75,5% of the encounters recorded whether the animal(s) moved

TABLE 4 OVERVIEW OF THE TOTAL NUMBER OF TRIPS PER MONTH PER YEAR (ALL TRIPS INCLUDING TRIPS WHERE NO CETACEANS WERE SIGHTED). MONTHS WHERE DATA WAS UNAVAILABLE IS DENOTED BY NA (NOT AVAILABLE).

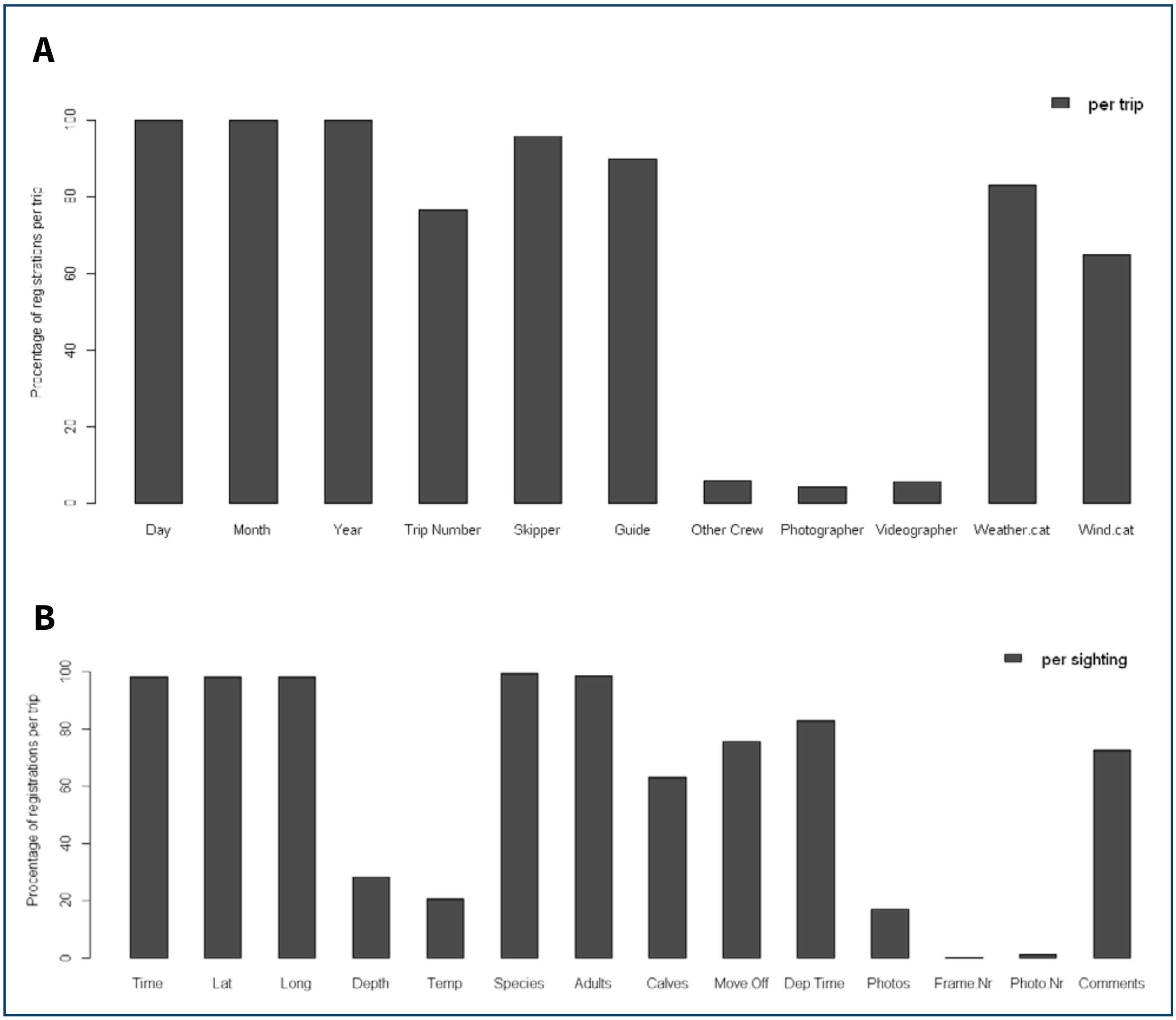
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
January	0	0	0	21	19	30	25	26	26	30	21	12	12	**222**
February	0	0	0	5	19	19	19	NA	14	23	9	13	16	**137**
March	0	0	0	7	23	26	19	10	28	23	12	11	22	**181**
April	0	0	0	5	17	6	21	8	7	31	6	12	3	**116**
May	0	0	0	1	12	12	11	2	7	11	7	7	6	**76**
June	0	0	2	10	8	14	18	17	10	NA	12	10	9	**110**
July	0	0	8	18	28	32	30	25	25	NA	28	21	24	**239**
August	0	14	35	27	50	59	61	80	63	53	49	34	51	**576**
September	0	22	47	28	53	72	82	85	61	42	42	42	40	**616**
October	17	37	41	54	75	86	110	102	100	89	63	71	46	**891**
November	18	38	51	51	80	92	105	76	91	60	64	58	NA	**784**
December	3	4	49	24	44	46	59	60	NA	36	24	26	NA	**375**
Total	**38**	**115**	**233**	**251**	**428**	**494**	**560**	**491**	**432**	**398**	**337**	**317**	**229**	**4323**

off from the vessel or not. Water depth, temperature, and information about photo documentation were the data types with the lowest CI (between 0,3 and 28,4%). In 63,2% of encounters the presence of calves was noted, however as absence of calves was not recorded it was impossible to calculate a CI.

A number of characteristics of the encountered animals was recorded, particularly age for example adult vs. sub-adult. Such characteristics were regarded as subjective and observer dependent and it is questionable whether all observers actually differentiated between adults and sub-adults. Since it was not always possible to identify the responsible observers throughout the study period it was not possible to assess if such characteristics were consistently recorded.

Photographic material was collected during the entire period of the WWV operation but recording of the presence of photo material was inconsistent with a CI of 16.9% and encounter related photo-frame numbers were only rarely recorded with a CI of 0.3% making a post-analysis (matching sightings and photos of specific sightings) impossible in many cases.

FIGURE 4
Consistency in data collection. A) per trip. B) per encounter.



3.5.2 VALIDITY

11. and 12. Latitude and longitude

The latitude and longitude positions of encounters were plotted using ArcGIS 9.3. From a total of 7512 available encounter positions (out of the total number of encounters of 7625) 118 positions (1.5%) were obviously incorrect, either representing positions on land or positions far out of the permit area. As the majority of these positions represent manual recordings of visual examinations of the display of a vessel-attached GPS it is very likely that clerical errors led to discrepant recordings. On top of the obvious errors that occurred at the degree or minute scale, there might have been unobvious errors at a finer scale, which were not possible to detect. In consequence, the 1.5 % error rate based on impossibility, could suggest that the total error rate will not be above 5%, but an exact measure is not possible to calculate.

13. SST

There was a strong correlation (R^2 = 0.928) between SSTs measured on the WWV and the SST deducible from satellite images (n = 100) (Figure 5) and the SST measure on the WWV are hence regarded as valid.

14. Water depth

A total of 1452 encounters contained water depth and latitude and longitude position, 1283 encounters at 0 – 15 m, 88 encounters at 15 – 20 m, 55 encounters at 20 – 30 m, 20 encounters at 30 – 50 m, and 6 encounters at 50 – 100 m. Each depth category was plotted in QGIS 2.8.3 and simply visually compared with the bathymetry of the area (Figure 6). The measured water depth values were generally within the relevant bathymetry boarders.

FIGURE 5
Correlation between the sea surface temperature measured on the WWV and from satellite images (n = 100) R^2 = 0.928.

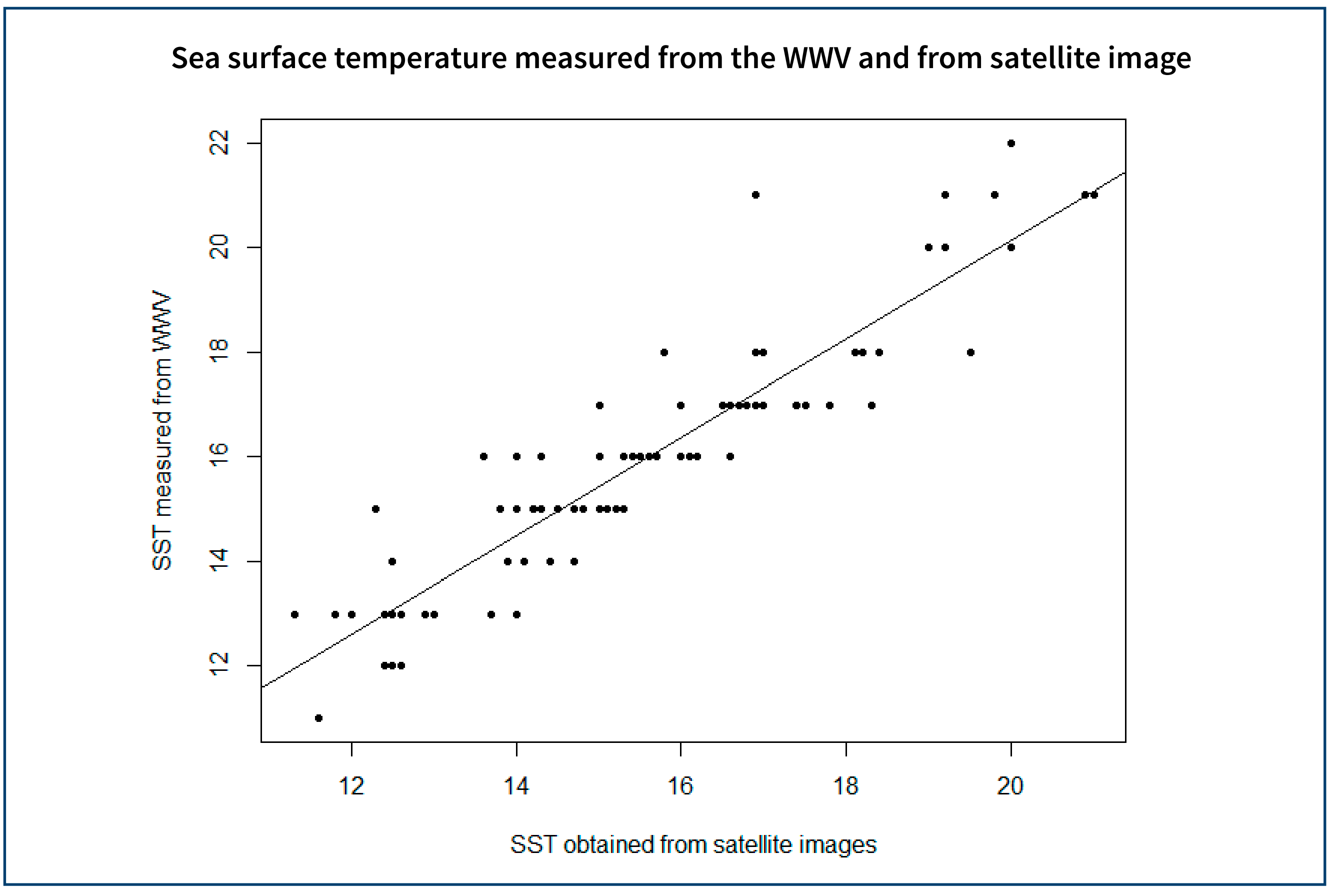
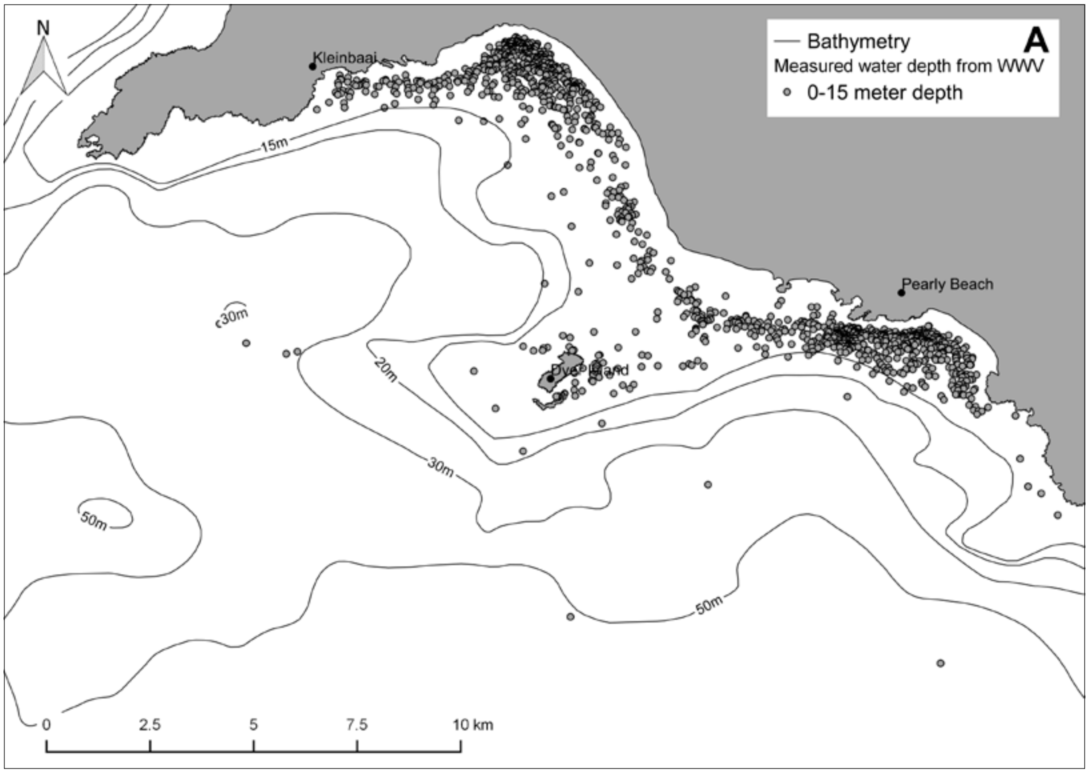
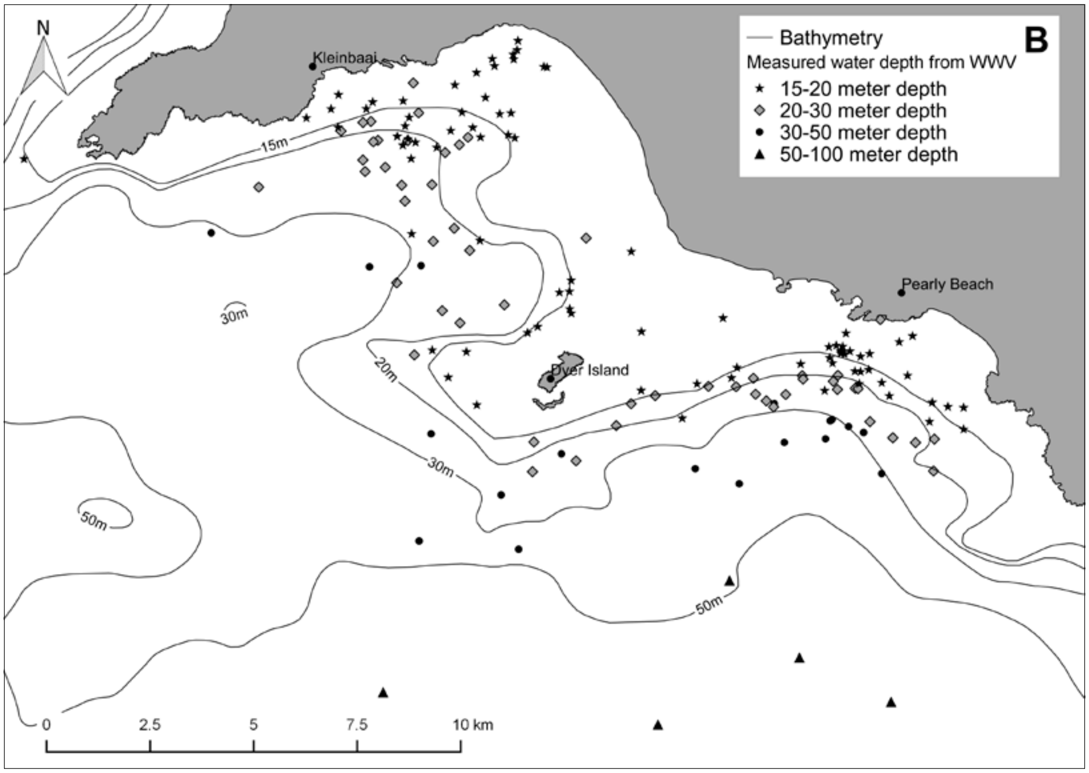


FIGURE 6

Water depth measurements. Water depth values measured from the WWV was plotted in QGIS 2.8.3 Wien and compared with the local bathymetry of the area.
A) water depth values between 0 – 15 m, measured from the WWV.
B) water depth values between 15 – 20 m, 20 – 30 m, 30 – 50 m and 50 – 100 m, measured from the WWV.





15. Species

Species identification was validated by comparing recorded species information with photographic material. This validation showed a complete agreement between recorded species and the species in photographs.

21. Behaviour comments

Several problems were noted when analysing the collected behaviour data. The original behaviour observations were recorded using a list of behaviour codes supplied by O&C (Table 2). Some of these codes were subjective and difficult to implement in practice, e.g. the code "Aggressive behaviour" included tail slaps and flipper slaps, which are actions that cannot equivocally be interpreted as an expression of aggressive behaviour. In some cases, there were long descriptive stories about the behaviour of the whales, whereas in other cases the log sheet would just contain a phrase like "lots of whales in the area". Despite a CI of 72,4% of recordings (Figure 4B), the validity of these comments were found to be poor since the observations were based on largely subjective codes and long descriptive stories could not be interpreted and hence not analysed. A method, which might make the behaviour data useful, could require an extensive analysis of the material where individual behaviour types were reclassified as singular events, based on standard categories from other studies (Lusseau et al. 2006, Lundquist et al. 2013). Such an attempt was made to reclassify the behaviour data but it was concluded that there were too many overlapping categories (Table 2) which also could account for more than one group category (cow-calf pair and surface active group) and the behaviour data were discarded for further analysis.

Effort

1. DIC conducted a total of 4323 trips between 2000 – 2012 cetaceans were encountered in 3764 trips (Table 3) and the total number of cetacean encounters was 7984 (data not shown).

2. The temporal data obtained from the harbour master showed a seasonal difference in trip duration. The trip duration was significantly longer (Students t-test $t_{df} = 1287$, $p > 0.001$) between July to December; mean =145.4 minutes ± 14.6 *SD*) than between January to June; mean = 99.2 minutes ± 14.8 *SD*). Hence, data should be separated into high (July to December) and low season (January to June) if used for temporal analysis.

3. The total number of trips between September 2011 and October 2012 was 422. Out of these trips a total of 242 trips held data on areas visited, which gives a CI of 57%. The most frequented area was Franskraal. 205 trips went to this area and 37 trips did not include Franskraal. 49 trips went only to Franskraal. 172 trips went to Dyer Island and 70 did not include Dyer Island. 17 trips went only to Dyer Island. The least visited area was Pearly Beach, with only 75 trips and no registration of trips between January and June (Table 5) and 167 trips not including Pearly Beach. 12 trips went only to Pearly Beach. 170 trips went only to Franskraal and Dyer Island while 9 trips went only to Franskraal and Pearly Beach and 8 trips went only to Pearly Beach and Dyer Island.

TABLE 5 OVERVIEW OF THE NUMBER OF TIMES THE THREE MAIN AREAS OF INTEREST FRANSKRAAL, PEARLY BEACH BAY, AND DYER ISLAND WAS VISITED PER MONTH (SEPTEMBER 2011 – OCTOBER 2012). FRANSKRAAL WAS THE MOST FREQUENTED AREA, DYER ISLAND THE SECOND MOST VISITED AREA AND PEARLY BEACH THE LEAST VISITED AREA.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Franskraal	3	2	5	2	1	2	3	1	35	91	43	17	**205**
Dyer Island	2	0	4	2	3	2	3	1	41	67	28	19	**172**
Pearly Beach	0	0	0	0	0	0	2	2	26	21	16	8	**75**

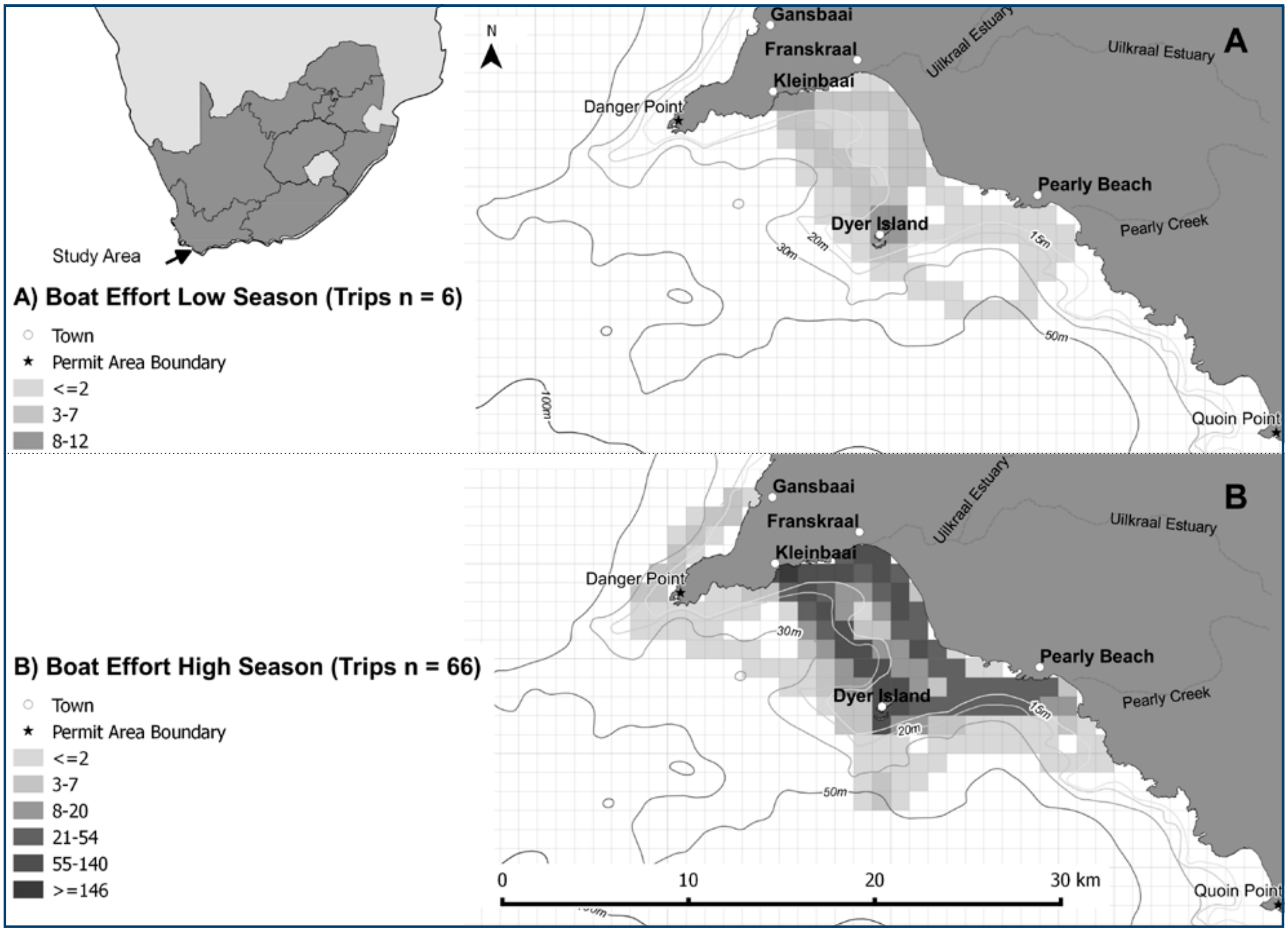


FIGURE 7
Spatial effort of the WWV based on GPS tracks collected between September 2011 and September 2012. (A) the low season (January – June) and (B) in the high season (July – December).

Grid cell size is 1km x 1km and colour grading (for example 3-7) show the total number of times the track of the WWV passed through each grid cell.

4. Typical search effort is shown in Figure 7 as the number of times the WWV track passed through each grid cell with high and low season presented separately. The 72 collected tracks were typical of the routes followed since 2003 according to co-author and owner of the WWV company since its inception in 2000; Wilfred Chivell.

3.6 Discussion

The present study has revealed that the quality of the analysed WWV data varied regarding consistency and validity. Less than half of the data-types were consistently recorded (6 out of 21); date, skipper name, time of encounter, latitude and longitude position, species, and number of adults, and only three of the data-types were found to be both consistent and valid; species, latitude and longitude position. It was found in this study that the pitfalls related to WWV data collection was; effort data, sea state, trips with no sightings, observer details, behaviour data, and photographic material. This finding suggests that data collection procedures could be improved to optimise the data quality and ensure that the data can be used for an analysis of presence, seasonal distribution, and identification of cetacean species. When the caveats of a dataset are identified, it is possible to evaluate and understand the limitations of the data in order to implement criteria for the data types which can be included in a further analysis of for example spatial distribution.

The study has also revealed that the design and content of WWV data log sheet influences, and for some data types dictates, the quality of the data. It is important to clarify the aim and analysis methods of the collected data before the data log sheet is designed. Which level of details is needed in the observations and what is realistic regarding the observers time and capacity. The contents and importance of the design of log sheets are discussed below and suggestions of a design and data collection protocol is provided.

3.6.1.1 Abiotic data (Beaufort scale, SST, and water depth)

Detailed weather registrations *in situ* can be very time consuming for the observers, and it is suggested that the log sheet is designed as simple tick boxes. Collecting weather data is useful as the sea state and wind direction influence the ability and capacity of the observers' to detect different species of cetaceans. High seas and choppy waters particularly decrease the ability of spotting dolphins and surveys should be conducted at sea state ≤2 (Whitehead 1999, Reeves and Brownell 2009), while larger baleen whales can often be spotted in up to sea state 5 (Thiele et al. 2000), due to their higher blow and larger bodies. It is essential that the data set contain sea state values which enables an exclusion of data for an analysis. It is important to collect sea state values even when cetaceans are not sighted, as this data has to undergo the same exclusion criteria as trips with sightings. Sea state can change during a tour and local conditions and if the sea state is only recorded at the beginning of a tour, it could be misleading. It would be beneficial for the data analysis if sea state was collected with the same interval for example every hour and at each encounter and not just once during the entire trip. This would improve the quality of the dataset. To optimise the data collection, the log sheet could contain a simplified Beaufort scale, as a tick off box: no white caps (sea state 0-2), few/sporadic white caps (sea state 3), frequent white caps (sea state 4), and consistent white caps (sea state 5). The data sheet should include at least include the three first categories and possibly all five.

Sea surface temperature and water depth can influence the distribution of cetacean species (Elwen et al. 2010). Collecting this information from the WWV is therefore important, particularly in data deficient areas, as bathymetries often do not exist in such areas. It is suggested that the log sheet include SST and water depth measurement for each encounter and not just for the entire tour. The measurements of water depth were found to be valid but inconsistently recorded. It was only possible to visually assess the water depth measurement values (in QGIS) since there are only estimated bathymetry lines and no fine scale bathymetry is available for the area and hence it was not possible to provide an exact figure of the number of water depth measurements which were incorrectly measured. SST measured from the WWV was compared to satellite derived temperatures and found to be valid. A minor temperature difference between the measured SST in an inshore environment and temperature determination based on satellite images from ocean temperatures is to be expected (Smit et al. 2013).

3.6.1.2 Trip information

The log sheets with the basic trip information must be kept with consecutive numbers in order to maintain a proper database with the collected data. Hence it is highly important that data on date, time, and trip numbers are consistently recorded, making it possible to assign of a unique trip number to every conducted tour. Results show that the date was consistently collected but data on arrival and departure time was inconsistent. This could be explained by the fact that the observer has to fill in a number of basic data at the beginning of an encounter (such as arrival time, species, number of animals, behaviour, latitude and longitude position) while at the departure from the encounter, the observer only has to record the departure time. If the observer is also covering the function as the guide on-board the vessel, it might be easy to forget to record the departure time, because the guide is busy elsewhere on the vessel with the clients and not focused nor close to the data sheet. It is recommended that an arrival and departure time is either collected with a GPS logger carried by the observer, which also enables collection of effort data, or the observer collects the data while carrying the log sheet with them at all times during the tour.

3.6.1.3 Cetacean encounters

Species identification of the cetacean encounters was found to be both consistent and valid. One of the most important qualifications of an observer is the ability to identify the species, and in this particular study there were five main species found in the area: southern right whales, humpback whales, Bryde's whales, Indian Ocean humpback dolphins and Indo-Pacific bottlenose dolphins, and three rarely seen species: killer whales, Heaviside´s dolphin, and common dolphins (Vinding et al. 2015b). These species are easy to tell apart, leaving the trained observer with little challenge. In other locations it can be a potential problem and proper training in species identification is essential, since observers' skills and training level can vary with respect to their ability to perform correct species identification and behaviour classification (Evans and Hammond 2004, Hauser et al. 2007). Photo documentation is highly recommended as validation source.

The number of adult animals encountered was consistently recorded, but consistency in registration of calves were not possible to measure. It is recommended that the design of the log sheet contain a simple yes/no tick box related to encounters of calves, which should provide reliable data on the absence of calves. A number of characteristics of the animals sighted, particularly age; adult vs. sub-adult were regarded as invalid, since the correct registration requires a level of experience and training which was not possible to know existed throughout the years. Therefore, it is questionable whether all observers actually differentiated between adults and sub-adults. It is worth to evaluate the importance of this type of details in the observations before it is included in the log sheet.

Whether the animal moved off from the vessel or not was only recorded in 75,5% of encounters. It is difficult to assess such open-ended categories, since it is not clear if the category was only filled in when the animal actually moved off.

3.6.1.4 Behaviour

The log sheets contained over 50 different descriptions of behaviours which were impossible to categorise or re-categorise as more formal accepted categories such as *"resting, milling, travelling, socialising, and feeding"* and some of the 25 pre-defined categories were subjective and difficult to distinguish. One of the most difficult tasks is to determine the behaviour of the animals. The majority (71%) of all encounters had a comment associated with the observation. Most of these comments were related to behaviour, but the quality and relevance of the comments varied considerably. Data like this is very difficult to analyse and categorise and it is recommended that the log sheet consists of restricted and simple tick boxes with four-five main behaviour types, e.g. socialising, milling, feeding, travelling, and resting (Lusseau 2004) with clear descriptions of typical behaviours observed in each category and a comment box for further details. The behaviour data collected from the WWV were discarded because the categories were too subjective and it was impossible to analyse the many different categories.

3.6.1.5 Photographic material

Photographic material was available from many of the trips, however registration of data necessary to associate the photos with sighting events was inconsistent which made matching of specific photographs and sightings impossible. For photographic material to be useful, it must ideally be categorised the same day, and notes related to the frames of photographs should be noted for each encounter where photographic evidence is collected. Settings of date and time from the camera is crucial and a GPS linked to the camera can be of great help for later analysis of the data. Depending on the required level of information and capacity of the WWV it is recommended to dedicate personnel for data collection, it is also recommended that photos of different encounters that are collected on the vessel should be divided with blank photos. The process of linking pictures to specific observations is very time consuming and almost impossible if done retrospectively.

3.6.2 EFFORT

The effort and route of the WWV does not follow a rigid scientific line transect while searching for whales; it often searches for whales by biasing the time of the encounters and their locations towards areas with, and seasons of, high cetacean densities (Hauser et al. 2007). This behaviour of the WWV is driven to satisfy the interests of the guests and maximise whale encounters and by the time and cost constraints of the trips (cost efficiency and back-to-back trips). The effort of the WWV in this study is biased towards areas with whales and where whales would have been observed previously and the distributions of other attractions including great white sharks (*Carcharodon carcharias*), and seabirds, for example the African penguins (*Spheniscus demersus*) which may vary between seasons. Thus, individual cetaceans might be encountered twice on the same trip or on days with more than one trip, animals in the area have a high chance of being encountered consecutive times. To account for this, one can randomly pick a representative trip for each day or choose to only use the first trip of each day. If the photographic material is of high enough quality, it would be possible to match the encounters from trip to trip and by that tease out re-encounters.

When analysing for spatial and temporal distribution it is necessary to be able to account for the effort spent at sea searching for cetaceans. One of the main reasons why effort data were not obtained from this particular WWV is that it is not included in the provided log sheet from O&C. The effort could only be approximated by number encounters per number of trips (in this case a total of 4323 trips), as GPS tracks were not available for the entire period. The absence of spatial effort data makes it difficult to ascertain the true distribution of the cetacean species, since areas with high occurrence of animals could also reflect a high search effort in that particular area where as areas with low search effort might have the same high occurrence of animals. Consequently, WWV data should include spatial and temporal effort information.

Simple collection of start and end time of the trip can be used as a reference for trip duration and as shown in this study, as a measure for difference in search effort between seasons. This result increased the quality and usefulness of the log sheet data. The spatial pattern based on the simplified area categories was similar to the pattern of the 72 tracks obtained with a GPS logger. This indicates that such simplified area categories can be useful as a spatial effort reference if a GPS is not available. The optimal way to obtain effort data would be to collect GPS tracks of the vessels thus providing precise data of the spatial route and temporal effort. This type of information would also provide O&C with a reliable way to check if the WWVs remain within the permit area. If possible, then it is important to distinguish between searches and encounter time, by logging the time spent by each encounter it will be possible to calculate search effort and encounter effort.

3.6.3 OBSERVER SKILLS AND TRAINING

The quality of the obtained data relies on the observers' skill. Foremost, the quality of observations could be subject to bias owing to many different observers (n = 14 in the present study). It is recommended that the log sheet include information about the person who is responsible for the data collection for each tour or if possible for each sighting. Having many different observers of varying experience can affect the consistency and validity of the collected data and crewmembers have to fulfil many tasks on the vessel, and collecting data is not always of high priority. An alternative way of using WWVs as a platform of opportunity is to have a dedicated team collecting data on board the WWV, like in e.g. Penry et al. (2011)´s study of Bryde's whales in Plettenberg Bay, South Africa and such collaboration between researchers and WWV companies are encouraged.

When the crew is responsible for the data collection, it is highly recommended that these responsible observers receive extensive training and instruction in the use of the log sheets before becoming the responsible person. It is also recommended that the law enforcement (in South

Africa; Ocean & Coast) recognize this responsibility and supply courses in species recognition, handling of log sheets, and the use of the collected data. In order to sustain a high level of quality and conduct quality control it is recommended that individuals who intend to observe and report WWV data must attend an (online) yearly exam and acquire a certificate.

3.6.4 PLATFORM OF OPPORTUNITY OR RANDOM POINTLESS OBSERVATIONS?

There are challenges regarding the quality and standards of data collected from platforms of opportunity. Firstly, as mentioned above, the challenges related to the WWV not following a systematic search pattern when data is collected. Secondly, WWV trips are likely to be biased in both the area and periods of their main effort. Particularly, the search effort is affected by the WWV route, which often is restricted to localised high abundance areas, sometimes seasonally dependent, and species specific. The active search effort is affected by the time spent at the different opportunistic encounters. To be able to correct for the spatial and temporal effort conducted by the WWV it is crucial that effort data are collected. Thirdly, scientific studies are restricted by sea state cut off limits depending on the study species and collection of weather data is crucial for the analysis of the WWV data to apply a sea state cut off limit (Redfern et al. 2008, Bailey et al. 2013) and assess the quality of the reported sightings. Finally, the data sheet provided by officials or the WWV itself dictates the standard and type of the collected data. The South African government provides the guidelines for the log sheets to the country's WW operations and by this they set the standard of the data collected by the WWV. If these standards are not at a level where the data are actually useful, it becomes a futile exercise for both the operators and the managers at O&C. Effort data is an important data-type which is completely overlooked in the log sheet requirements by O&C in South Africa. This could be remedied by O&C placing an electronic GPS logger on each WWV, sampling the tracks of the permitted WWVs. This system would also enable O&C to ensure that the WWVs adhere to the assigned permitted area as well as calculate the time spent searching and at an encounter. It is also suggested that O&C conduct regular on site quality control visits at the WWV.

From a research point of view, the data collected must be valid and consistent to be most useful. Since the focus of WWV is on the passengers and no on the data collection, it is important to simplify the log sheet as well as prioritise the required information. In order to improve the consistency and validity of data collected from WWV it is recommended that the log sheet are amended to contain at least the elements given in Table 2. It is also recommended that the logbook must be filled in at sea *in situ* and it should ideally be digitised the same day by the observer. Depending on the required level of information and capacity of the WWV to dedicate personal for data collection, it is also recommended that photos of different encounters that are collected on the vessel should be divided with blank photos and organised and linked to the relevant observations on the day of the observations. The process of linking pictures to specific observations is very time consuming and almost impossible if done retrospectively.

A simple, yet important, factor concerning the data was that when the digitised data were compared with the hard copies it was clear that in some cases it was either impossible, or very difficult, to read the hand writing of the observer. This could be due to people writing during rough and high swell conditions. Ideally, the observer who writes the notes must also be the one entering the data the same day or within a few days from the trip. It also re-affirms the fact that tick-box observation sheets are more user-friendly, less time consuming, and will provide more accurate data, e.g. when taking behaviour notes.

3.6.4.1 Data collection Apps

A more modern approach to data collection is the use of apps and a number of well-designed Apps have already been developed. These apps are often available for IPhone, IPad, and Android phones and are often free to download. The advances in technology has provided access to mobile phones at a global scale and it is common to own a mobile phone even in many developing countries. Most modern mobile phone devices have an inbuilt GPS which is highly useful when the device is used for data collection through an App. The apps are designed with the clear goal of collecting spatial and temporal effort. Using such apps can reduce costs (for example GPS logger) and ensure that effort data is collected in the correct standard, since it is an inbuilt feature in the App. At this point in time there are the following Apps available, which are highly recommended for data collection from platforms of opportunities.

The Spotter Pro app (Spotter 2016), (The-Spotter-Pro-App 2016). This app was developed by California´s Marine Sanctuaries and Point Blue Conservation Science to reduce ship strikes along the west coast of the US but it has also been for example in Iceland from WWVs (Rasmussen et al. 2015). This app is very user friendly and the standard settings for data collection are; trip information (skipper, departure port, operator, data collector, assistant, areas covered and comments), weather conditions (cloud cover, visibility, wind direction, swell, Beaufort scale, comments), sightings (species, number sighted, bearing, distance, latitude, longitude, photos taken (yes/no), calf present (yes/no), birds present (yes/no), comments,) and behaviour (bowriding, breach, feeding, fluking, high-speed travelling, jawing, jawslap, lobtail, logging, porpoising, quick dive, rolling, rubbing, spy hop, surfing, travelling, and milling. It is possible to contact the developer and have a customised version of the app for example regarding the species and behaviours.

Coastal Walkabout (Coastal-Walkabout 2015). This App has been developed by Murdoch University, Duke University, and Marine Ventures foundation, to engage and motivate local communities to help gather scientific information along the vast coastline of Australia. The App can also be used in other parts of the world and is very user friendly. It collects spatial and temporal effort and has species identification photos and descriptions.

3.6.5 WORLD-WIDE GUIDELINES

Consistency of national or even worldwide data collection methods (Robbins and Frost 2009) would generate a powerful and versatile dataset for broad scale comparison of datasets. It would be beneficial to develop such recommended guidelines for data collection and analysis from different platforms of opportunity (sea, land, and air) for each type of platform. Having such guidelines could aid new and current WWV operators and government officials to design data

TABLE 6 RECOMMENDED LIST OF DATA TO BE COLLECTED FROM WHALE-WATCHING VESSELS

• Responsible observer name
• Other crew names
• Effort (time and spatial); Hand held GPS or start/end time of the trip
• Weather conditions (Beaufort scale)
• Time arrival at sighting
• Longitude and latitude of sighting
• Water depth
• Water temperature
• Species
• Number of animals; adults and calves
• Behaviour observation; Easy fill-in tick-box and a comment option
• Photos with blanks between observations
Trip data must be collected even if no cetaceans are encountered

sheets, which are easy to fill in and contain the relevant data types needed for the data analysis. Providing guidelines for the data analysis along with the guidelines for data collection, it could supply an insight into why it is important to collect certain data types, such as effort data and sea state and hence ensure a high standard of the data sheet and prevent the collection of useless data. Having guidelines for the data analysis could also facilitate the actual data analysis and maybe prevent years of accumulated unanalysed WWV-data.

It is recommended that a global independent organisation such as the International Whaling Commission (IWC) define worldwide guidelines for the standard of data sheets, recommendations on how to improve the quality of data, and guidelines on how to analyse the collected data. Such guidelines could promote higher quality and better understanding of future data collection and data analysis and enable global data comparison.

3.7 Conclusion

Based on the analysis of consistency and validity of the data from a local WWV it is concluded that data from such platforms of opportunity can provide indications of spatial and temporal distribution of cetacean species in the related area. However, caution must be taken when using such data sources and development of worldwide or at least regional standards (guideline and protocol) is strongly encouraged to ensure a high standard of the collected data.

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4

4 Shore-based observations of five cetacean species in the Greater Dyer Island area, South Africa: Spatial distribution, seasonality, and group composition

4.1 Abstract

Shore-based observations of cetaceans were conducted from two stations near Gansbaai, South Africa (34°40'18" S, 19°28'16" E) to investigate behavioural and spatial and temporal patterns of habitat use. Hourly scans were conducted to provide information on species presence, location, group size, group composition, and surface behaviour. Focal groups were tracked with a surveyor's theodolite to provide detailed information on movements. A total of 1558 hours and 26 minutes was spent on effort over 270 days between 24 August 2011 and 11 December 2014. A total number of 1204 scans, where 1175 scans were conducted at sea state < 5. All sighting data were filtered to remove periods of poor weather conditions, only observations collected at sea state ≤ 2 for dolphin species, and ≤ 5 for baleen whales were analysed. The longest focal follow from each day was used for southern right whales and all focal follow tracks of dolphin species were included. Five cetacean species were regularly observed: southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Balaenoptera brydei*), Indian Ocean humpback dolphins (*Sousa plumbea*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), while common dolphins (*Delphinus delphis*) were only seen on three occasions. The results of this study strongly support the temporal and spatial patterns of the five most regularly observed cetacean species described from data collected from a local whale watching vessel. Southern right whales were by far the predominant species in the area. There was a change group type from surface active groups (SAGs) in the beginning of the season to cow/calf pairs (cc-pairs) later in the season. Southern right whales predominantly used the area for socialising and/or nursing. The large bay area in Pearly Beach, in particular, was the preferred area of the cc-pairs. All southern right whales were found to be swimming at a speed less than 5.1 km/h. Swimming speed of cc-pairs (n = 121) ranged from 0.2 to 4.3 km/h (mean = 1.15 ± 1.13 km/h SE), SAGs (n = 83) ranged from 0.3 to 3.7 Km/h (mean = 1.00 ± 0.64 Km/h SE), and unaccompanied (UA) were the fastest (n= 19), with speed ranging from 0.6 to 5.1 km/h (mean = 2.18 ± 1.39 km/h SE). The number of sightings on simultaneous days of southern right whales from the WWV and the theodolite scans were compared. The total number of sightings from the theodolite station was generally higher than the total number of sightings from the WWV during the months of September, October, and November. Sightings of other species were too few to provide any patterns. Humpback whales exhibited marked seasonality peaking in winter period (June – August) which was similar to the results of the WWV-study. The primarily observed behaviour of humpback whales was travelling and 80% of the tracked animals were travelling south-east towards Cape Agulhas. The temporal distribution

of Bryde's whales was similar to the results of the WWV-study but with a peak in February and March instead of in April. There were no clear patterns of the behavioural use of the area. The temporal peak of dolphin species in the summer period (December – February) was not as pronounced as in the WWV-study. The two inshore dolphin species were mainly observed in the bay areas where all four defined behaviours were observed and no clear trends in behavioural patterns was found. The dolphin species with the highest leg speed was the common dolphin (n = 8) with a top speed of 17.5 km/h down to 3 Km/h (mean = 11.96 ± 5.47 Km/h SE), followed by the Indo-Pacific bottlenose dolphin (n = 19) ranging from 1.5 to 9.3 Km/h (mean = 5.19 ± 2.20 Km/h SE), and the Indian Ocean humpback dolphin (n = 17) ranging from 0.9 to 6.3 Km/h (mean = 2.79 ± 1.66 Km/h SE). Three species are particularly using the inshore environment (southern right whale, Indo-Pacific bottlenose dolphin, and Indian Ocean humpback dolphin) and hence face potential human impacts from local vessels and construction sites disconnecting the along shore environment.

4.2 Key words

Distribution, Fine scale movements, Habitat utilization, Seasonality, Theodolite tracking, VADAR, Whale watching vessel.

4.3 Introduction

The research field of marine mammology has expanded rapidly both concerning new applied technologies for example D-tags (Johnson and Tyack 2003, Madsen et al. 2006, Boye et al. 2010), satellite tags (Mate et al. 1997, Wade et al. 2006, Baird et al. 2010, Mate et al. 2011, Elwen et al. 2012, Garrigue et al. 2015), Unmanned Aircraft Systems (Koski et al. 2009, Durban et al. 2015), and passive acoustic monitoring (Bailey et al. 2009, Parks et al. 2011, Marques et al. 2013). Yet, there are 45 cetacean species listed as "data deficient" out of 87 evaluated species by the IUCN cetacean specialist group (IUCN 2015) and remote locations, still need to be investigated (Elwen et al. 2011). Knowledge on fine scale temporal and spatial patterns of cetacean species is of paramount importance in order to define and apply a conservation plan. Particularly, inshore cetacean species are exposed to human impacts in the form of underwater noise from e.g. shipping (McKenna et al. 2013), ship collisions (Kemper et al. 2008), entanglement in fishing gear (Atkinson and Sink 2008, Leandro et al. 2010, Meÿer et al. 2011), construction (Thompson et al. 2010), pollution (Cockcroft et al. 1989, Atkinson and Sink 2008) and ocean based tourism (Elwen and Leeney 2010).

The study area is situated approximately 55 km from the southernmost point in South Africa, Cape Agulhas, and is part of the inshore Agulhas Bank temperate shallow shelf system which forms the southern boundary of the Benguela upwelling system and hence is affected by both current systems (Hutchings et al. 2009b). The cetacean fauna of the study area has been poorly studied to date (Chapter 2, Vinding et al. 2015). Results from the analysis of 10 years of cetacean observation data obtained from the local whale watching vessel analysed as part of this PhD (Chapter 2) showed that five main species of cetaceans known to frequent the study area regularly: southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Balaenoptera brydei spp.*), Indian Ocean humpback dolphins (*Sousa plumbea*) and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), and two occasionally observed species: killer whales (*Orcinus orca*), and common dolphins (*Delphinus* spp) (Chapter 2, Vinding et al. 2015). These species occur within a few kilometres from the coast where human impacts are highest (Halpern et al 2008). Along the South African coast there are multiple human threats to marine life including physical changes to the coastline (Sink et al. 2012), effects of fisheries including depletion of prey (Atkinson and Sink 2008), entanglement in fishing gear (Atkinson and Sink 2008, Meÿer et al. 2011), potential establishment of nuclear power stations (Griffiths and Robinson 2011), pollution (Cockcroft et al. 1989, De Kock et al. 1994, Atkinson and Sink 2008), and boat traffic including recreational, eco-tourism, and fishing vessels (Turpie et al. 2005, Waerebeek et al. 2006, Elwen and Leeney 2010, Meÿer et al. 2011). The human activities potentially impact cetaceans in the study area include two whale watching operators, eight shark cage diving operators, abalone fishing (legal and illegal), seasonal small vessel activity (particularly holiday periods), modification of river estuaries with potential implication for access for dolphins and their prey, potential fin-fish farming, and the possible construction of a nuclear power station.

Cetacean surveys along the approximately 3000 km long South African shores has been conducted (Findlay et al. 1992, Elwen et al. 2011), but consistent and long term data sets are not available for some of the inshore species and some of the more remote areas, which still needs to be investigated in details with regards to spatial and temporal distribution and habitat use of inshore cetacean species (Elwen et al. 2011). Particularly the Indian Ocean humpback dolphin is of high conservation priority, due to low numbers and strictly inshore distribution (Elwen et al. 2011). A species in South Africa for which a long term ID-cataloug exist is the southern right whale, which has been studied in South Africa since the 1969 by Peter B. Best (Best 2000). From these aerial studies it is known that southern right whales exhibit site fidelity, where most female calves (>93.4%) born at the South African coast return to give birth to their first calf, with 52.9% found in the same area or adjacent area. From other studies by Peter Best it is known that the yearly right whale season extend from June until December/early January with a peak in September (Best and Scott 1993).

This study investigated the detailed behaviour patterns, spatial, and temporal distribution of the cetacean species in the area before further human impacts are implemented in the region. An additional aim was to investigate how reliable the results from the WWV are in comparison to a more strictly structured scientific survey. If the results from the WWV study show the same or very similar temporal and spatial distribution patterns for the five species as the present theodolite study, there is evidence that WWV data can be used as a reliable source to obtain baseline data in otherwise data-deficient areas.

4.4 Methods

4.4.1 STUDY SITE

This study was conducted in the Greater Dyer Island area in Pearly Beach Bay (34°40’18” S, 19°28’16” E) (Figure 1). Pearly Beach Bay is characterised as a sandy bottomed gently sloping bay with adjacent rocky coastal reefs and kelp forest. A nearby island complex is a fully protected 390 ha nature reserve which consists of Dyer Island and Geyser Rock. Dyer Island is the largest of the two islands (20 ha), and hosts 12 different seabirds and five terrestrial bird species breeding on the island, including the endangered African penguin (*Spheniscus demersus*) (BirdLife South Africa 2015) and the adjacent Geyser Rock with a healthy and increasing colony of Cape fur seals (*Arctocephalus pusillus pusillus*) (Kirkman et al. 2013). The area is mainly known for the year round presence of great white sharks (*Carcharodon carcharias*), which supports a large shark-viewing industry operating eight vessels (MLRA 2008).

The study area is situated inshore of the Agulhas Bank which forms the southern boundary of the Benguela upwelling system and displays characteristics of both an upwelling system and a temperate shallow shelf system (Hutchings et al. 2009a). The prevailing wind changes throughout the year: in summer (December – February) winds are predominantly southerly or south-easterly, Autumn (March – May) similar to summer months but more frequent north-westerly winds, in winter (June – August) is characterised by strong winds from north-west, south-east, or south-west, and in spring (September – November) predominantly southerly, south-easterly, or south-westerly (Law 1999).

Sea temperature was measured with a Starmon mini, underwater temperature recorder (Star Oddi 2016) every half-hour by the Department of Environmental Affairs, Ocean & Coasts (Ocean&Coast 2015) from 25 July 2012 at 12:00 until 2 September 2013 at 12:30 close to Quoin Point (34°45’48.50”S, 19°35’12.28”E) at 35 m depth of water and approximately 10 km from the study site. Average temperature over the entire period was 13.3°C, over the summer period (December – February) was 11.7°C, and over the winter period (June – August) was 14°C.

4.4.2 SHORE-BASED STATIONS

Land-based focal follows were conducted from two vantage points (Figure 1); a water tower (station 1000) 34°39’34.37” S, 19°29’21.53” E, eye height: 38.79 m above mean sea level (MSL) (Figure 2) and the balcony of a private house (station 2000) 34°40’15.03” S, 19°30’29.84” E, eye height; 14.65 m above MSL (Figure 3). The two stations compensate for each other, since it was possible to

FIGURE 1
Orientation map of the research area. The two land-based theodolite stations are marked with a triangle symbol.

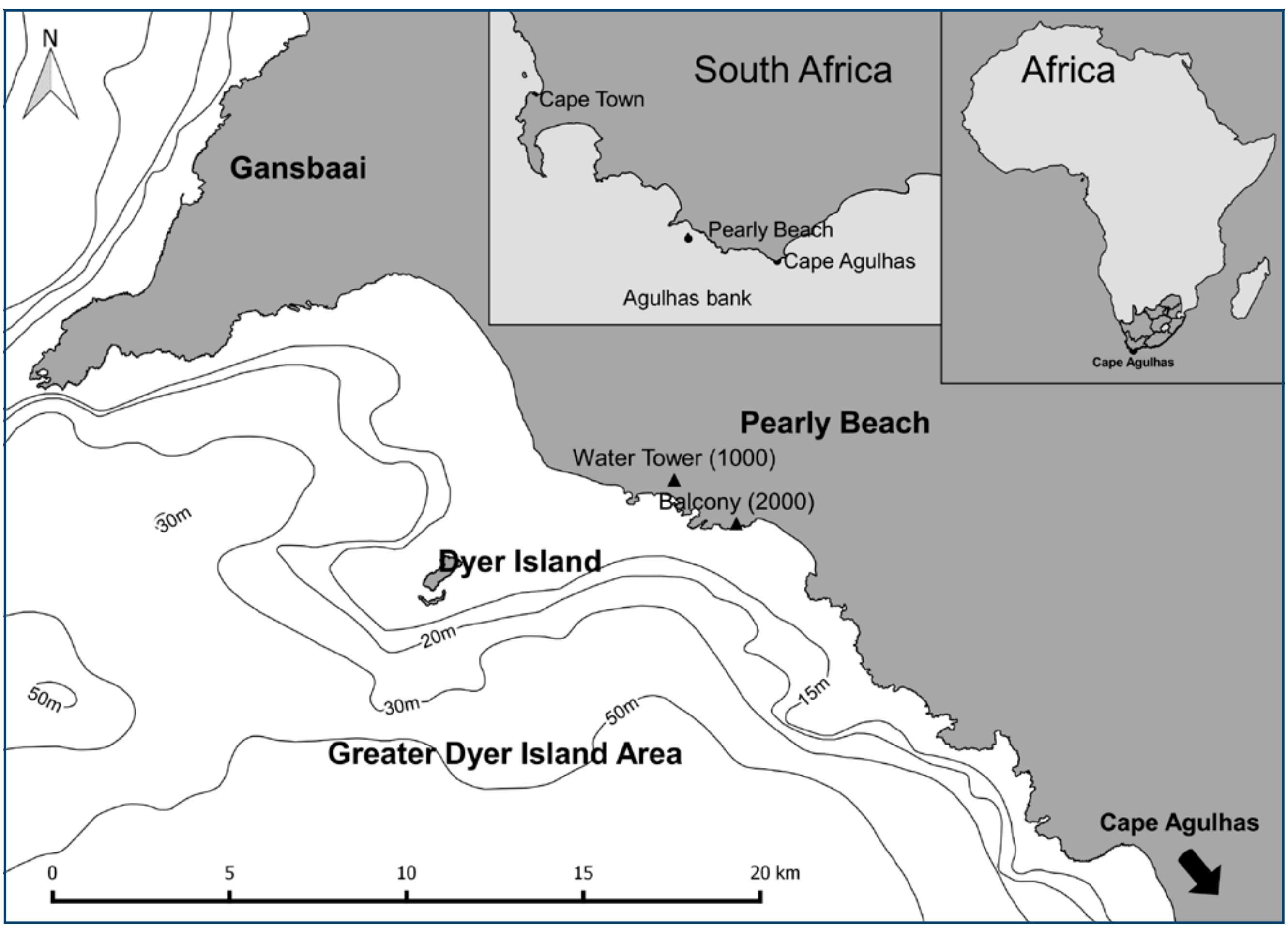


FIGURE 2
Theodolite tracking station water tower (station 1000). ***PHOTO CREDIT*** *ED SCOTT*

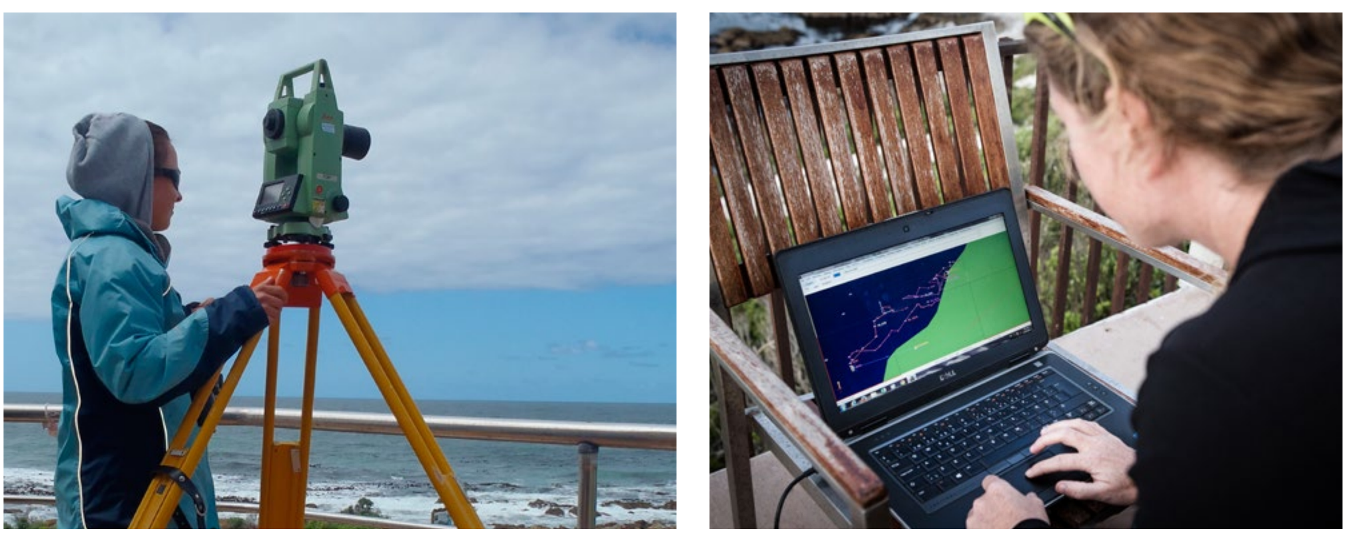


FIGURE 3
Theodolite tracking balcony station (station 2000). ***PHOTO CREDIT*** *HARRY STONE*

observe further off shore from station 1000 (it being highest) and it was possible to observe the entire Pearly Beach bay from station 2000 (view was partly obscured by houses from station 1000). The stations were used on an alternating basis.

The two total station positions of the theodolite were set up directly over a location exactly mapped by a land surveyor (Van Dyk Land Surveyor 2011). Positions of the relevant reference points (triangulation pillars) were also obtained from the land surveyor. The theodolite was firstly levelled and set up using the same mark on the ground for rough centring, and triangulation pillars at adjacent mountain tops were used for zeroing (Sagnol et al. 2014) (e.g. Groot Hagel, height 213.70 m and Hagelkraal mountain, height 275.30 m). A Leica TC307 digital total station was connected to a DELL E6430 ATG laptop with a customised version of VADAR (Visual & Acoustic Detection and Ranging at Sea, Dr. Eric Kniest, Newcastle University, Australia) from August 2014. Prior to 2014, data were stored internally on the total station and downloaded after each field day. The theodolite observations were manually matched in Excel with the written notes from the field each day. This data was later imported into VADAR for analysis, and the measured vertical and horizontal degree readings from the theodolite were converted to position coordinates (Pryor and Norris 1991).

4.5 Data collection

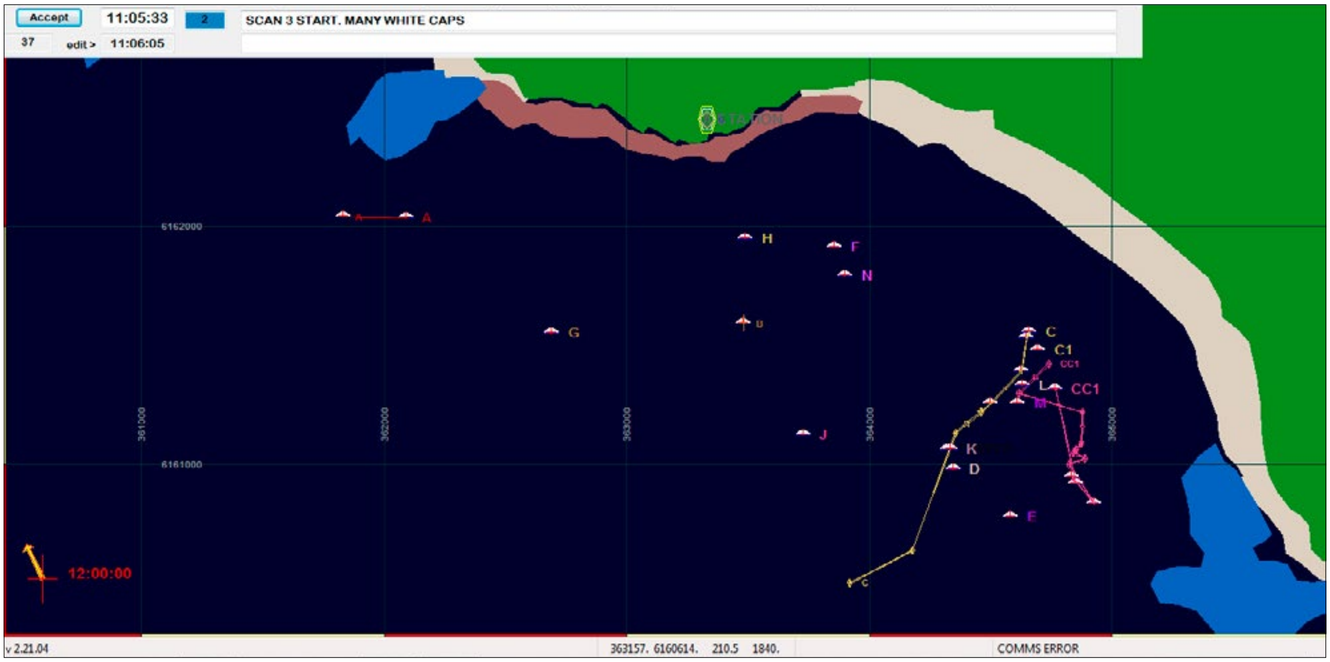
Data were collected from two land-based theodolite tracking stations during four southern right whale seasons (August – December) from 2011 – 2014 and one summer/autumn season in 2013. An overview of the data collection periods is provided in Table 1. Data collected before 24 August 2011 were regarded as obtained during a training period and not included in the analysis.

4.5.1 SHORE-BASED STATIONS

Hourly tide height was obtained from the South African Navy Hydrographic Office and tide harmonics were incorporated into the software Visual & Acoustic Detection and Ranging at Sea (VADAR 2014), which was used to calculate the geospatial coordinates (latitude and longitude) of the cetacean sightings. The tidal cycle of the area has an amplitude range between 0.2 m to 1.7 m above chart datum. Beside tidal cycle, other parameters can also affect the accuracy of the fix points, particularly swell height and the specific station height (Pryor and Norris 1991). To minimise impacts from swell height (see data collection), fix points were taken consistently at predefined positions on focal follow animals (e.g. the head region of southern right whales) and vessels (e.g. the front of the vessel). The tracking team consisted of two to five observers (normally three). One observer was in charge of the total station (theodolite) and would relay behaviour and group size to the observer in charge of the laptop or written notes, entering; group ID, size, behaviour, and comments (and theodolite file number before 2014). Additional observers were "spotters" keeping track of the focal follow, spotting animals, and participated during

TABLE 1 DATA COLLECTION PERIODS FROM 2011 – 2014. DATA WAS COLLECTED FOR AN ENTIRE YEAR AND 8 MONTHS INCLUDING THE SUMMER/AUTUMN SEASON IN 2013. DATA COLLECTED BEFORE THE 24 AUGUST 2011 WERE REGARDED AS OBTAINED DURING A TRAINING PERIOD AND NOT INCLUDED IN THE ANALYSIS.

Data collection years	Data collection period start	Data collection period end
2011	7 August 2011	13 December 2011
2012 and 2013	5 May 2012	26 December 2013
2014	6 June 2014	11 December 2014



distribution scans. The task of the spotter was shared between the total station operator and the computer operator when the spotter was absent. All observers were trained by the first author "Katja Vinding Petersen".

FIGURE 4
VADAR example of a focal follow track of a cc-pair (cc-pair 11) obtained on the 12 October 2012 from the water tower.

4.5.2 DATA COLLECTION PROTOCOLS

Two observational data collection protocols were used. Firstly, "Distribution scans" were conducted hourly to provide point estimates of the species, number, surface behaviour, and location of all cetacean species, and vessels in the area. Secondly, "Theodolite tracking" of focal groups or animals to generate, detailed information of the behaviour and movement patterns of animals.

Weather permitting, surveys began no earlier than half an hour after sunrise and ended no later than half an hour before sunset. Three different data collection methods were conducted throughout the whole field day:

1. Environmental data

2. Distribution scan

3. Search or focal follow

An example of a focal follow track VADAR (2014) can be seen in Figure 4.

4.5.3 ENVIRONMENTAL DATA AND SIGHTING CONDITIONS

To account for the effect of weather conditions on the ability to see cetaceans and assess their behaviour, data on the weather conditions were collected every hour before the start of each distribution scan.

The following data were collected:

- Time (start and end time of the weather scan)
- Environmental scan number of the day
- Wind direction (N, NW, W, SW, S, SE, E, NE)
- Maximum wind speed (km/h), surface wind speed measured with a hand held anemometer (Kestrel 3000) held perpendicular to the wind direction (digital from 31 May 2012 and onwards)
- Beaufort Sea state
- Cloud cover expressed as a fraction of eight over the observation area
- Glare (measured where the glare started at the horizon with theodolite)
- Swell height (m), visually assessed
- Weather index (M (mist) R (rain/drizzle) H (heat haze) C (clear) S (sea fog, haze over the ocean as a result of wind)), overall description of the environmental conditions
- Visibility (measured with the theodolite from three horizontal angles: 330, 20 and 55), measured as the maximum vertical angle where it was possible to distinguish between individual wavelets as a repeatable index of distance observed
- Sightability index on a scale of 1–5 (1 (extremely poor) 2 (poor) 3 (moderate) 4 (good) 5 (excellent, clear)), a subjective of the overall weather condition summarising how good overall conditions were for spotting whales, and taking all factors into account
- Comments

4.5.4 DISTRIBUTION SCAN

Scans were conducted every hour and each scan was assigned a unique number within the database (yyyymmdd_Scan number). Scans lasted from 10 to 30 minutes, depending on the number of animals in view, and all team members participated (except on rare occasions when a group of dolphins was present and the theodolite operator continued collecting data thereon). All team members had binoculars (7x50 Steiner Marine, Bushnell, or similar). One person searched with the naked eye and the rest of the team with binoculars. Initially, only the number of groups and associated data on size, composition and behaviour were collected. From 10 October 2012, the theodolite was used to record the position of all sighted cetaceans and vessels during the scan.

4.5.5 FOCAL FOLLOWS OR SEARCH MODE

Focal follows were conducted to obtain detailed information about the behaviour, swimming speed, and swimming direction of groups and single animals. Focal follows began immediately after the end of each distribution scan. Each focal follow individual or group was assigned a track group ID-number.

When conducting focal follows of southern right whales, an attempt was made to distinguish and track a single focal individual within the group. Attention was paid to individual recognition marks of right whales, for example, callosity pattern (particularly lip callosities) and body colouration (Schaeff et al. 1999). Focal follow groups were chosen arbitrarily between the individuals or groups in the vicinity of the station (to optimize the accuracy of fix points), unless they had been tracked previously during the same day.

If a group of animals had been tracked in the previous hour and it was possible to continue tracking it, after a scan, the same track group number was kept and, if possible, the group was tracked for the entire duration of the field day. Depending on the number of animals in the area, it was often possible to continue the focal follows during the scans, particularly with slow moving southern right whales. It was often possible to track more than one group at the same time, particularly with the southern right whale cow-calf pairs (cc-pair). A maximum of five right whale groups could be tracked at the same time. Focal follows were terminated when weather conditions were not optimal and the team was on standby when a group was visually lost or if groups joined and/or were mixed up. Groups were assigned new ID names if, for example, groups of right whales fused and it was impossible to determine which group was the original track group or if two groups of cc-pairs fused and split up again. If groups divided into subgroups, the original group number was kept for both groups but the group without the focal follow animal was appended "_2".

Priority of the focal follows were:

1. Dolphin species
2. Humpback whales
3. Bryde's whales
4. Southern right whale cc-pairs
5. Southern right whale surface active groups (SAG)
6. Solitary southern right whales

This priority was based on the results from the WWV, which showed that southern right whales were clearly dominating in the area from August until December and collecting tracks of southern right whales were therefore expected to be high whereas the other species were not that often present in the area and hence given priority.

Surface active groups (SAGs) are defined as groups with high levels of social interaction at the surface with physical interaction between individuals, and where most attention is directed towards a focal animal (or animals) (Kraus and Hatch 2001, Best et al. 2003). If special situations occurred, such as an orphaned southern right whale calf (Best et al. 2015), the team would start tracking the special situation if possible.

If no animals were observed during the scan, the team switched to search mode with at least one person with binoculars, and one person without, searching the area for animals. If a sighting was observed before the start of the next distribution scan, a track number would be assigned and the team would switch to focal follow mode. These sightings were categorised as incidental observations and not part of the distribution scan data unless they were observed during a distribution scan.

The following standards were set for the collection of fix points:

A fix point was taken when the target for the theodolite cross hairs was at the waterline and the object was at the bottom of a swell. The cross hairs were aimed at different positions depending on the tracked object. It was aimed at the head region for southern right whales, the blow or the body for humpback and Bryde's whales, leading individual within a group of dolphins, and the bow of the vessels.

The following data were collected during focal follows at each fix:

- Time (of the theodolite file)
- Observation number (file number from the theodolite)
- Track group number
- Cue: B (Body) BL (Blow) BR (Breach) SP (splash) F (fluke print, slick)
- Species: Be, Ea, Mn, Ta, Sc, Other whales, Other dolphins, Vessel, WWV
- Group size; minimum, best, max
- Surface behaviour: S (Social), T (Travelling), R (Resting/Logging), F/D (Foraging/Dive), O (Other)
- Dispersion: B (Bunched), SG (Sub groups), D (Dispersed)
- Comments

TABLE 2 SURFACE BEHAVIOUR CATEGORIES FOR BALEEN WHALES BASED ON THOMAS AND TABER (1984) AND LUNDQUIST ET AL (2012)

State	Definition
Socializing	Whale is engaging with at least one other individual. Touching, rubbing, rolling, or other interactive action (*see below for SAG and cc-pairs for southern right whales).
Travelling	Whale moving directionally forward from a location to a new location. Leaving flukeprints behind at the water surface.
Resting / Logging	Whale stays motionless at the surface or close to the surface in the same location. Mainly moving to breathe. Might be drifting with current.
Other	Arching, Feeding, Tail or pectoral flipper slapping, Playing with kelp, Breaching.

TABLE 3 SURFACE BEHAVIOUR CATEGORIES FOR SOUTHERN RIGHT WHALES

Southern right whales Socializing	Socializing was categorized according to the type of animals engaged in the activity. The group name described the group composition.
SAG	Surface Active Groups (SAG) are defined as two or more adult animals interacting at the surface, less than one body length apart and with frequent physical contact (Kraus and Hatch 2001)At least one focal animal was given the most attention and other animals (non-focal animals) in the group would try to get close to the focal individual. Agitated surface activity involving rolling, spy-hopping, bubble blowing, enforced blows, flipper, and tail slapping. The focal animal is typically female and non-focal animals are males (Best et al. 2003, Parks et al. 2005)
Cow/calf-pair	Cow and the calf were interacting with each other or other cc-pairs. Interactions involved rolling, spy-hopping, flipper slapping, tail slapping, and calf rolling on the back or belly of the cow. (Thomas and Taber 1984)

TABLE 4 SURFACE BEHAVIOUR CATEGORIES FOR DOLPHIN SPECIES BASED ON LUSSEAU (LUSSEAU 2004, LUSSEAU AND HIGHAM 2004)

State	Definition
Foraging / Diving	Dolphin(s) exhibit "steep dive", arching to increase the speed of descent and potentially porpoising at the surface when chasing prey. Direction movements varies. Individuals dive synchronously for long periods. Maybe visible fish leaping out of water surface.
Socializing	Dolphin(s) exhibit many different behaviours. Body contacts, breaching, tail slapping, white belly visible under other individuals, individuals changing positions in the group and short time spend under the surface.
Travelling	Dolphin(s) moving steadily in a roughly constant and straight direction. Swimming with relatively constant dive intervals.
Resting / Logging	Dolphin group is tight together. Group slowly swim in same direction, turn and swim in the opposite direction, still close together.
Other	Surfing in waves, bow riding.

In 2014 positional fixes were collected as follows; every 5 minutes for southern right whales, at least every 2 minutes for dolphin species, and whenever cues were visible for humpback whales and Bryde's whales. Positional fixes in the previous years were taken more frequently and adjusted for over–sampling in the data preparation and filtration (see data analysis).

4.5.6 SURFACE BEHAVIOUR IN WHALES

The following behaviour categories were used to identify the surface behaviour of the baleen whales see Table 2 and 3. Observations of the behaviour of single individuals was categorised according to Table 2. Behaviour category was assigned based on the behaviour of the focal animals, when more than one animal was observed in a group was hence only assigned one behaviour type. The behaviour observations of cc-pairs were primarily based on the behaviour of the cow, due to the visual advantage of the size of the cow.

4.5.7 SURFACE BEHAVIOUR IN DOLPHINS

The following behaviour categories were used to identify the surface behaviour of the dolphin species, (Table 4).

4.6 Analysis

4.6.1 EFFORT

To investigate and provide a reference of the distribution of the effort spent in the field, the following were calculated; duration of total hours of effort per day, time of the day, and monthly distribution per year.

4.6.2 DATA PREPARATION AND FILTERING

To investigate the temporal distribution, spatial distribution, spatial behaviour patterns, and focal follows of the six observed cetacean species, only observations made during scan periods of good visibility, no precipitation, and sea state <5 (Thiele et al. 2000), were included in the analysis of right, humpback, and Bryde's whales. Scan observations of dolphin species were only included when obtained at sea state ≤2 (Whitehead 1999, Reeves and Brownell 2009).

Land-based theodolite tracking from the water tower.

PHOTO CREDIT
HARRY STONE

4.6.2.1 Temporal distribution

Data from the distribution scans were used to investigate the seasonal pattern of the cetacean species. To account for variable search effort, sighting rate was calculated for each species as the total number of sightings per month divided with the total number of scans conducted in all years per month, yielding the unit: sightings/hour of scanning per month.

4.6.2.2 Spatial analysis

Positions of animals recorded during distribution scans were used to investigate the spatial distribution of the cetacean species using (VADAR 2014). The sighting locations and associated data from the distribution scans were imported into QGIS 2.8.1 and ArcGIS 9.8, projection UTM 34S, datum WGS84. The study area was overlaid with a 1 km x 1 km grid and the coordinates of the sightings of each species were plotted in the grid. Number of sightings per grid cell was calculated as points in polygons and the sum of sightings per grid cell.

4.6.2.3 Behaviour analysis

The sightings from the distribution scans were used to investigate the spatial distribution of different behaviour types of the cetacean species. The coordinates of the sightings were plotted in QGIS 2.8.1 and ArcGIS 9.8, projection UTM 34S, datum WGS84, overlaid with a 1 km x 1 km

grid and the observations of each species were filtered for behaviour. Species with more than 100 behaviour sightings were also plotted as empirical heat-maps in QGIS 2.8.1 with a radius of 1000 m, 2000 rows, and a Quartic (biweight) kernel shape, with high density represented in blue, less density areas in light blue, and low density areas in light yellow.

4.6.2.4 Focal follow

To investigate the swimming speed, reorientation, and linearity the fix points of focal follow groups were analysed. Table 5 provides an overview of the calculations performed for each species.

In preparation of the data for analysis it was important to ensure a standard frequency of fix recordings across the entire dataset, hence surplus fix points were removed and the dataset manually adjusted. The standard followed the data collected in 2014 with 2 minutes (dolphin species) and 5 minutes (southern right whales) time intervals between fixes. For all species the following criteria were applied in processing focal follow tracks: Estimated positions were omitted from the track calculations and obvious clerical errors in fix point positions were discarded. Following the data analysis method of Barendse and Best (2014) a track consisted of a minimum of three fix points. Additionally, species-specific selection criteria to the focal follow tracks as follows.

4.6.2.5 Inshore dolphin species

Fix points of focal follow tracks of the two inshore dolphin species were oversampled and hence adjusted to meet the criteria of minimum three fix points and with 2 minutes' time intervals between fixes. If a track had surplus fixes, this track was manually adjusted by removing surplus fix points. For example, if fix points were made at 10:02:01, 10:03:44, 10:04:14, 10:04:55, 10:05:30, and 10:06:15, the adjusted track would consist of the fix points: 10:02:01, 10:04:14, and 10:06:15. If there were longer than 2 minutes between fixes for example when animals were submerged, then the fix point when the animal resurfaced was used as the next fix point and every 2 minutes from then onwards.

4.6.2.6 Bryde's whales

The behaviour of this species made it challenging to ensure consistent focal follows of individual Bryde's whales, animals had a short surface time, long dive intervals, and highly unpredictable resurfacing position and were often a long distance from shore. Only scan positions of this species were used and sightings with more than one adult individual in the same area (for example close to Dyer Island) were categorised as an aggregation of Bryde's whales.

4.6.2.7 Humpback whales

Most humpback whale groups are a long distance greater than 5 km from shore and the focal follow tracks were not reliable regarding swimming speed, but it was possible to determine the overall travelling direction by using only the first and last fix point in the tracks (a track consisted of more than three fix points and lasting longer than 10 minutes).

4.6.2.8 Southern right whales

The longest track of the day of each of the group types: cc-pair, SAG, and unaccompanied whales was included in the analysis and a track should consist of three or more fix points and last longer than 10 minutes and with 5 minutes' time intervals between fixes. If a track had surplus fixes, this track was manually adjusted by removing surplus fix points. For example, if fix points were made at 8:34:01, 8:35:02, 8:37:55, 8:38:35, 8:40:08, 8:42:15, 8:43:35, 8:44:45, 8:45:05, 8:45:20 the adjusted track would consist of the fix points: 8:35:02, 8:40:08, and 8:45:05. If there were longer than 5 minutes between fixes for example when animals were submerged, then the fix point when the animal resurfaced was used as the next fix point and every 5 minutes from then onwards.

TABLE 5 OVERVIEW OF THE CALCULATIONS PERFORMED FOR EACH SPECIES

Species	Leg speed (km/h)	Reorientation Rate	Linearity	Other
	Net speed	Degrees/min	Net distance	
Bryde's whales	No	No	No	Fix point during distribution scan
Humpback whales	No	No	No	Fix point during distribution scan First and last position, to determine travelling direction
Southern right whales	Yes	Yes	Yes	
Indo-Pacific bottlenose dolphins	Yes	Yes	Yes	
Indian Ocean humpback dolphins	Yes	Yes	Yes	
Common dolphins	Yes	Yes	Yes	

Tracks contained all types of behaviour, but all the adjusted tracks were manually reviewed and sections within the tracks consisting of 3 or more fix points with 5 minute intervals where the group was only travelling, were included in a separate analysis to investigate the swimming speed.

Three movement parameters were calculated for all species except Bryde's and humpback whales; leg speed, reorientation rate, and linearity. Leg speed (net speed) is the distance between two successive points divided by the time interval. Reorientation rate (degrees/minutes) is how much a group changed course over time. The sum of absolute values of heading changes (0 to 180 degrees relative to current bearing). Linearity is the net distance from the first fix point to the last fix point divided by the sum of all the distances for each leg (from 0 to 1).

4.6.3 COMPARISON BETWEEN WWV-DATA AND THEODOLITE OBSERVATIONS

A total of 44 days with theodolite observations and registered encounters form the WWV was available from 2011 and 2012 (16 days in 2011 and 38 days in 2012). Only one trip conducted by the WWV and one scan conducted from the theodolite station was used per day. The time of the WWV trip and the theodolite scan was matched where possible, for example if the WWV trip was conducted from 10.15 to 12.30 the theodolite scan from 11.00 was included in the analysis for that day. The total number of sightings per day of each cetacean species from each platform was calculated and number of sightings compared.

4.7 Results

4.7.1 EFFORT

The total effort comprised an accumulated observation time of 1558 hours and 26 minutes distributed over 270 days from 24 August 2011 to 11 December 2014. The duration of on-effort hours per day (observation periods) ranged from a minimum of 25 minutes to a maximum of 11 hours and 20 minutes (Figure 5A). The duration of each "on-effort days" was between 3 and 6 hours in 68% of the days on effort (Figure 5A). A total number of 1204 were conducted and 1175 scans were conducted at sea state < 5; 82% of these scans were conducted between 8:00 and 14:00,

TABLE 6 THE TOTAL NUMBER OF SCANS CONDUCTED PER MONTH EACH YEAR FROM 2011-2014

	2011	2012	2013	2014	Total
January	0	0	36	0	**36**
February	0	0	44	0	**44**
March	0	0	43	0	**43**
April	0	0	54	0	**54**
May	0	14	60	0	**74**
June	0	72	51	9	**132**
July	0	34	52	0	**86**
August	16	82	36	35	**169**
September	29	63	54	51	**197**
October	0	53	36	20	**109**
November	53	58	31	33	**175**
December	15	12	20	9	**56**
Total	113	388	517	157	**1175**

Marianne Cannon working with the theodolite tracking program VADAR.

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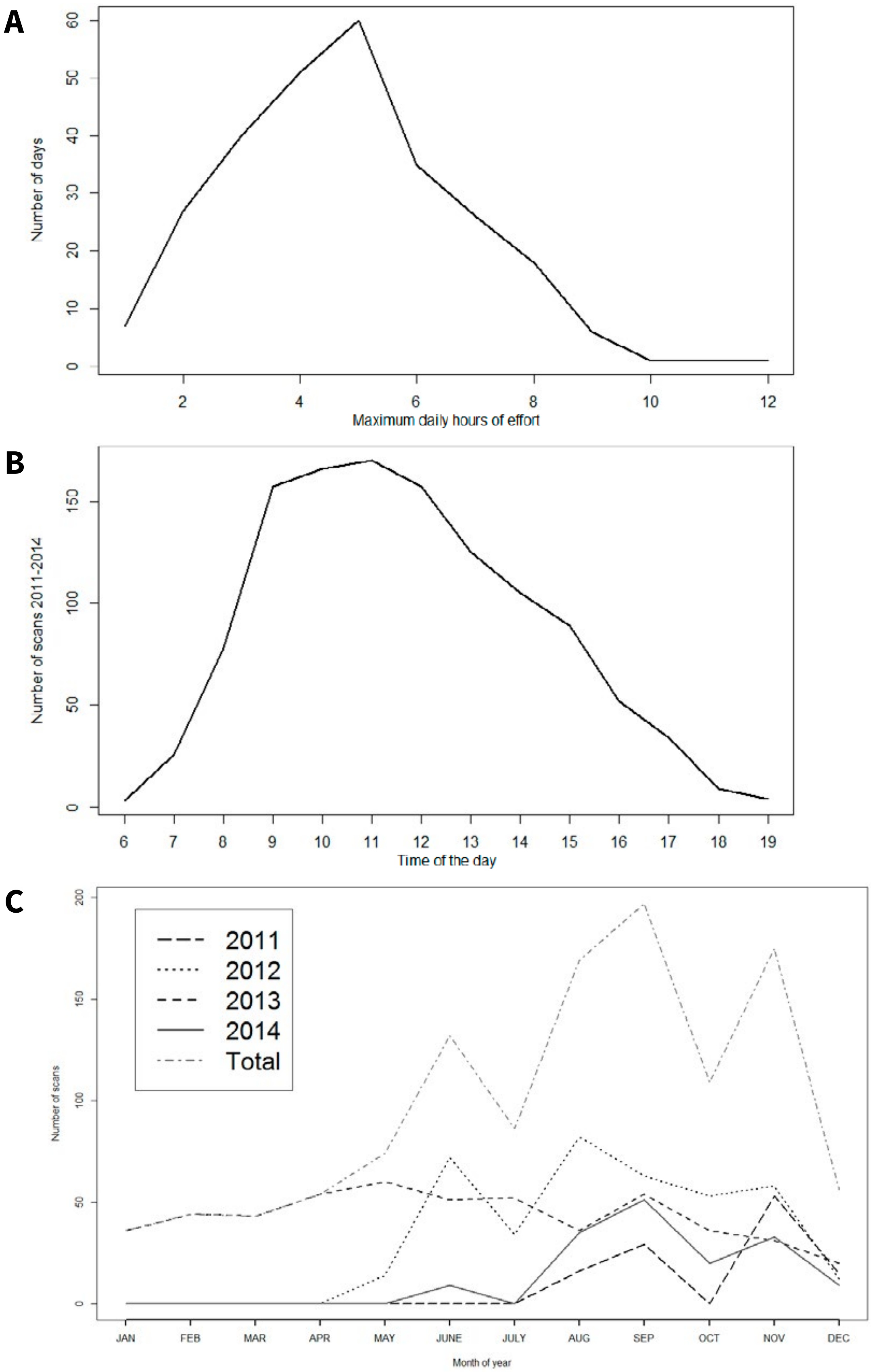
FIGURE 5
A. Distribution of daily search duration at sea state <5 for the entire study period (2011 – 2014).

B. Distribution of search scans effort at sea state <5 as a function of time of the day.

C. Monthly distribution of scans at sea state <5 from 2011 – 2014.



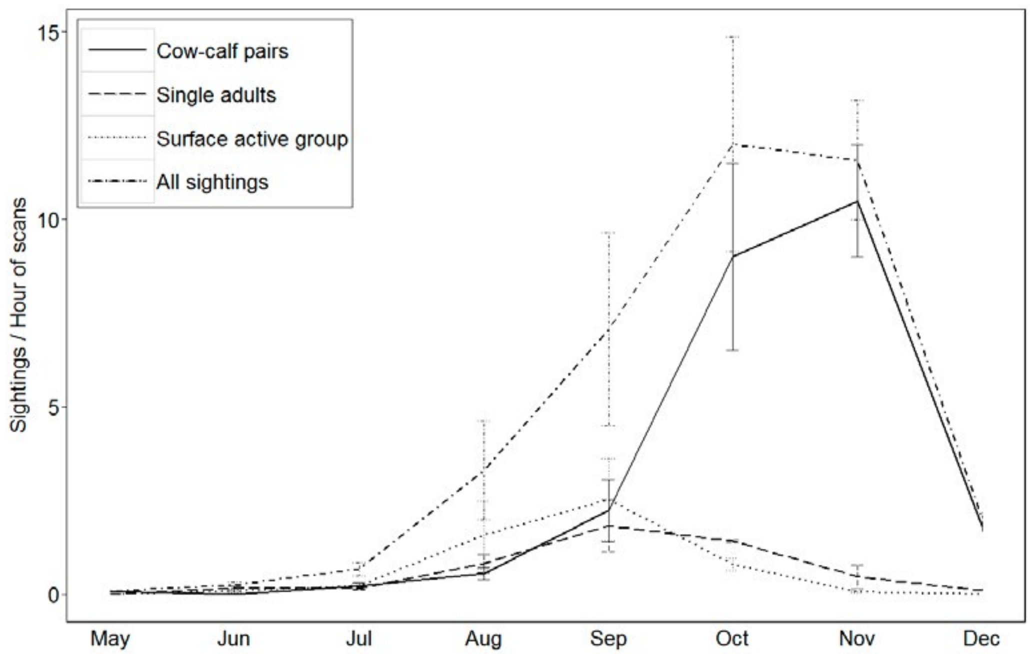


FIGURE 6
Temporal distribution in the Greater Dyer Island area of southern right whales (2011 – 2014) per daily scan per month (across all years) at sea state <5.

Error bars represent standard deviation.

where 55% of scans conducted at sea state < 5 were conducted between 9:00 and 12:00 (Figure 5B). The monthly distribution of effort is shown in Figure 5C. The distribution of scans was not uniform over months, as the majority of scans were obtained from May to December. The total number of scans conducted per year for each month is provided in Table 6.

4.7.2 TEMPORAL DISTRIBUTION PATTERNS OF CETACEAN SPECIES

Six different cetacean species were observed in the area; southern right whales, humpback whales, Bryde's whales, Indian Ocean humpback dolphins, Indo-Pacific bottlenose dolphins, and common dolphins. By far the most frequently sighted species was the southern right whale. The monthly sighting rate is shown in Figure 6. The right whales exhibited clear seasonality with no sightings from January to May and a peak in occurrence in October and November. The majority of groups observed were cow calf pairs, completely dominating the months of November and December. Surface active groups (SAGs) and unaccompanied whales (UAs) peaked from August to October. Humpback whales and Bryde's whales exhibited marked seasonality peaking in June – August and December – April, respectively (Figure 7) and a clear seasonality was apparent for the two main inshore dolphin species which were primarily observed in the summer months (December – February) (Figure 8). On six days both Indo-Pacific bottlenose dolphins and Indian Ocean humpback dolphins were sighted simultaneously (in March, April, May, and July).

4.7.3 SPATIAL DISTRIBUTION

4.7.3.1 Southern right whales

A total of 685 sightings of southern right whales were made, making it the most dominant species in the area. The maximum distance measured from the land stations was 8 km (Figure 9). Spatial distribution of SAGs, cc-pairs, and UAs are shown in Figure 10 with cc-pairs as the most observed group type.

FIGURE 7
Temporal distribution in the Greater Dyer Island area of humpback whales and Bryde's whales (2011 – 2014) per total number of scans at sea state <5. Error bars represent standard deviation.

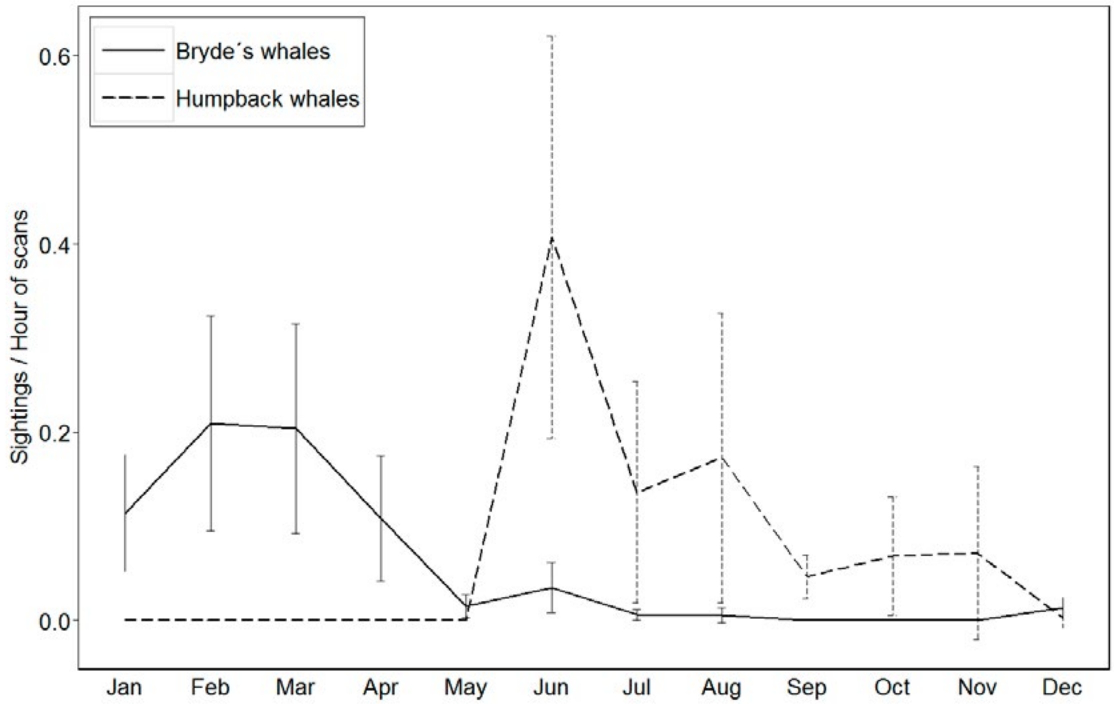
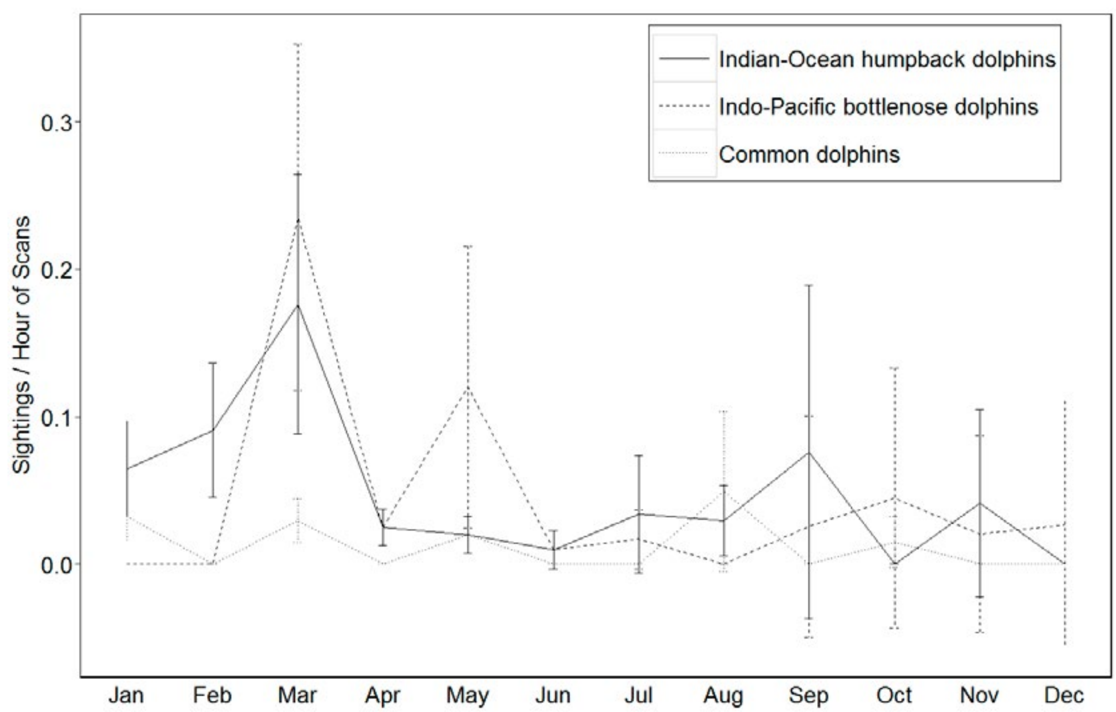


FIGURE 8
Temporal distribution in the Greater Dyer Island area of the three dolphin species (2011 – 2014) per total number of scans at sea state ≤ 2. Error bars represent standard deviation.



4.7.3.2 Humpback whales

A total of 51 sightings of humpback whales were distributed across the entire study area, at a maximum distance of 16.5 km from the land stations (Figure 11).

4.7.3.3 Bryde's whales

A total of 45 sightings of Bryde's whales were distributed across the entire study area, at a maximum distance of 13 km from the land stations (Figure 11). Most sightings were single or pairs of individuals but one aggregation of a maximum of eight Bryde's whales were observed, on 22 December 2013.

4.7.3.4 Dolphin species

A total of 21 sightings of Indian Ocean humpback dolphins, 18 sightings of Indo-Pacific bottlenose dolphins, and 3 sightings of common dolphins were collected. Common dolphins were generally observed further off shore than the two other dolphin species, which were recorded within 1 km from the coastline (Figure 12). Because of the low number of sightings of common dolphins, they were regarded as occasional visitors (Figure 12). The Indian Ocean humpback dolphin exhibited a preference for the sandy bays instead of the area with kelp forest and reef along the shore. This preference was not as pronounced for the Indo-Pacific bottlenose dolphins (Figure 12).

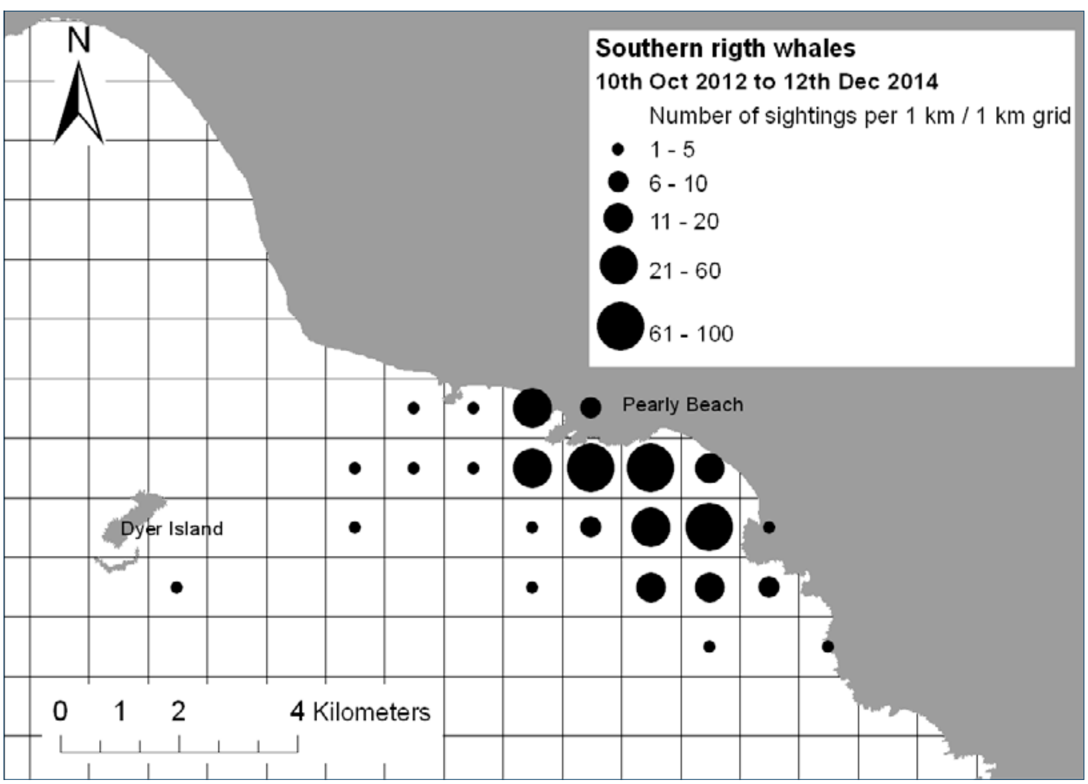
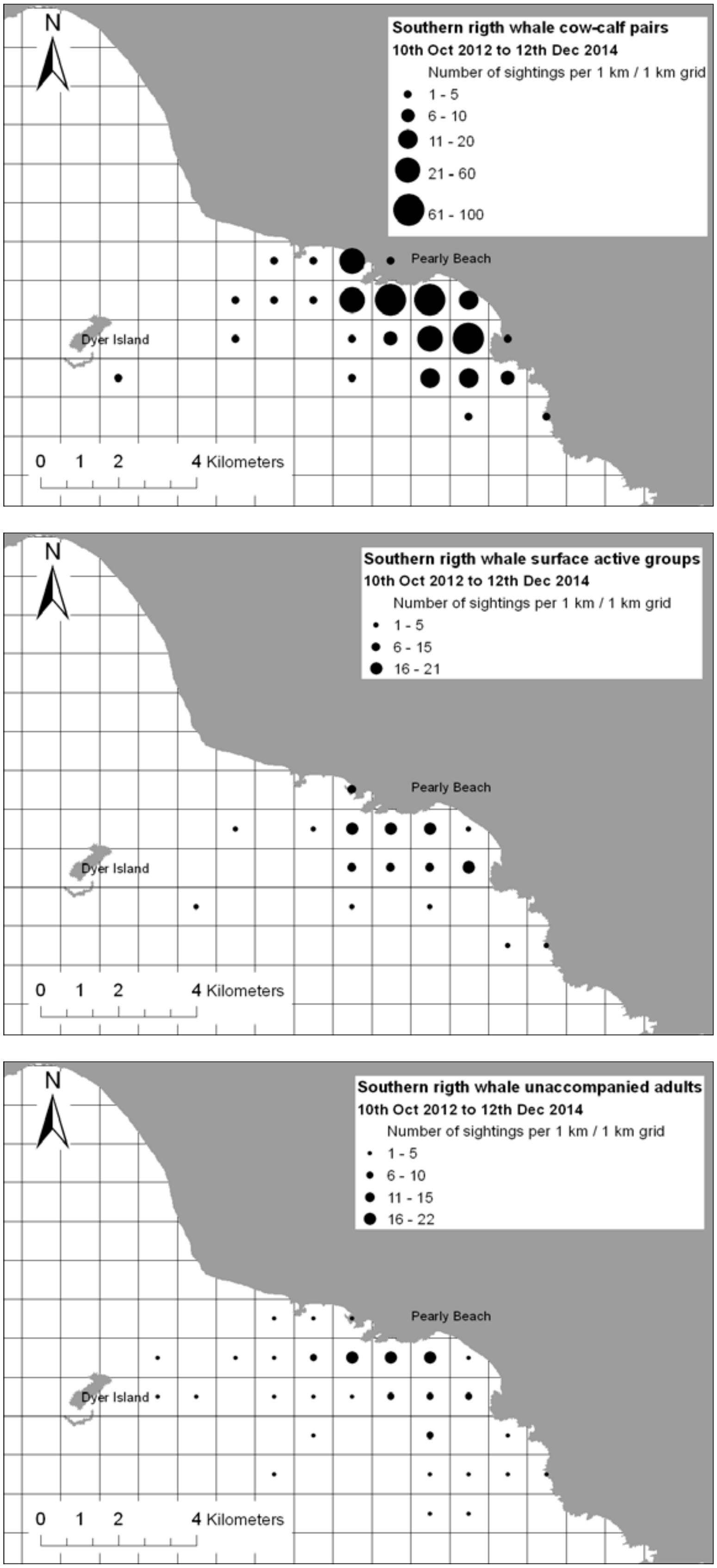
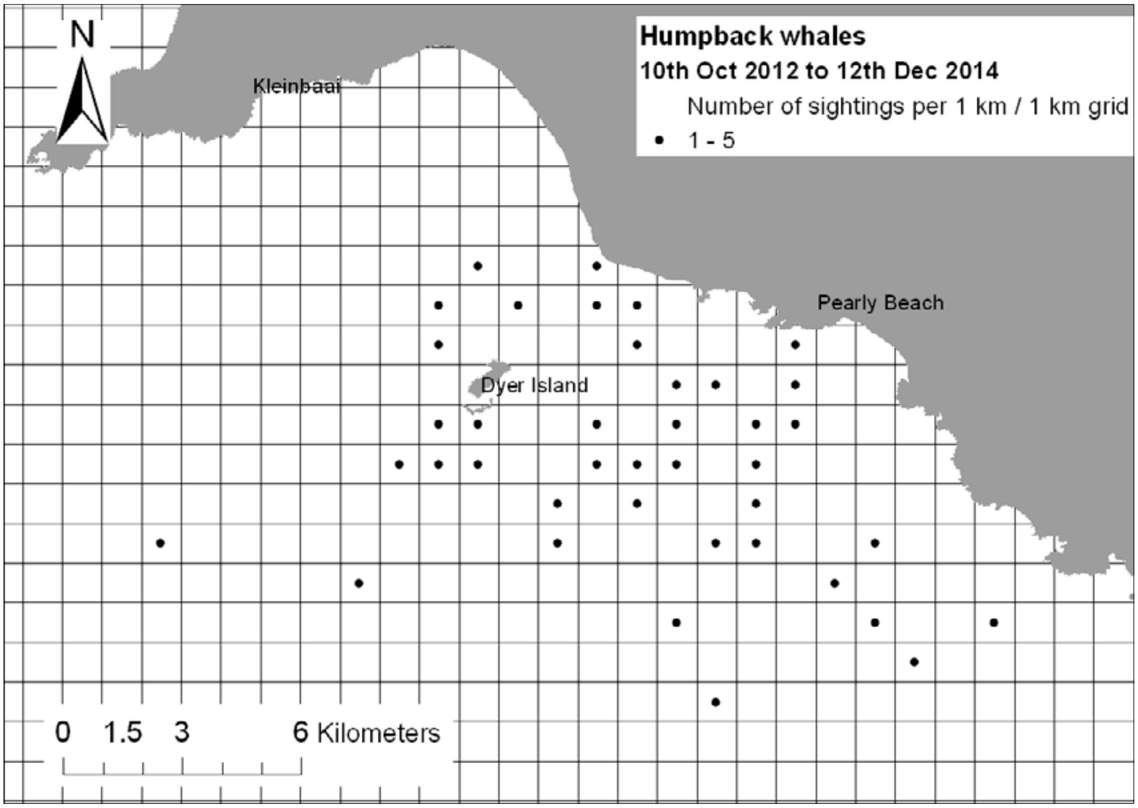


FIGURE 9 Spatial distribution of southern right whales for the study period.

FIGURE 10
Spatial distribution of southern right whale cow-calf pairs, surface active groups, and unaccompanied adults for the study period.





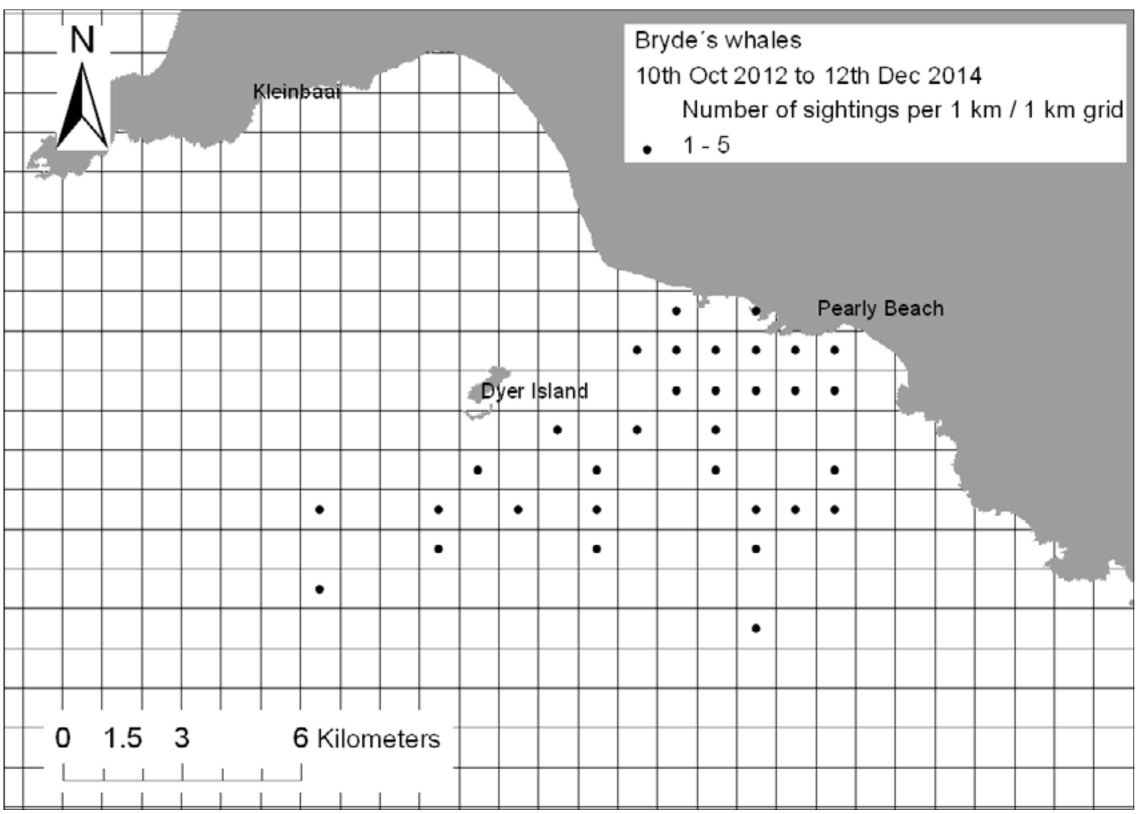
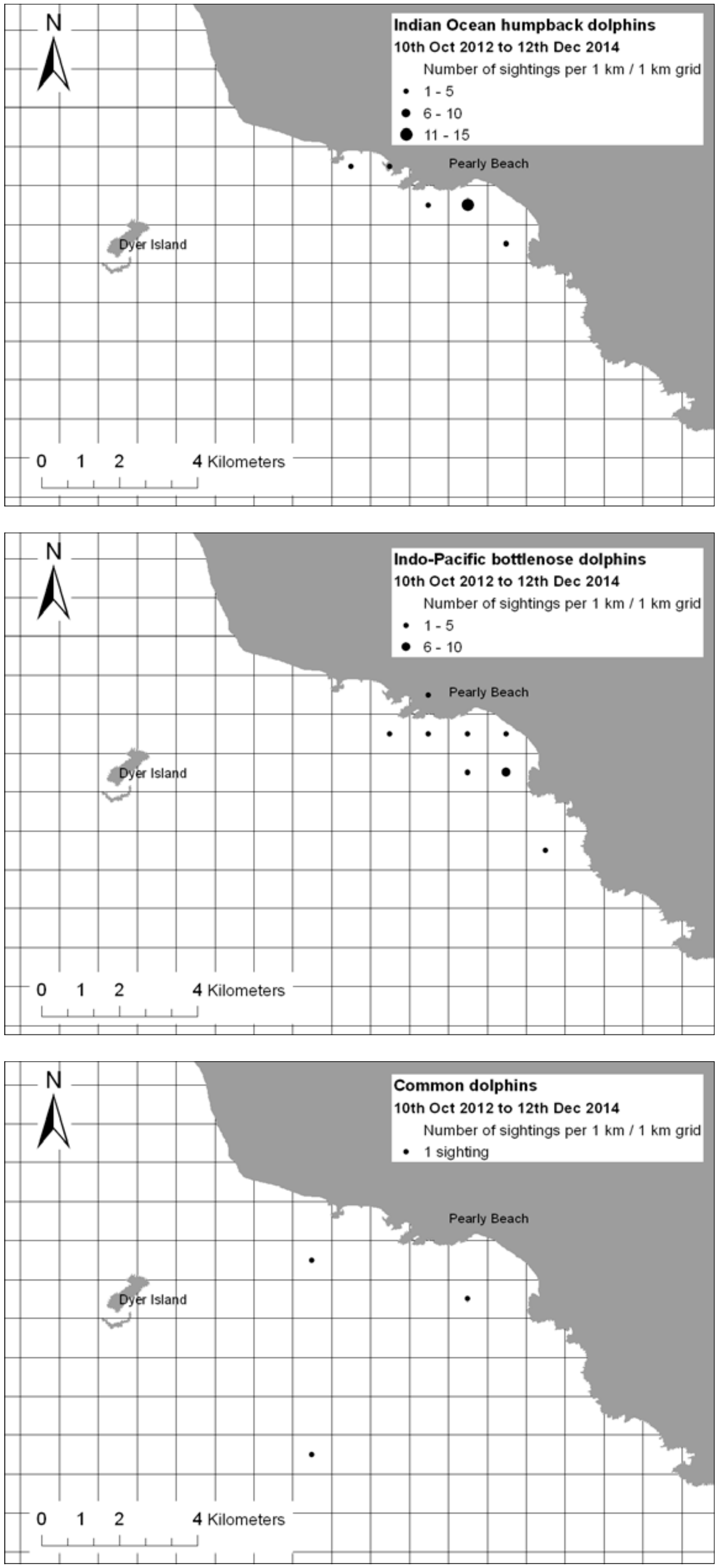


FIGURE 11
Spatial distribution of humpback whales and Bryde's whales for the study period.

FIGURE 12
Spatial distribution of the three dolphin species for the study period.



Collecting samples and measurements of a stranded southern right whale calf.

PHOTO CREDIT
HARRY STONE

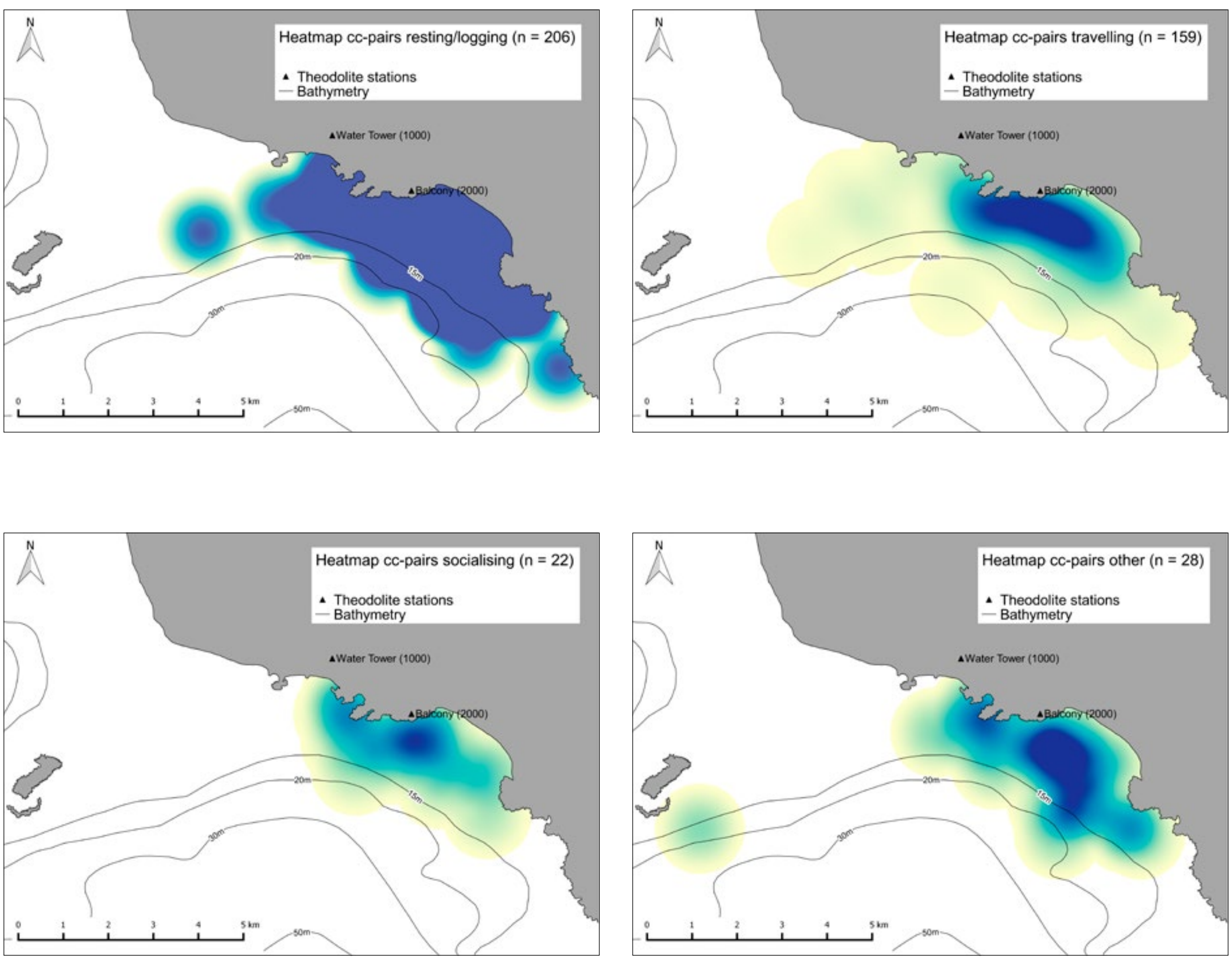
4.7.4 BEHAVIOUR

4.7.4.1 Southern right whales

The only species with more than 100 behaviour sightings was the southern right whale. Heat-maps were plotted for all four behaviour categories. The two main behaviours exhibited by cc-pairs were travelling and resting/logging, where resting/logging was the most dominating behaviour. Socialising and other was least observed (Figure 13).

The dominating behaviour of the SAGs was socialising, which was observed in the inshore area of the survey area (Figure 14). Resting/logging and travelling were the main two behaviours exhibited by the unaccompanied adults. There was no clear difference between the spatial patterns of the different behaviour categories (Figure 15).

FIGURE 13
Heat-maps of surface behaviour of southern right whale cc-pairs.
Where high density areas are represented in blue and low density areas in light yellow.



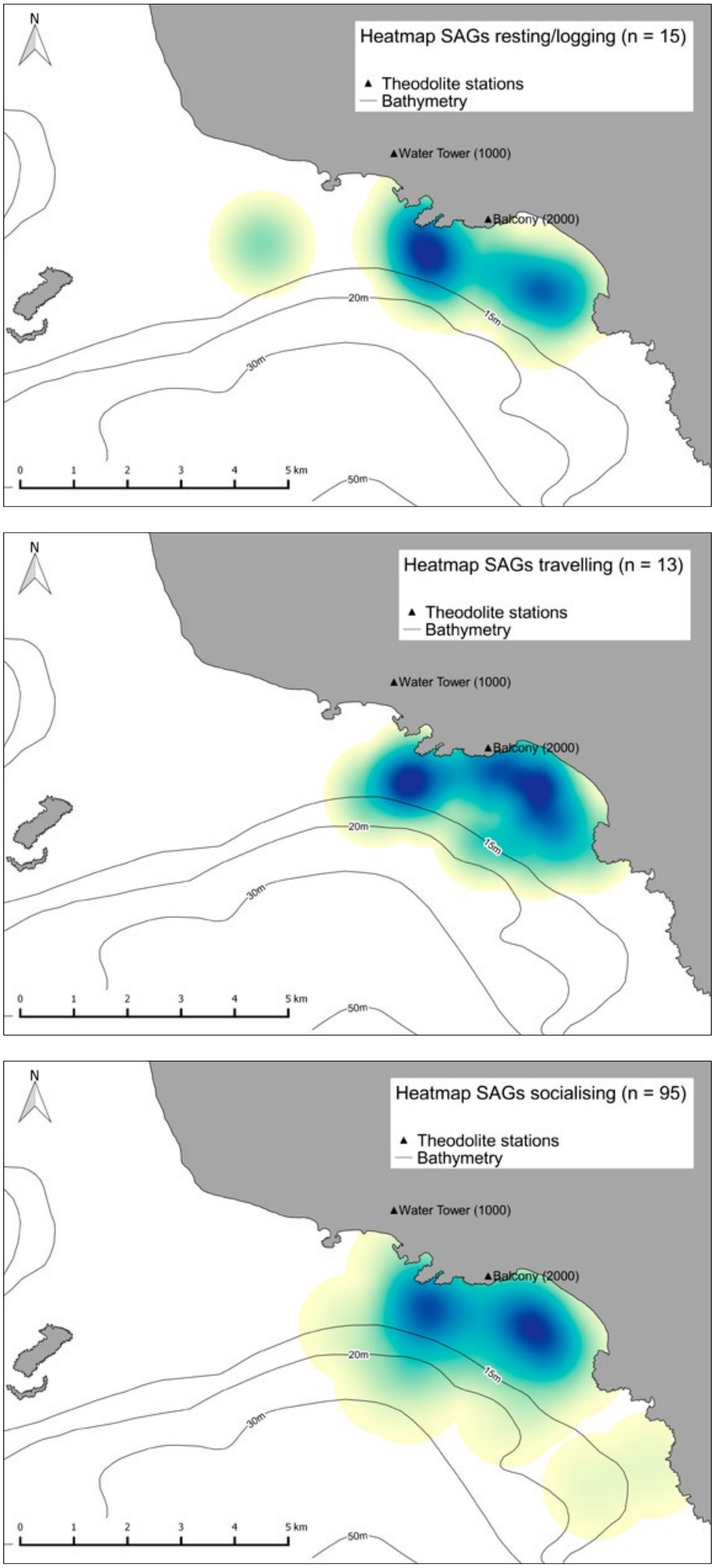
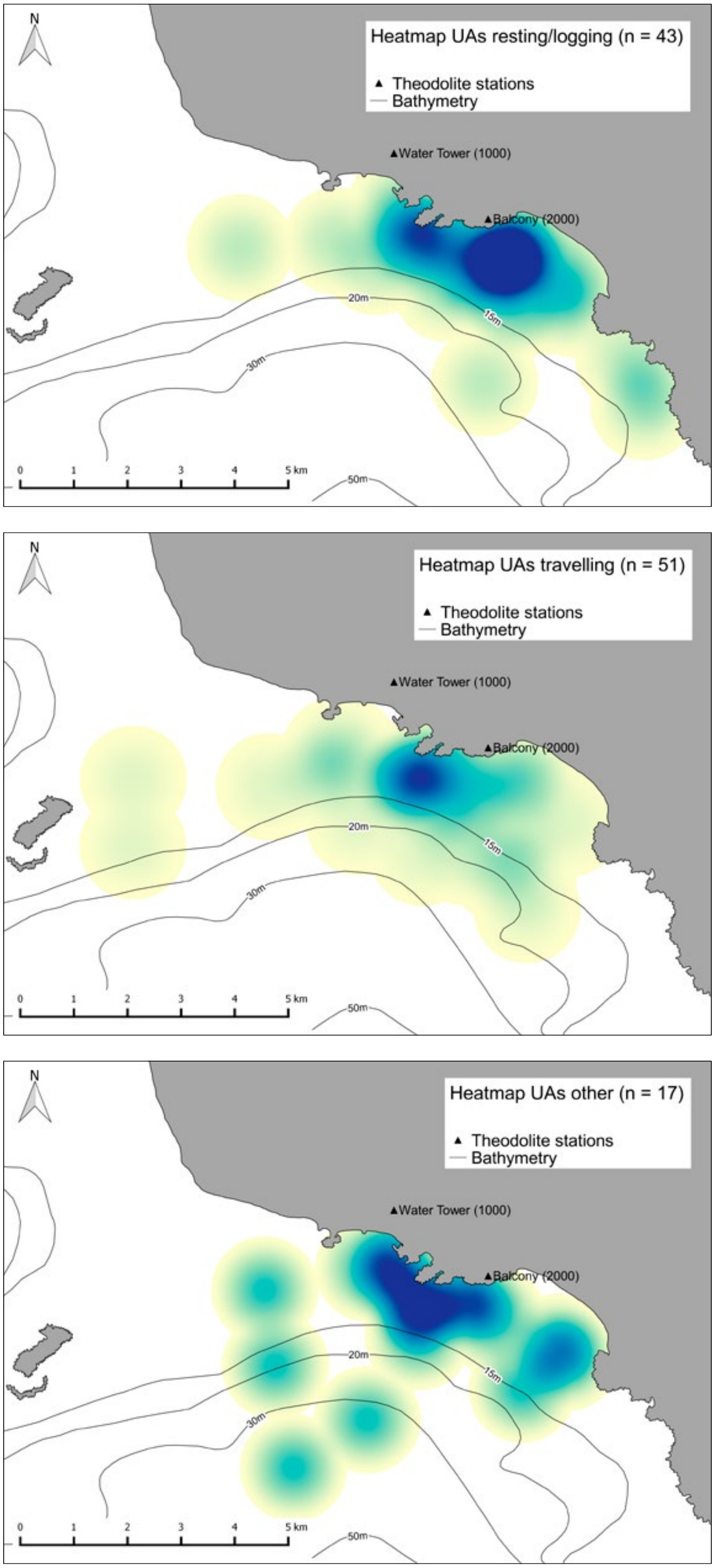


FIGURE 14
Heat-maps of surface behaviour of southern right whales surface active groups. Where high density areas are represented in blue and low density areas in light yellow.

FIGURE 15
Heat-maps of surface behaviour of southern right whales unaccompanied adults. Where high density areas are represented in blue, and low density areas in light yellow.



4.7.4.2 Bryde's whales and humpback whales

There were no clear patterns of the Bryde's whales' behavioural use of the area (Figure 16). All types of behaviour were observed across the entire survey area.

The primarily observed behaviour of humpback whales was travelling. Socialising was observed three times (Figure 16).

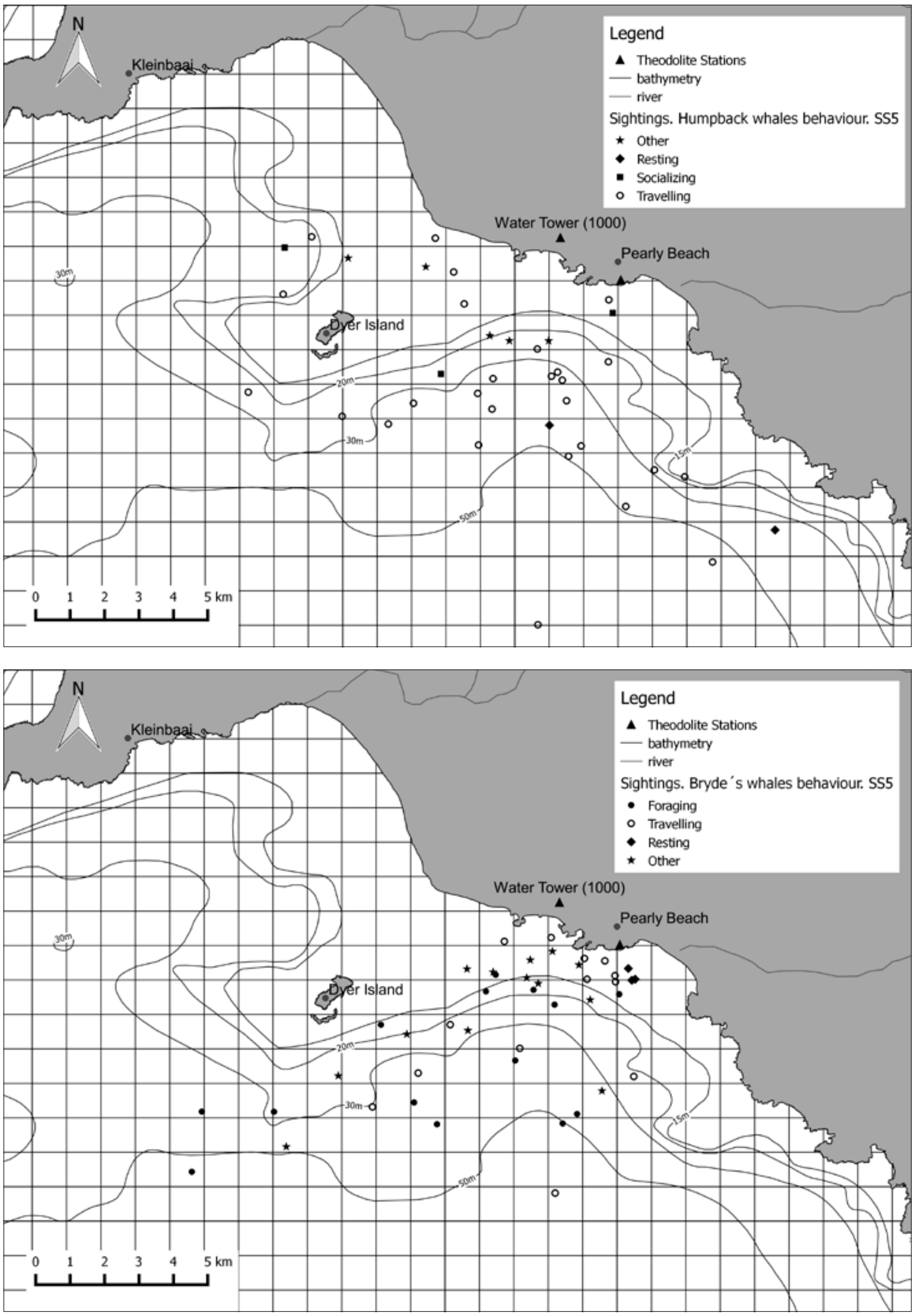
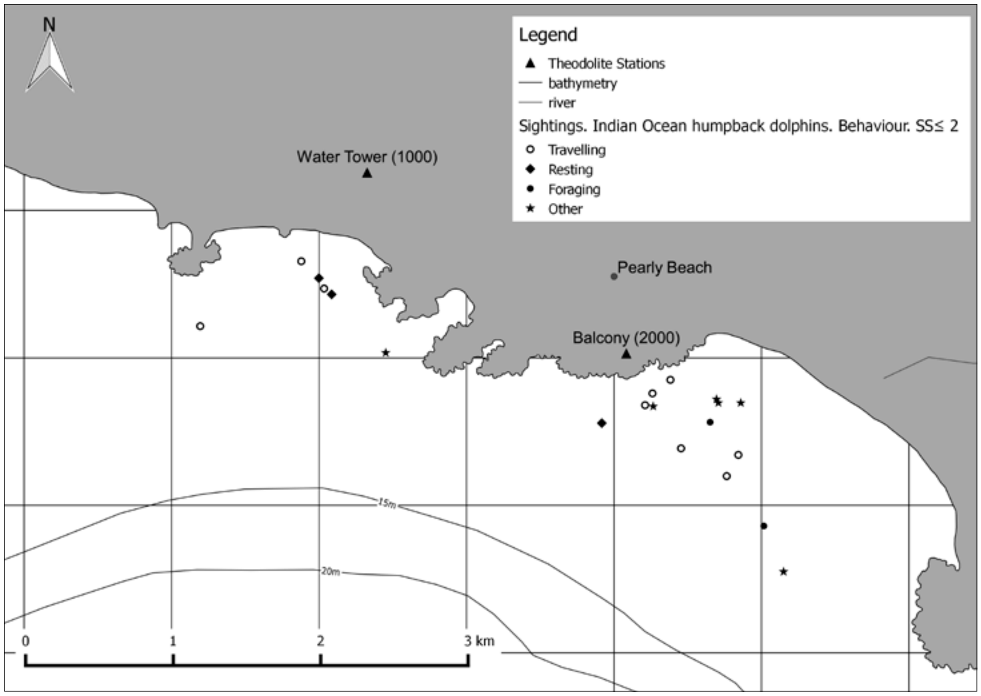


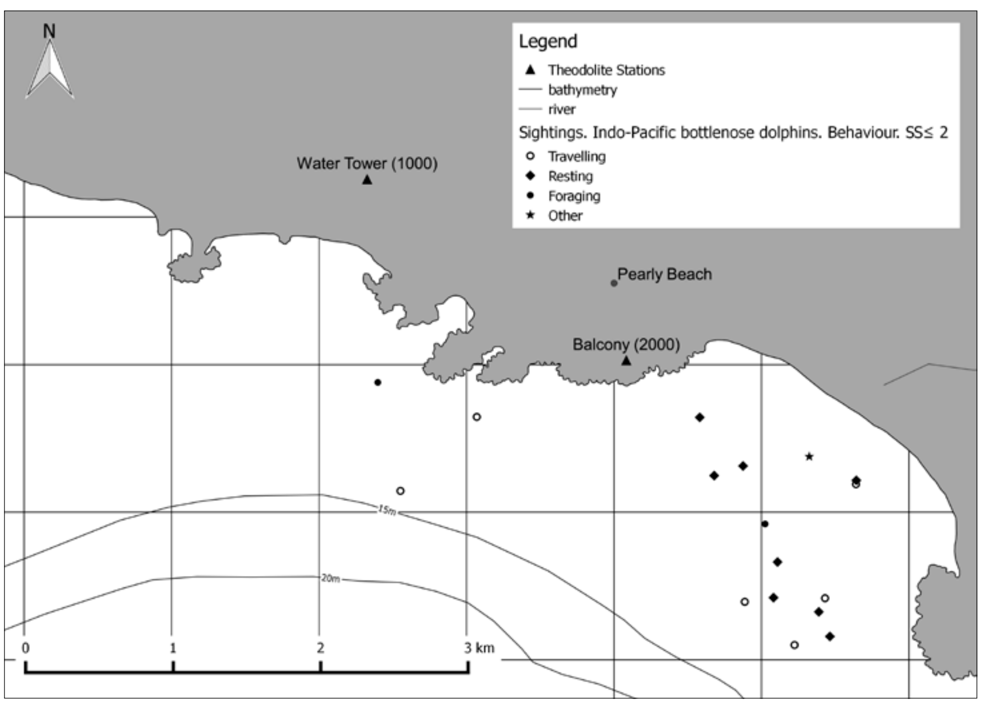
FIGURE 16
Spatial distribution of surface behaviour of humpback whales and Bryde's whales.

4.7.4.3 Dolphin species

The two inshore dolphin species were mainly observed in the bay areas where all four defined behaviours were observed. There were no clear trends in behavioural patterns, but the Indo-Pacific bottlenose dolphins used the large bay area at Pearly Beach for resting in 7 out of 13 sightings (Figure 17).

FIGURE 17
Spatial distribution of surface behaviour of Indian Ocean humpback dolphins and Indo-Pacific bottlenose dolphins.





4.7.5 FOCAL FOLLOWS

The fine scale movements of southern right whales and inshore dolphin species were investigated using the focal follow tracks. Table 7 is an overview of the total number of tracks of each group type per year.

4.7.5.1 Southern right whales

The longest track from each field day from 2011 to 2014 of each of the three main group categories was included in the analysis, providing a total of 247 tracks: 121 tracks of cc-pairs, 83 tracks of SAGs, and 43 tracks of UAs (Table 7).

The longest focal follow was a cc-pair lasting 5 hours and 54 minutes, and the shortest was an unaccompanied adult lasting 13.5 minutes. Average tracking duration was 63.87 minutes ± 69.41 minutes (SD). Table 8 provides an overview of measured leg speed, re-orientation rate, linearity, slowest leg speed (km/h), fastest leg speed (km/h), longest track (m), shortest track (m), shortest distance of track (m), and longest distance (m), from 2011 to 2014. Table 9 provides an overview of the focal follow tracks containing solely travelling behaviour, measurements were the same as mentioned for the data in Table 8.

4.7.5.2 Humpback whales

A total of 48 tracked humpback whales were included in track line analysis. Of these, 35 showed a clear travelling direction, of which 28 (80%) were travelling south-east towards Cape Agulhas.

TABLE 7 THE TOTAL NUMBER OF TRACKS INCLUDED IN THE ANALYSIS, OF EACH GROUP TYPE (OF SOUTHERN RIGHT WHALES) PER YEAR

	All behaviours				Solely travel behaviour			
Year		**CC-pairs**	**SAG**	**UA**		**CC-pairs**	**SAG**	**UA**
2011	28	12	11	5	25	17	4	4
2012	91	47	29	15	49	31	5	13
2013	84	39	25	20	39	26	5	8
2014	44	23	18	3	-	-	-	-
Total	**247**	**121**	**83**	**43**	**113**	**74**	**14**	**25**

TABLE 8 OVERVIEW OF FOCAL FOLLOW TRACKS OF ALL SIX SPECIES, ALL YEARS (2011-2014)

ALL YEARS 2011–2014	**Leg speed (km/h)**	**Reorientation Rate**	**Linearity**	**Slowest leg speed (km/h)**	**Fastest leg speed (km/h)**	**Shortest track (min)**	**Longest track (min)**	**Shortest distance (m)**	**Longest distance (m)**
Southern right whale CC-pairs (n = 121)	1.15 ± 1.13	9.52 ± 6.44	0.50 ± 0.28	0.2	4.3 (11.2)	11.9	459.6	125	7019
Southern right whale SAG (n = 83)	1.00 ± 0.64	7.8 ± 5.85	0.59 ± 0.27	0.3	3.7	11.5	367.1	105	9293
Southern right whale Unaccompanied adult (n = 40)	1.41 ± 1.12	5.93 ± 4.54	0.61 ± 0.32	0.1	5.1	55.3	398.8	3616	7088
Indian Ocean humpback dolphins (n = 17)	2.79 ± 1.66	16.69 ± 10.49	0.52 ± 0.34	0.9	6.3	13.5	130.9	434	6305
Indo-Pacific bottlenose dolphin (n = 19)	5.19 ± 2.20	16.96 ± 13.02	0.59 ± 0.37	1.5	9.3	7.2	304.9	428	19602
Common dolphins (n = 8)	11.96 ± 5.47	14.74 ± 10.93	0.71 ± 0.20	3	17.5	10.7	37.8	1870	7981

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Land-based
theodolite tracking.

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TABLE 9 OVERVIEW OF FOCAL FOLLOW TRACKS OF SOUTHERN RIGHT WHALES USING ONLY TRAVELLING BEHAVIOUR (2011-2013)

	Leg speed	Reorien-tation	Linearity	Slowest	Fastest	Shortest	Longest	Shortest distance	Longest distance
CC (n = 67)	1.63 ± 1.02	6.73 ± 5.58	0.73 ± 0.28	0.2	7	10.5	151.5	58	5114
SAG (n = 13)	1.83 ± 1.00	6.87 ± 4.01	0.77 ± 0.26	0.4	4.7	9.9	91.6	317	1244
UA (n = 19)	2.18 ± 1.39	2.46 ± 2.17	0.88 ± 0.18	0.6	5.1	11.4	99	238	7088

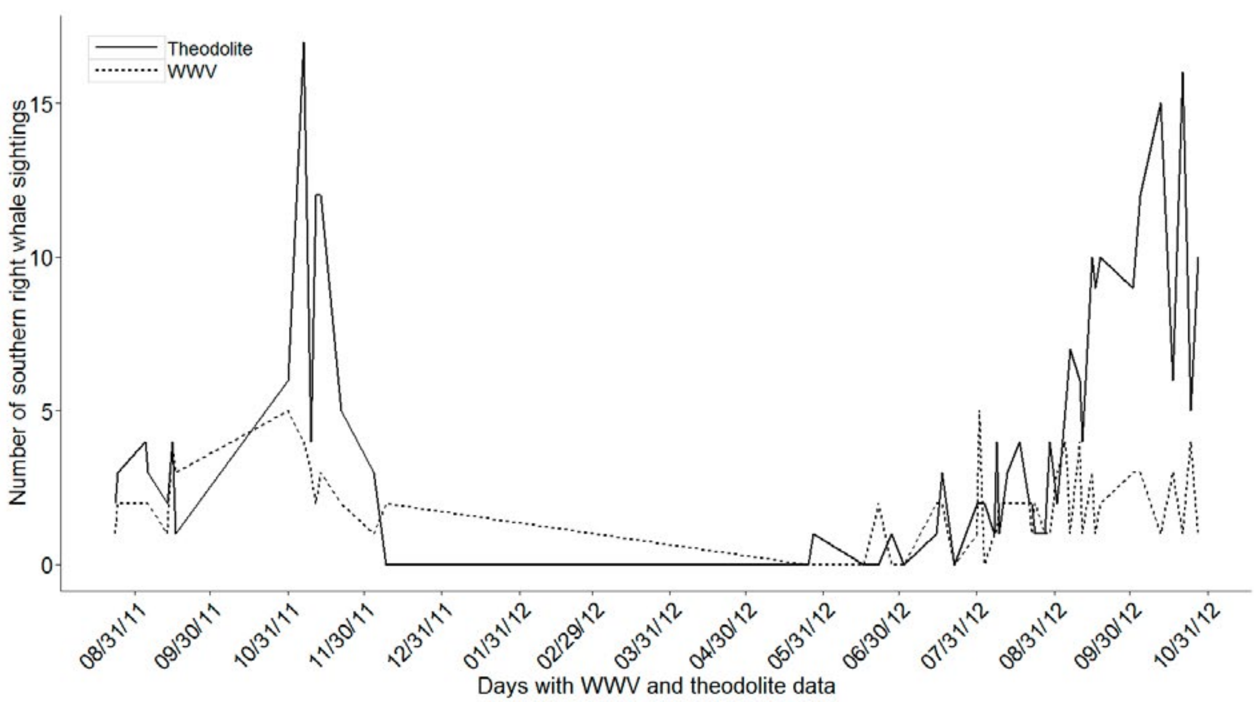
4.7.5.3 Dolphin species

A total of 44 tracks of dolphin species were included in the analysis (collected between 2011 and 2014); 17 tracks of Indian Ocean humpback dolphins, 19 tracks of Indo-Pacific bottlenose dolphins, and 8 tracks of common dolphins. In 2014 only one short track of a group of Indian Ocean humpback dolphins was collected which only consisted of two fix points and hence was discarded.

4.7.6 COMPARISON BETWEEN WWV-DATA AND THEODOLITE SIGHTINGS

It was possible to compare the sightings of southern right whales from the two platforms on 53 days of which sightings of animals were recorded from both platforms on 48 (Figure 18). The total number of sightings from the theodolite station was generally higher than the total number of sightings from the WWV during the months of September, October, and November. The most sightings of right whales from the WWV on one day was five sightings. Sightings of other species were too few to provide any patterns.

FIGURE 18
53 days with sightings of southern right whales collected from both platforms; WWV and theodolite stations.



4.8 Discussion

4.8.1 SEASONALITY AND DISTRIBUTION OF CETACEAN SPECIES

This study found that there were five main cetacean species using the area, which has multi-purpose functions related to the different cetacean species.

4.8.2 SOUTHERN RIGHT WHALES

The southern right whales were by far the predominant species in the area, which was expected. The temporal and spatial distribution of cc-pairs, SAGs, and unaccompanied adults were similar to the results of the WWV-study (Vinding et al. 2015). The change in dominant group type from SAG´s in the beginning of the season to cc-pairs later in the season correspond with previous studies of right whales in South Africa (Best and Scott 1993, Best 2000, Best 2007, Mate et al. 2011). Cc-pairs were the most frequently sighted of the three defined group categories (cc-pairs, SAGs, and UAs), which indicate that it is an important nursing area for this species, especially later in the season (October - December). The large bay area in Pearly Beach, in particular, was the preferred area of the cc-pairs, which corresponds with results from other studies which also found this preference for protected, shallow, gentle sloping sandy bay areas (Thomas and Taber 1984, Elwen and Best 2004*a*, Elwen and Best 2004*b*). The most frequently observed behaviour was resting/logging, which was observed mainly inside the large sandy bay. Travelling was the second most observed behaviour also observed inside the large sandy bay, and socialising was the least observed behaviour. This result is slightly different from Thomas and Taber (1984) who found in their study of cc-pairs in Argentina, that the predominant behaviour was travelling, and the second most observed behaviour was resting/logging. Thomas and Taber (1984) also found that there was a difference in the behaviour of the cows and the calves, with the cows spending more time resting than the calves. The behaviour of the cc-pairs was mainly categorised by the behaviour of the cow in the present study, as they are easier to see than calves. The need for the cow to conserve energy while nursing her calf can explain the observed predominating resting/logging behaviour.

The SAGs were the second most sighted category and they shared the same preferred locations as the cc-pairs, but were more prevalent at the beginning of the season, with the cc-pairs exceeding them in numbers from October onwards. A nursery area has been identified to the area east of the research area in De Hoop Marine Protected Area (Elwen and Best 2004*a*, Elwen and Best 2004*b*), where the majority of the southern right whale cows give birth and nurture their calves in the month of August before they start migrating along the South African coast line towards the west. This can explain the later peak of the cc-pairs in the research area. One of the most crucial factors of the survival of a new born calf is to remain close to the cow which can be why the cows with neonates choose areas with less unaccompanied animals and SAG´s (Elwen and Best 2004). Unaccompanied adults were sighted throughout the right whale season and peaked in September.

All groups of southern right whales were found to be swimming at a speed less than 5.1 km/h which is less than expected as the maximum swimming speed (except one cc-pair in 2013 reaching a speed of 11.2 km/h while in the presence of a whale watching vessel). The swimming speed of cc-pairs in the present study (n = 121) ranged from 0.2 to 4.3 km/h (mean = 1.15 ± 1.13 km/h SE). These results are on a par with other theodolite tracking studies (Best 2000, Hain et al. 2013) as well as speeds estimated using other techniques like large scale photo-ID resightings (Best 2000) and satellite tracking (Mate et al. 2011). The swimming speed of all three right whale group categories was faster when only including travelling behaviour than the focal follow tracks which contained more behaviour categories. Particularly the swimming speed of UA was faster (n= 19), with speed ranging from 0.6 to 5.1 km/h (mean = 2.18 ± 1.39 km/h SE) compared to tracks containing all behaviour categories (n=40) ranging from 0.1 to 5.1 km/h (mean = 1.41 ± 1.12 km/h SE). For cc-pairs (n= 67), the speed ranged from 0.2 to 7 km/h (mean = 1.63 ± 1.02 km/h SE) when solely including travelling behaviour. In the present study, the average swimming speed of all

SAGs (n = 83) ranged from 0.3 to 3.7 Km/h (mean = 1.00 ± 0.64 Km/h SE) and for SAG´s when solely including travelling behaviour (n= 13), the speed ranged from 0.4 to 4.7 km/h (mean = 1.83 ± 1.00 km/h SE). The top speed in both cases are lower than what was measured by Barendse and Best (2014) at the West coast where they found that the actual swimming speed for all groups (n = 57) ranged from 0.2 to a maximum of 7.6 km/h with a mean of 2.71 ± 0.08 km/h SE. Barendse and Best (2014) also found that the swimming speed decreased with increasing group size with an average speed of 3.23 ± 0.144 km/h SE for unaccompanied animals (n = 144) to 1.92 ± 0.135 km/h SE in groups of three or more (n = 73). Interestingly, Mate et al. (2005) showed a significant increase in net speed of off shore southward moving animals ranging from 4.4 – 6.5 km/h and the inshore swimming speeds were markedly different from the individuals (n = 5) tracked off shore with swimming speeds ranging from 2.8 – 3.8 km/h (mean = 3.3 ± 0.37 km/h). This show that the migrating animals are increasing their swimming speed as well as animals feeding off shore (Mate et al. 1997, Barendse and Best 2014). The animals in the present study was in a nursing, and socialising area, which can explain the measured fairly slow swimming speeds, which correspond to inshore swimming speed measured in other studies.

From Mate et al. (2011) satellite tagging study of southern right whales in South Africa, it is known that there is a westward movement of animals (starting at St. Sebastian Bay) throughout the right whale season and that the majority of the cc-pairs are found at De Hoop Marine Protected Area (east of the study site, see Figure 1) early in the right whale season, and slowly move at an average speed of 2.02 km/h ± 1.17 along the coast to areas in the west, such as the study site. Even though there is an overall movement of animals from east to west, it is possible that specific areas on the route are used for specific purposes. The fine-scale study of the behaviour of the animals in Pearly Beach show that the animals spend most of their time resting/logging which could indicate that such protected bay areas are important for this type of behaviour.

This inshore distribution of southern right whales and particularly nursing cc-pairs could make them more exposed to potential human impacts. Current inshore human activities count WWV, shark cage diving, commercial and leisure fishing vessels. It is important that such activities are regulated in order to reduce the potential impacts.

4.8.3 HUMPBACK WHALES

The temporal distribution of humpback whales was similar to the results of the WWV-study (Vinding et al. 2014) with a clear winter peak from June to August and a peak in July. The spatial distribution was also similar with the majority of sightings in the deeper waters. From the present study, it was evident that the most frequently observed behaviour was “travelling”, which occurred at the same time as the winter peak, coinciding with the annual migration of this species. Humpback whales in the study area may be part of either the east or the west coast populations. The population migrating up the east coast is *en route* to breeding grounds referred to as Breeding Stock C (BSC1) by the IWC (Best et al. 1998), while those passing the west coast are part of Breeding Stock B (BSB), which consists of a large breeding population (BSB1) off tropical West Africa, and a much smaller sub-stock BSB2 (estimated at approximately 500 individuals in 2010) (Barendse et al. 2011), which feeds of the west coast of South Africa in spring and summer (Barendse et al. 2010). The study area is located between the Western most area predicted to be used by BSC whales, namely Cape Agulhas (Cerchio et al. 2008), and the south-eastern most location where BSB humpback whales have been identified, namely Cape Point (Barendse et al. 2011). The majority of the animals seen (80%) were travelling eastwards towards Cape Agulhas, which could indicate that they are *en route* to the east coast of Africa, and are associated with Breeding Stock C (BSC1), but the affinity of the humpback whales sighted in the study area is uncertain and evidence from genetic, acoustic, or photographic matches is needed. Certainly the low overall number of sightings in the current study suggest that the study area is not part of the main migration route (c.f. Findlay et al. 2011), and the whales sighted may have miscued their point of arrival at the continent on their northward migration.

4.8.4 BRYDE'S WHALES

The temporal distribution of this endemic species (Best 2007) was similar to the results of the WWV-study (Vinding et al. 2015) but with a peak in February and March instead of in April. The spatial distribution was also similar with the majority of sightings in the deeper waters. The Bryde's whales observed in this study are very likely part of the inshore population which do not migrate to Antarctica to forage, and is believed to stay on the Agulhas Bank subject to minor local movements due to migration of prey (Best 2007). Penry et al. (2011) state that the abundance of prey is more likely the driving factor in relation to distribution of Bryde's whales. Their main prey species (pilchard and anchovy) shifts south and eastward in the summer (Crawford 1981, Coetzee et al. 2008). All types of behaviour, except socialising, were recorded, and on a few occasions, feeding aggregations were recorded and particularly the area beyond 20 m depth and in the vicinity of Dyer Island was found to be related to feeding areas. The seasonality of Bryde's whales could be linked to the distribution of their main prey species, which has been suggested for Plettenberg Bay (Penry et al. 2011). To confirm this, it is necessary to investigate prey distribution in the area. It would also be beneficial to establish collaboration with the research team in Plettenberg Bay and compare ID-photos of Bryde's whales to investigate if there is a coherency in the animals visiting the Greater Dyer Island Area and Plettenberg Bay.

4.8.5 INSHORE DOLPHIN SPECIES

The spatial distribution of the two main dolphin species was similar to the results of the WWV-study, with the known strict coastal habitat of the Indian Ocean humpback dolphin within 1 km from the shore (Saayman and Tayler 1979, Findlay et al. 1992). The Indian Ocean humpback dolphin exhibited a preference for the sandy bay compared to the edge of the kelp. This inshore distribution makes these species more vulnerable to potential human impacts, particularly the local vessels using the inshore environment (WWV, shark cage diving, commercial and leisure fishing) and construction sites which divide the along shore environment.

The temporal peak in the summer period (December – February) was not as pronounced as in the WWV-study; this could be a reflection of the low effort of the WWV in the summertime when the main target species, the southern right whale is not present in the area. During that time of the year the WWV normally conduct one trip a day of approximately 2 hours and efficient search time is approximately 1 hour. In comparison, the effort of the theodolite tracking team each day was up to 12 hours, hence the increased possibilities of sighting the dolphin species this time of the year. Whereas in the winter period the WWV underestimated the number of whales present because the vessel focused on presenting a few animals to the guests compared to the theodolite which counted all the animals in the area.

The fact that both dolphin species were present on 6 days outside of the main season (December – February) indicates that the same factor, for example, a specific type of prey could drive their presence. All types of behaviour were recorded for both dolphin species and behavioural patterns related to spatial distribution were not clear, but with 7 out of 13 sightings of Indo-Pacific bottlenose dolphins using the bay for resting, this could indicate that the bay is one of their preferred sites for this type of behaviour. The dolphin species with the highest leg speed was the common dolphin with a top speed of 17.5 km/h (n = 8), followed by the Indo-Pacific bottlenose dolphin at a speed 6.3 km/h (n = 19), and the Indian Ocean humpback dolphin at a speed of 6.3 km/h (n = 17) (Table 8). The relatively low number of sightings could be related to the low number of individuals at population level, or it could be because the location is a shoulder area of the distribution of these species. The occurrence of the two inshore dolphin species was below a level where the area can be categorised as residential, but rather as an area used as part of their inshore habitat.

4.8.6 BIAS

Observing and tracking cetaceans from land-based stations has certain limitations. First of all, cetaceans are submerged periodically and hence out of visual range. The study set-up accounted for this as the distributional scans were conducted by at least one person searching with binoculars and one with naked eyes as well as at a slow pace, which provided time for submerged whales to surface.

Secondly, there is a limit to the visual range of which it is possible to reliably determine the species, group size, and behaviour. In this study it was possible to detect large cetaceans and large groups of delphinids at a distance of about 20 km at sea state <5 and smaller groups of inshore dolphin species at a distance of about 5 km at sea state ≤ 2. Sightings of single individuals of Indian Ocean humpback dolphins were the most difficult to detect because they often were very close or within the kelp and the shape of the kelp can in some instances look like a dorsal fin of a dolphin. Larger groups of dolphins can be detected from white splashes in the water and particularly large groups, for example a group of >500 common dolphins. The smaller groups of inshore dolphins would not provide as much white splashes and hence not be detectable as far of shore as a larger group.

Thirdly, with the high number of southern right whales in the study area, it was not possible to distinguish individuals between tracking days and same animals would have been seen on consecutive days. The high number of right whales would also result in re-sighting of the same individuals on the consecutive hourly scans within the same day. Each scan was therefore viewed as a single and separate event in order to determine the spatial and temporal distribution of animals in the area. If animals were recognised, it was noted, but otherwise animals were given a new scan number during each hourly scan.

4.8.7 INHERENT INACCURACY

Inaccuracy related to station height caused by height of the station, (particularly the balcony in this study), swell, tide, and consistency in fix point placement (for example where on the body of the whale the position it is taken) can result in errors in the precision of tracks and fix points. A study on harbour porpoises (*Phocoena phocoena*) by Koschinski et al (2003) used a station 14 m above sea level and accepted tracks in an area of 600 x 2000 m for the survey. Porpoises are more difficult to spot than dolphin species and baleen whales, such as southern right whales, which are larger and spend a lot of time at the surface (Hain et al. 2013) It is generally necessary to know the height of the station within ± 10 cm when tracking dolphin species, but accuracy of the measured fix point of any animal is not critical when animals are within 500 m of the observation station or if the station is higher than 45 m (Pryor and Norris 1991).

A study of Chilean dolphins (*Cephalorhynchus eutropia*) used a vantage point of 102.78 m above sea level and estimated that a 50 cm error in theodolite eye height would cause a position error of 15 m at a range of 3000 m (Ribeiro et al 2007). Bejder and Dawson (2001) estimated that a 20 cm error in theodolite height from their station at 27.4 m above sea level would cause an error of 7 m at a distance of 1000 m. In this study a 10 cm error in height (caused by e.g. swell and tide) from the balcony station could result in a distance error of 4 m at 500 m distance, 17 m at 2.5 km distance, and 39 m at 5 km distance (Pryor and Norris 1991). The error would be less from the water tower station, due to the station being higher and could result in a distance error of 1 – 2 m at 500 m distance, 2 – 5 m at 2.5 km distance, and 5 – 12 m at 5 km distance (Pryor and Norris 1991). Tracks of focal follow of Bryde's whales and humpback whales were not included in the analysis of leg speed, reorientation rate, and linearity, as these tracks often extended beyond 5 km from the tracking stations and the error in for example calculated swimming speed was found to be too large.

Southern right whale with the mouth partially open.

PHOTO CREDIT
KATJA VINDING PETERSEN

4.8.8 COMPARISON BETWEEN WWV-DATA AND THEODOLITE SIGHTINGS

Sightings of southern right whales were recorded from both platforms on 48 days. It is difficult to compare these two dataset completely objectively, since the areas covered by the two platforms do overlap completely in either time or area. However, the two methods used are both attempting to answer the same questions of distribution and abundance datasets and a comparison of answers obtained is thus valuable. The WWV typically covers two bays (Chapter 2) and searches much further from shore than the theodolite stations which are limited to relatively near shore waters around Pearly Beach. When comparing the results of this study to those of Chapter 2, the spatial and temporal distribution of the five main cetacean species in the area is very similar for all species. Sightings of southern right whales from the theodolite stations were higher than those of the WWV during the months of September, October, and November. This likely reflects the difference methods from the two platforms. The WWV rarely encounters more than 4 right whale groups a trip (Figure 18) while shore based tracking teams collected data all day, weather dependent. This is an important factor if data from a WWV is to be used in population estimates or as a measure for population growth, particularly in high-density areas. Although both shore based studied and those using platforms of opportunity have limitation, the similarity of results of seasonal presence and distribution is positive and strengthens the confidence in the results of both parts of the study, within the known constraints of each technique.

4.9 Conclusions

In conclusion, this study provided the temporal, spatial, and behavioural distribution of the five main cetacean species using the area. The area has multi-purpose functions related to the different cetacean species which indicates that this is an important area to these species; southern right whale, humpback whales, Bryde's whales, Indian Ocean humpback dolphins, Indo-Pacific bottlenose dolphins: 1) it is an important location for nursing and socialising southern right whales, 2) it is part of the edge of a migration route of humpback whales 3) it appears to be a summer and autumn feeding area for Bryde's whales, 4) it is an area frequented by two inshore dolphin species throughout the year, peaking in summertime, and serving both as a feeding, socialising, and resting area, and 5) it is occasionally visited by common dolphins.

A comparison of the results from the analysis of 10 years of cetacean observation data obtained from the local whale-watching vessel (Vinding et al. 2015) with the results of the present study, showed a very similar temporal and spatial distribution pattern, which could indicate that such data sources from platforms of opportunity can be useful and indicative of distribution of cetacean species.

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5

5 Passive acoustic monitoring of southern right whales

5.1 Abstract

The aim of this study was to investigate whether it was possible to use passive acoustic monitoring PAM to monitor presence of southern right whales in an area well-known for being an important location with aggregations of animals during the winter period. Acoustic recordings obtained with a DSG-Ocean Loggerhead were combined with visual observations from land-based theodolite stations. A total of 44 days of sound recordings were collected during three periods in January/February, September, and October 2014. A total of 26 hours and 28 minutes of visual theodolite observations were conducted in September 2014 simultaneously with the collection of acoustic recordings. Acoustic signals were recorded either continuously at a sampling rate of 10 kHz or using two sampling regimes; at 10 kHz (20.5, or 54.5 minutes) combined with 40 kHz (4.5 minutes each half hour or each hour). Sound recordings were analysed using Raven Pro 1.5 (Bioacoustics Research Program, 2013). Southern right whale groups observed during visual scans were categorised as either: Surface active groups (SAGs), cow-calf pair (cc-pairs), or unaccompanied adults (UAs). All vocalisations were classified following Urazghildiiev and Parks (2014) and call characteristics from two of the six main classes: narrow-band up-calls (NU) which are known contact calls and wideband gunshots (WG) which are known to be associated with social groups were analysed. Additionally, the total number of up-calls and gunshots during the visual observation periods was noted and call rate per hour was calculated for comparison to number of visually counted animals. Unexpectedly, humpback whale song was also recorded despite no visual observations. One of the sounds used by humpback whales was very similar to the up call of right whales; these were compared with data from this and other studies. A total of 193 SAGs (group size: 3 – 8, 2.8 ± 1.0 individuals), 97 cc-pairs and 124 UAs were observed. Due to the simultaneous presence and large number of individuals from the three group categories, it was not possible to link a specific vocalisation pattern to any of the group types. Southern right whale sounds were recorded in 79% of the scans where animals were visually observed. Gunshots were short in duration (0.11 ± 0.09 second) with a start frequency of 80 ± 47 Hz and a high-end frequency above 30 kHz. Up-calls had a centre frequency of 107 ± 16 Hz (SD), a start frequency of 56 ± 13 Hz, and a duration of 0.92 ± 0.28 second. The up-call of right whales differed significantly from those recorded as part of humpback whale song (centre frequency 149 ± 6 Hz, a start frequency of 94 ± 12 Hz, and duration of 0.63 ± 0.11 s). In conclusion, PAM is useful to record the presence of southern right whales but, in the high-density study area with simultaneous occurrence of several group types, it was not possible to correlate sound production to animal numbers or to specific behaviour or group type. Future studies could include localization of vocalising individuals, which may enable a linkage between vocalisation, group type and behaviour.

5.2 Key words

Cow-calf pair, gunshot, humpback whale, land-based, unaccompanied adults, up-call, surface active group, theodolite tracking, vocalisation.

5.3 Introduction

The southern right whale is the only species of right whale in the Southern Ocean (Best 2007). The South African population is considered healthy, as it has increased at a rate of approximately 7% per year since 1969 when monitoring began (Brandao et al. 2010). The right whales in South Africa occur primarily along the Cape south coast from June until December with a peak from August to October (Best and Scott 1993), although there is a general westward shift of animals over the season (Mate et al. 1997, Best 2000). The South African population shows some level of segregation with the majority of pregnant and nursing cow-calf pairs (cc-pairs) found off De Hoop marine protected area and in St Sebastian Bay to the east of Cape Agulhas (Figure 1) (Best 2000). The highest numbers of adults unaccompanied by calves (UAs), and surface active groups (SAGs, which are socialising/mating groups) are observed in Walker Bay (Figure 1) immediately to the west of the study site (Elwen and Best 2004*b*). Along the South African coast, right whales have been shown to prefer shallow sloping bay areas with a sandy or muddy bottom, protected from open ocean swell and seasonal winds, usually within 2km of shore (Elwen and Best 2004*a*, Elwen and Best 2004*b*). With the increase of the population, sightings of southern right whales have become more frequent and year-round in some areas including the west coast of the South Africa (Barendse and Best 2014). Passive acoustic monitoring offers a potentially powerful way to remotely monitor the presence and number of animals along the coast, to improve management of potentially negative human-whale interactions such as entanglement in fishing gear (Meyer et al. 2011) or ship strike which has been a serious conservation concern for North Atlantic right whales (Knowlton and Kraus 2001). For PAM to be effective and to enable calculation of the probability of detection of animals, it is necessary to have a good understanding of the call types and rates of the study animal (Zimmer 2011).

Several studies have described the sound production of southern (*Eubalaena australis*), northern (*E. glacialis*), and northern Pacific right whales (*E. japonica*), although different categorisation schemes have been used to describe their call repertoire and direct comparisons are challenging. In all species the majority of energy is below 1 kHz (Clark 1982, Parks and Tyack 2005, Urazghildiiev and Parks 2014) and studies from Argentina show that the vocalisation of the southern right whales is mainly concentrated in the frequency range 50 – 500 Hz (Clark 1982, Urazghildiiev and Parks 2014). Southern right whale vocalisations in South Africa, including call repertoire, overall call rate, call rate per whale, and call rate per number of groups sighted from a vessel, have been previously described by Hofmeyr-Juritz (Hofmeyr-Juritz and Best 2011) from a boat-based study of animals in Walker Bay. Calls were classified using 13 categories based on four frequency contour trajectories (up, down, flat, and variable) and three starting frequencies (55 – 100 Hz, 100 – 200 Hz, 200 – 440 Hz). Broadband, impulsive 'gunshot' sounds were placed in a separate category. The most commonly recorded sound was the 'low up' call (starting frequency between 55 – 110 Hz and an up-shaped contour) (Hofmeyr-Juritz 2010). Within the categorisation of right whale vocalisation there are a wide variety of classifications and varies from two (Mellinger et al. 2004) to 13 (Hofmeyr-Juritz 2010). Many studies have included the two categorisations "Up-call" and "Gunshot" (Parks and Tyack 2005, Hofmeyr-Juritz 2010, Trygonis et al. 2013, Urazghildiiev and Parks 2014, Webster 2015) and a consensus was agreed between right whale acoustic researchers that these two vocalisations can be used to identify right whale presence (Webster and Vinding 2015). Urazghildiiev and Parks (2014) categories of these two call types were used in the present study because the description is based on objective facts and provide a global standard.

Two call types are considered characteristic of all right whale species and have been used in several studies to identify the presence and behaviour of the right whale species (Matthews et al. 2001, Ildar R. Urazghildiiev et al. 2002, Parks et al. 2005, Laurinolli et al. 2006, Urazghildiiev and Clark 2006, Urazghildiiev and Clark 2007, Munger et al. 2008, Urazghildiiev et al. 2008, Clark et al. 2010, Hofmeyr-Juritz and Best 2011, Munger et al. 2011, Mussoline et al. 2012). These call types are: a) up calls and b) gunshots. Up-calls have been described as a contact call (Urazghildiiev and Clark 2006, Clark et al. 2010) and produced by all age-groups and both males and females (Parks et al. 2011). Gunshots are believed to be produced by right whale males in a reproductive context and may function as an antagonistic sound towards other males and/or an advertisement sound to attract females (Parks et al. 2005). Gunshot sounds are known to be distinctive to right whales and have not been recorded from other cetacean species, such as the humpback whale (Parks et al. 2005, Stimpert et al. 2007). Ship strikes is a potential threat to right whales and auto-detection buoys are deployed in Massachusetts Bay providing an early warning systems to reduce the risk of ship collision (Morano et al. 2012, Mussoline et al. 2012). These buoys detect up-calls (Morano et al. 2012, Mussoline et al. 2012, Soldevilla et al. 2014) and when a call is detected it makes a cell or satellite call to the Cornell Lab of Ornithology, where the call is being verified before a warning is sent out to ship using the area.

The up-call is also known as the “contact call” and has been recorded for example when a male approached or was separated from a SAG (Parks and Tyack 2005). The characteristic gunshot sound has so far been assigned a male display sound or a male-male agonistic sound (Parks et al. 2005) but it is still in debate and might have more functions and also be produced by females (Gerstein et al. 2014).

The aim of the present study was to investigate whether it is possible to use PAM to monitor presence of southern right whales in an area well-known for being an important area with aggregations of animals during the winter period. Two methods were combined: PAM and visual observations from land-based, theodolite tracking stations. The main question addressed was: how reliably can the vocalisations of southern right whales be used to monitor habitat use and group composition? Classification of vocalisations in the present study was based on Urazghildiiev and Parks (2014) and two of the six main sound classes were used in the analysis: up-calls and gunshots.

5.4 Methods

5.4.1 STUDY SITE

This study was conducted in the Greater Dyer Island area in Pearly Beach (34°40’18” S, 19°28’16” E). The shores of Pearly Beach consist of shallow rocky reefs, kelp forest and a large sandy gently sloping bay. The small river, Pearly Creek, flows into the bay. The water depth is less than 50 m in the bay (Figure 1). Less than 10 km from the sandy bay is an island complex, which is a fully protected nature reserve (BirdLife South Africa 2015), consisting of Dyer Island (20 ha) and Geyser Rock (3 ha). The area is well known for the year-round presence of great white sharks (*Carcharodon carcharias*) and it is used by both whale watching (MLRA 2008a) and shark cage diving companies (MLRA 2008b).

The study area is situated inshore of the Agulhas Bank which forms the southern boundary of the Benguela upwelling system and displays characteristics of both upwelling system and a temperate shallow shelf system (Hutchings et al. 2009).

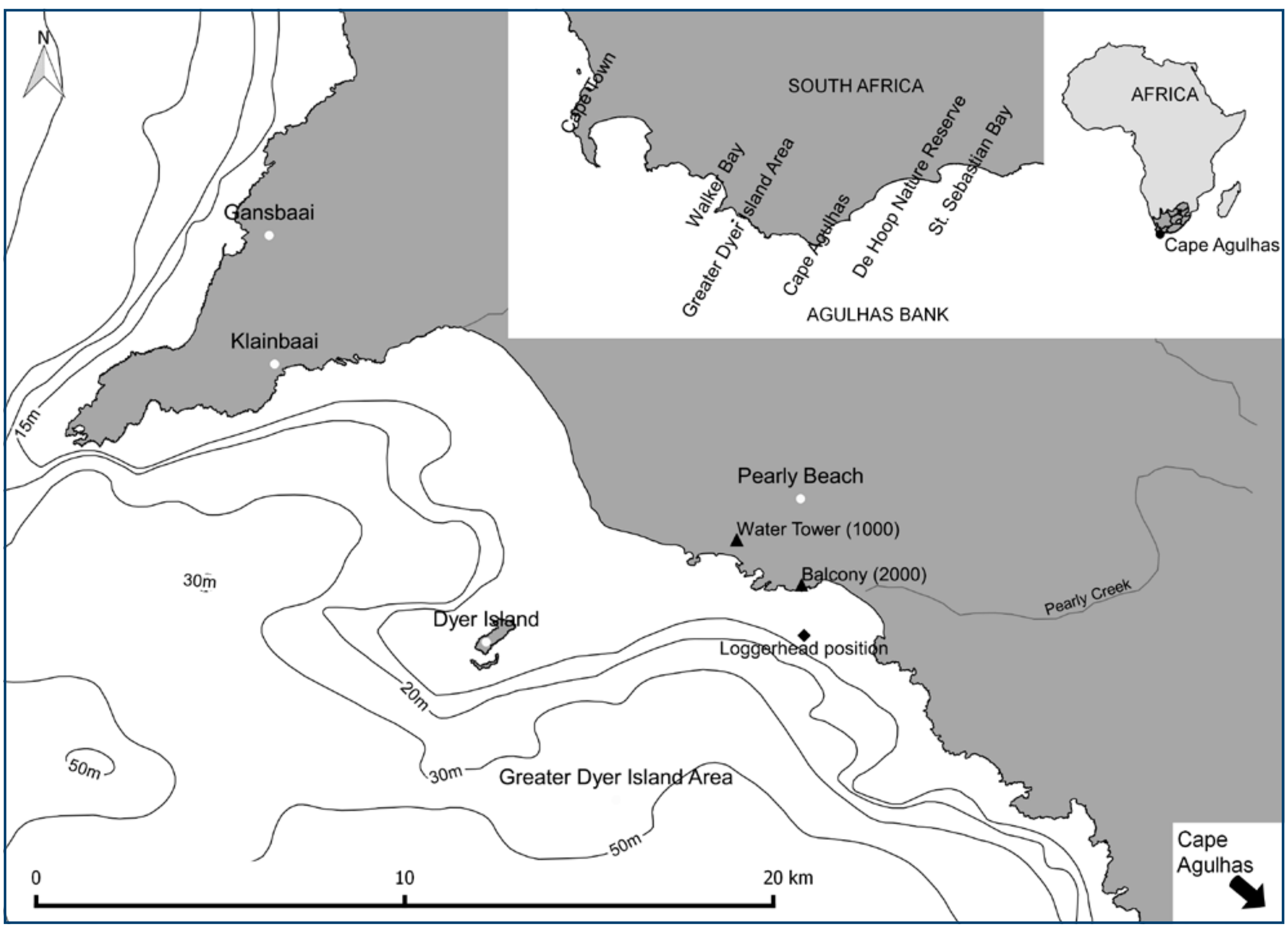
The prevailing wind direction varies throughout the year: during the summer months (December – February) winds are predominantly southerly or south-easterly; autumn (March – May) is similar to the summer months but with more frequent north-westerly winds; winter (June – August) is characterised by strong winds from north-west, south-east, or south-west; in spring (September – November) the predominant wind direction is southerly, south-easterly or south-westerly (Law 1999).

Sea surface temperature and pressure was measured every half hour by the South African Government, Ocean & Coast Management, from 25 July 2012 until 2 September 2013 using a Starmon mini (Star Oddi 2016) moored to the sea floor and situated at 35 m depth, close to Quoin Point (34°45'48.50"S, 19°35'12.28"E). Average temperature over the entire period was 13.3° C; average during the summer period (December – February) was 11.7° C while average over the winter period (June – August) was 14.8° C.

5.4.2 STUDY SETUP

Sounds from PAM, using a single-bottom moored hydrophone, and visual observations from two land-based theodolite tracking stations were obtained simultaneously. Acoustic localization was not applied and so no attempt was made to assign calls to specific groups or individuals. The total number of groups present in the area (SAGs, cc-pairs, and UAs), as well as their location and behaviour were visually recorded each hour on the hour (see Chapter 11).

FIGURE 1
Orientation map of the research area within the Greater Dyer Island Area. The acoustic logger and the theodolite stations were situated in the town of Pearly Beach. The diamond symbolise the position of the Loggerhead and the two land-based theodolite stations are marked with a triangle symbol.



5.4.3 PASSIVE ACOUSTIC MONITORING

One DSG-Ocean Loggerhead hydrophone (Loggerhead Instriuments 2013) (Figure 2, 3, 4, 5, and 6) was deployed off Pearly Beach (34°40'59.70" S, 19°30'31.75" E) (Figure 1) at 15 m depth, approximately 8 m above the sea floor. Originally there were two loggers, one was lost during a storm, which led to a change in the design of the mooring. Mooring tests were conducted in 2013. The wider study area is a very exposed inshore environment characterised by a sandy substrate interspersed with patches of reef. The reef patches were found to have relatively high levels of background noise. The mooring location was chosen as a sandy area with relatively low background noise and with less likelihood of impact from high swells. The identification of the quietest location was chosen in 2014 by listening with a handheld hydrophone (Brüel and Kjær, 8104, connected to an Etec amplifier, a M-Audio Microtrack recorder, and earphones) at different locations in the bay.

The mooring system used in 2014 was custom designed to be able to withstand the harsh local inshore conditions, and not create noise when moving in the water column. The mooring system (Figure 2A) included a round concrete block (main anchor) from which two attachments were connected - a sand anchor (second anchor) and a rope riser to which the Loggerhead was attached. All exposed metallic parts and ropes were covered in thick plastic hosepipe to dampen any noise caused by movements. The riser was made buoyant with an elongated float (which mimicked the movement of kelp fronds and shed the energy of wave and current action). A special designed 'silent swivel' connected the float to the rope of the main anchor (Figure 2A). The Loggerhead was placed approximately 2 m beneath the float, approximately 5 m above the swivel and approximately 8 m above the sea floor. The logger was moored and retrieved by a team of divers (Shark Diving Unlimited).

The first deployment of a DSG-Ocean Loggerhead was conducted on 2 September 2013 with a different mooring design than the mooring in 2014 (Figure 2B). The 2013 mooring was placed at 15 m depth in front of the water tower and close to the reef to secure the base of the mooring (Figure 4). The first service occurred on 1 October 2013, where batteries and memory card was replaced at sea before re-deployment (Figure 5). The collected sound recordings were investigated but recordings were noise polluted from the initial anchoring system and this noise was masking most of the low frequency calls, making it impossible to use these recordings for the analysis of southern right whale vocalisation. The logger was retrieved on 28 October and the anchoring system was replaced with enforced rope and a smaller riser. The logger was re-deployed on the same day. On 1 January 2014 the logger was located free-floating in the bay as the rope at the base of the mooring was broken. A new mooring system was developed as described above and in Figure 2 and the logger was deployed on 31 January 2014 (Table 1).

TABLE 1 OVERVIEW OF THE ACOUSTIC SOUND RECORDING PERIODS AND DUTY CIRCLES. FOR DETAILS ON DUTY CIRCLE SETTINGS, SEE MAIN TEXT.

Start date	Period	Start recording time	End date	End recording time	Total recording time	Comments
02-Sep-2013	1		01-Oct-2013		29 days deployment	Unsuccessful deployment, noise from mooring
01-Oct-2013	1		28-Oct-2013		28 days deployment	Unsuccessful deployment, noise from mooring
28-Oct-2013	1		10-Jan-2014		Unknown when logger broke off mooring	Unsuccessful deployment
31-Jan-2014	1	11:30	24-Feb-2014	12:00	24 days, 23 hours, 30 min.	Successful deployment
03-Sep-2014	2	11:45	16-Sep-2014	17:45	13 days and 6 hours	Partially successful deployment, shorter recording time than scheduled
18-Oct-2014	3	15:00	25-Oct-2014	9:30	7 days, 5 hours, 30 min.	Partially successful deployment, shorter recording time than scheduled

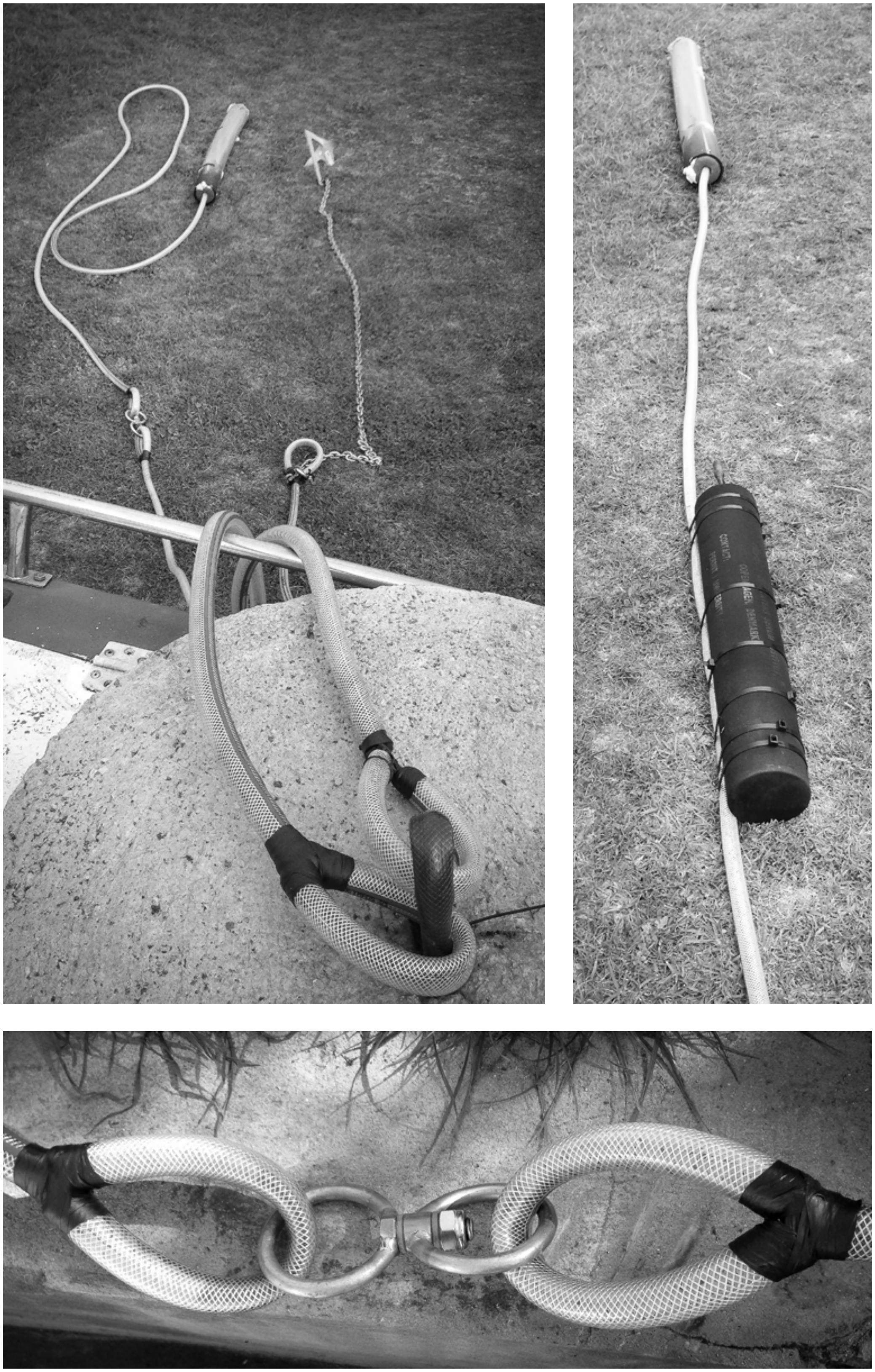


FIGURE 2A
The custom designed mooring used in 2014.

FIGURE 2B
The mooring used in 2013.

FIGURE 3
First deployment of the loggerhead DSG-Ocean on 2nd September 2013.
Mooring system from figure 2B was used. ***PHOTO CREDIT*** *HARRY STONE*

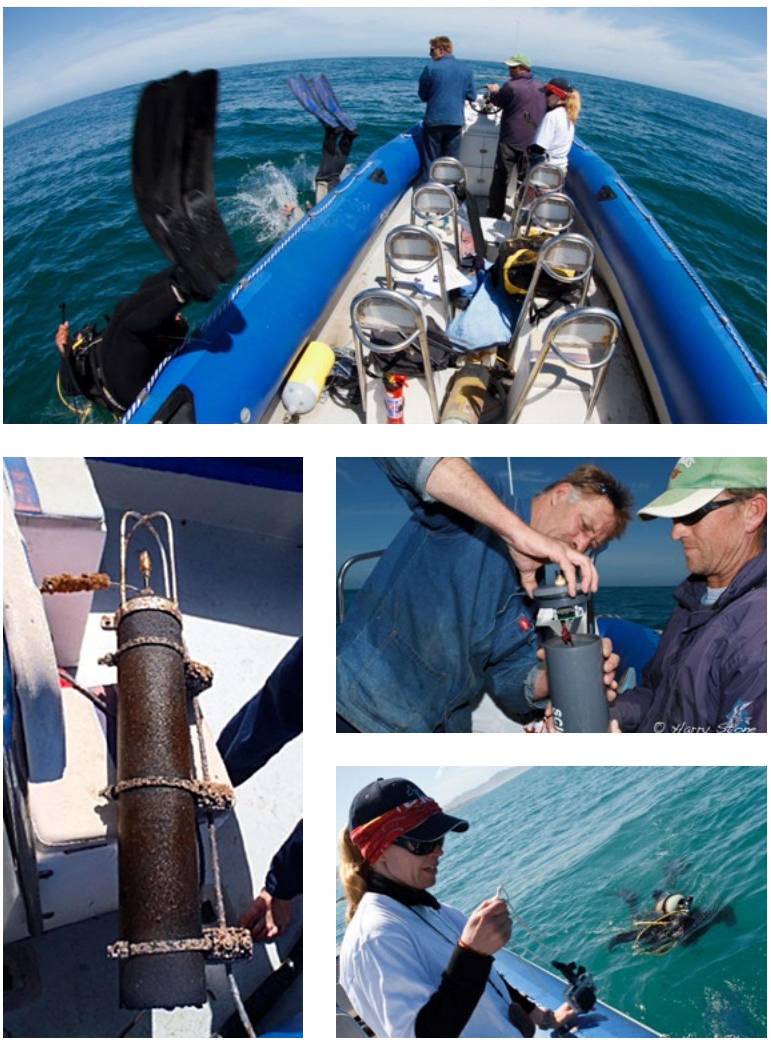


FIGURE 4
First retrieval and service (after deployment on the 2nd of September 2013) of the loggerhead DSG-Ocean on 1st October 2013. ***PHOTO CREDIT*** *HARRY STONE*

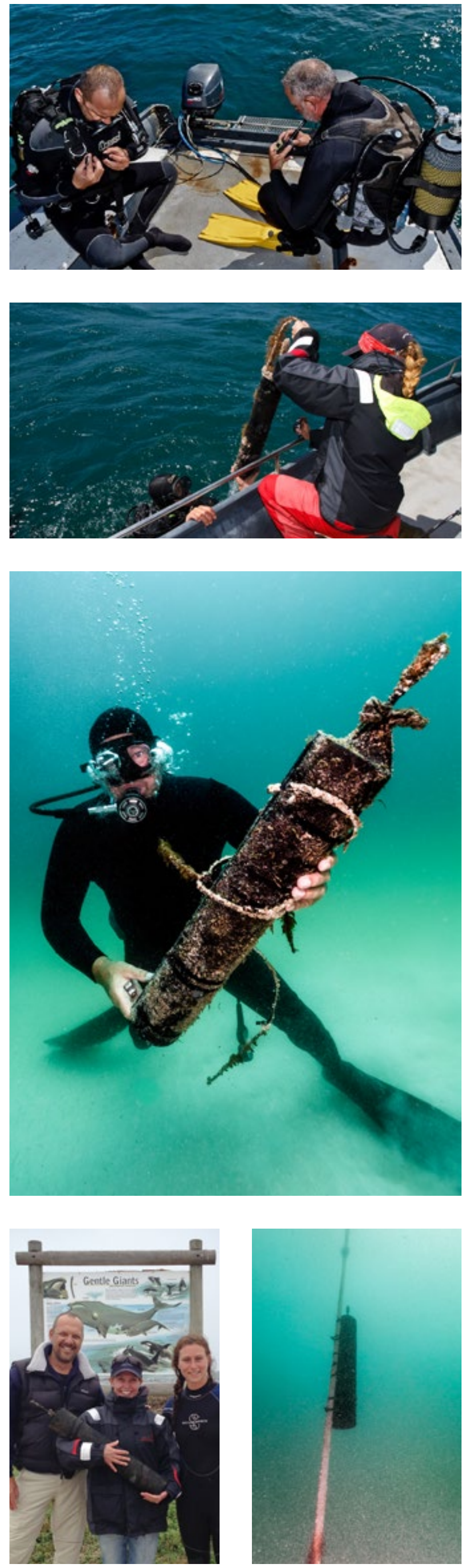


FIGURE 5
Retrieval of loggerhead DSG-Ocean on 30th March, 16th October and 23rd December 2014. ***PHOTO CREDIT*** *HARRY STONE*

All recordings were collected with system gain 20 dB and hydrophone sensitivity of -180 dBV/µPa. Only the standard DSG-loggerhead 35 kHz 3-pole low-pass filter on the hydrophone input was used. The hydrophone and pre-amplifier had a flat frequency response from 32– 25,000 Hz. Recordings were written to a 128 GB memory card. The settings and total number of recording hours are provided in Table 1. The base sampling rate was 80 kHz with a 16-bit sample size.

Period 1. The recording schedule comprised two duty cycles: 1) low frequency (LF) recording with a decimation factor of 8, sampling rate of 10 kHz, for 20.5 min; 2) high frequency (HF) recording with a decimation factor of 1, sampling rate 40 kHz, for 4.5 min. The LF/HF duty circles switched every half hour, on the half hour and on the hour. Enabling a total recording period of 23 days and 2 hours.

Period 2. The recording schedule again comprised two duty cycles: 1) LF recording with a decimation factor of 8, sampling rate 10 kHz for 54.5 minutes; 2) HF recording with a decimation factor of 1, sampling rate of 80 kHz, for 4.5 min, beginning on the hour every hour. Enabling a total recording period of 44 days and 12 hours.

Period 3. Continuous recording with a decimation factor of 8 sampling rate of 10 kHz. Enabling a total recording period of 69 days.

The duty cycle was changed between period 1 and period 2 to extend the recording period, but the loggerhead only sampled for 13 days and 6 hours in period two, due to unidentified technical problems. The duty cycle was changed to continuous for the 3rd recording period after communication with and advice from the developer of DSG-Ocean loggerhead. During period three, the logger only recorded for 7 days, 5 hours, and 30 minutes instead of the scheduled 69 days, and it was not possible to identify the technical problem causing this reduction in sampling time.

To keep the equipment inconspicuous, surface buoys were not used.

5.4.4 LAND-BASED THEODOLITE TRACKING

Land-based focal follows were taken from two high vantage points; water tower (station 1000) 34°39’34.37” S, 19°29’21.53” E, 38.79 m above mean sea level (MSL) and a private balcony (station 2000) 34°40’15.03” S, 19°30’29.84” E, 14.65 m above MSL (Figure 1). A Leica TC307 digital total station was connected to a DELL E6430 ATG with a custom set up version of the computer program VADAR (Visual & Acoustic Detection and Ranging at Sea, Dr. Eric Kniest, Newcastle University, Australia) in 2014. Weather allowing, visual surveys began no later than half an hour after sunrise

TABLE 2 OVERVIEW OF THE VISUAL LAND BASED OBSERVATION PERIODS THAT COINCIDED WITH UNDERWATER SOUND RECORDINGS

Date	Station	Time start	Time end	Total effort duration (hh:mm)
03-Sep-2014	2000	12:00	15:36:00	3:36
03-Sep-2014	2000	15:48	17:24:00	1:36
04-Sep-2014	2000	14:57	17:24:00	2:47
08-Sep-2014	2000	8:06	10:21:00	2:15
12-Sep-2014	2000	9:00	13:31:00	4:31
13-Sep-2014	2000	8:06	12:33:00	4:27
14-Sep-2014	1000	9:03	12:02:00	2:59
16-Sep-2014	2000	8:10	12:27:00	4:17

and ended no later than half an hour before sunset. Three main modes were conducted throughout the whole field day in following order; environmental data, distribution scan, and search or focal follow (see Chapter 4 for further details). Only data from the distribution scans were used in this chapter and the data used in this chapter is a subset of the complete data-set presented in Chapter 4 (complete data-set: 7 August to 13 December 2011, 5 May 2012 to 26 December 2013, and 6 June 2014 to 11 December 2014). During September 2014 a total of 26 hours and 28 minutes (29 clock hours) of land-based visual observations were conducted while the DSG-Ocean loggerhead was recording (Table 2).

Positions of vessels and positions, behaviour, and group size of cetaceans were collected during the distribution scans. Southern right whales were categorised in three different groups: cow-calf pairs, Surface active groups (SAGs) defined as groups with high levels of social interaction at the surface with physical interaction between individuals, and where most attention is directed towards a focal animal (or animals) (Kraus and Hatch 2001, Best et al. 2003), and finally unaccompanied adults. All visual observations included in this study were conducted at sea state < 4.

5.5 Data analysis

5.5.1 PASSIVE ACOUSTIC MONITORING

Categorization of southern right whale calls followed Urazghildiiev and Parks (2014), where classification of impulsive signals were based on the distribution of signal energy in the time and frequency domain.

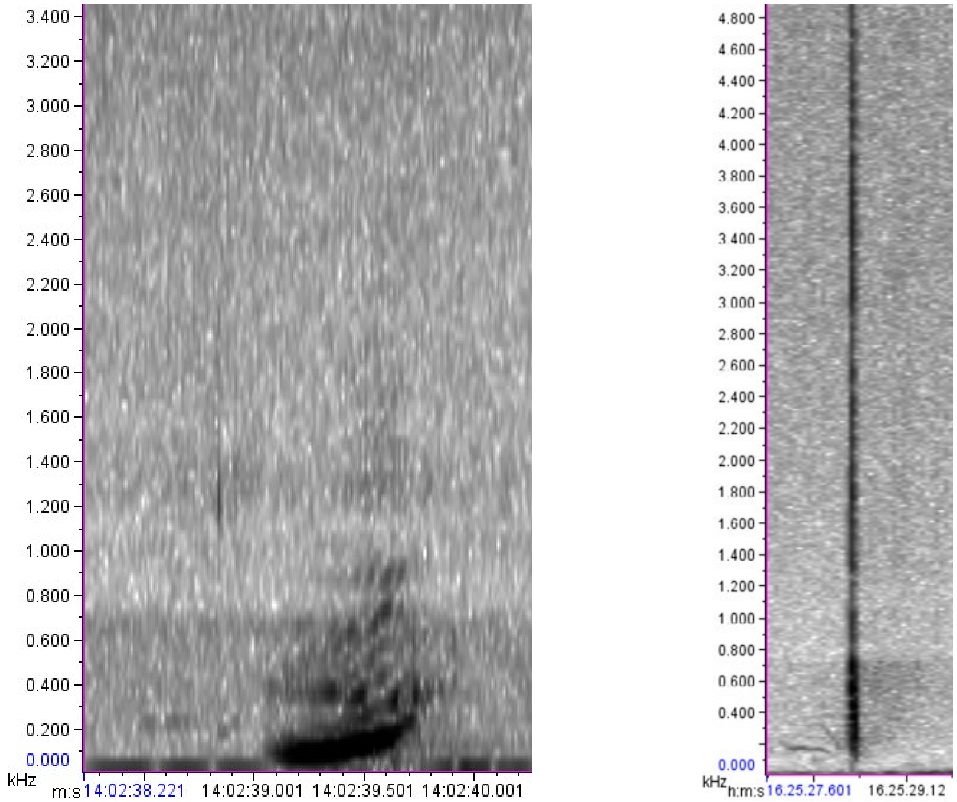
Two of the main sound categories were included in the present analysis (Table 3): a) up-calls (NU) (Figure 6), narrowband frequency modulated (FM) signals, with one inflection point and main energy > 200 Hz; b) gunshot sounds, wide band signal, shorter than 1.5 seconds (Figure 3).

Analysis was conducted in Raven Pro 1.5 (Bioacoustics Research Program, 2013). Firstly, all types of calls were logged manually (the fundamental and the entire call were each logged separately). Secondly, using hot keys, each logged selection in the annotation tables were assigned; call type, Signal-to-noise Ratio (SNR), and call selection category (fundamental or entire call for up-calls and fundamental/entire call for gunshot sounds). Finally, the categorization of all marked up-calls and gunshot selections were manually re-confirmed three times. Sampling rate for low frequency recordings were 10 kHz and spectrograms were made with a 512-point Hann window (3 dB bandwidth = 14 Hz) with 50% overlap, and a 1024-point DFT, yielding time and frequency measurement precision of 51.2 ms^{-1} and 9.8 Hz. Sampling rate for high frequency recordings were 80 kHz and spectrograms were made with a 512-point, Hann window (3 dB bandwidth = 28.4 Hz) with 50% overlap, and a 4096-point DFT, yielding time and frequency measurement precision of 25.4 ms^{-1} and 19.5 Hz.

TABLE 3 CALL DESCRIPTION OF THE TWO CALL TYPES; NARROWBAND FM UP-CALL (NU) AND GUNSHOT (WG) FROM URAZGHILDIIEV AND PARKS (2014)

Main call category	Call Sub category	Call description	Frequency
Frequency modulated	Narrowband FM up-call (NU)	Narrowband low frequency upsweep signal. One infliction point.	Peak frequency
Wideband	Gunshot sound (WG)	Wideband gunshot sound. Very distinguishable on the spectrogram. Shorter duration than 1.5 seconds	< 200Hz Bandwidth ≥ 100Hz extending above 5khz

FIGURE 6
Examples of the two call types included in the sound analysis; up-call and gunshot.



Besides the selection bounds (Start Time, End Time, Low Frequency, and High Frequency), additional temporal and frequency measurements were made (Table 4).

TABLE 4 DESCRIPTION OF THE TEMPORAL AND ACOUSTIC MEASUREMENTS CONDUCTED IN RAVEN PRO 1.5

Measurements	Description
Centre time (s)	The point in time at which the selection is divided into two time intervals of equal energy.
Time 5%	The point in time that divides the selection into two time intervals containing 5% and 95% of the energy in the selection.
Time 95%	The point in time that divides the selection into two time intervals containing 95% and 5% of the energy in the selection.
Duration 90% (s)	The difference between the 5% and 95% times.
Q1 time (s)	The point in time that divides the selection into two time intervals containing 25% and 75% of the energy in the selection.
Q3 time (s)	The point in time that divides the selection into two time intervals containing 75% and 25% of the energy in the selection.
Centre frequency (Hz)	Frequency that divides the detection at the median of cumulative acoustic energy (Hz)
Peak frequency (Hz)	Frequency at which maximum power occurs within the detection (Hz)
Q1 frequency (Hz)	The frequency that divides the selection into two frequency intervals containing 25% and 75% of the energy in the selection.
Q3 frequency (Hz)	The frequency that divides the selection into two frequency intervals containing 75% and 25% of the energy in the selection.
Frequency 5% (Hz)	The frequency that divides the selection into two frequency intervals containing 5% and 95% of the energy in the selection.
Frequency 95% (Hz)	The frequency that divides the selection into two frequency intervals containing 95% and 5% of the energy in the selection.

FIGURE 7
Southern right whale up-calls illustrating SNR categories 'Excellent', 'Potential' and 'Poor' (left to right respectively).

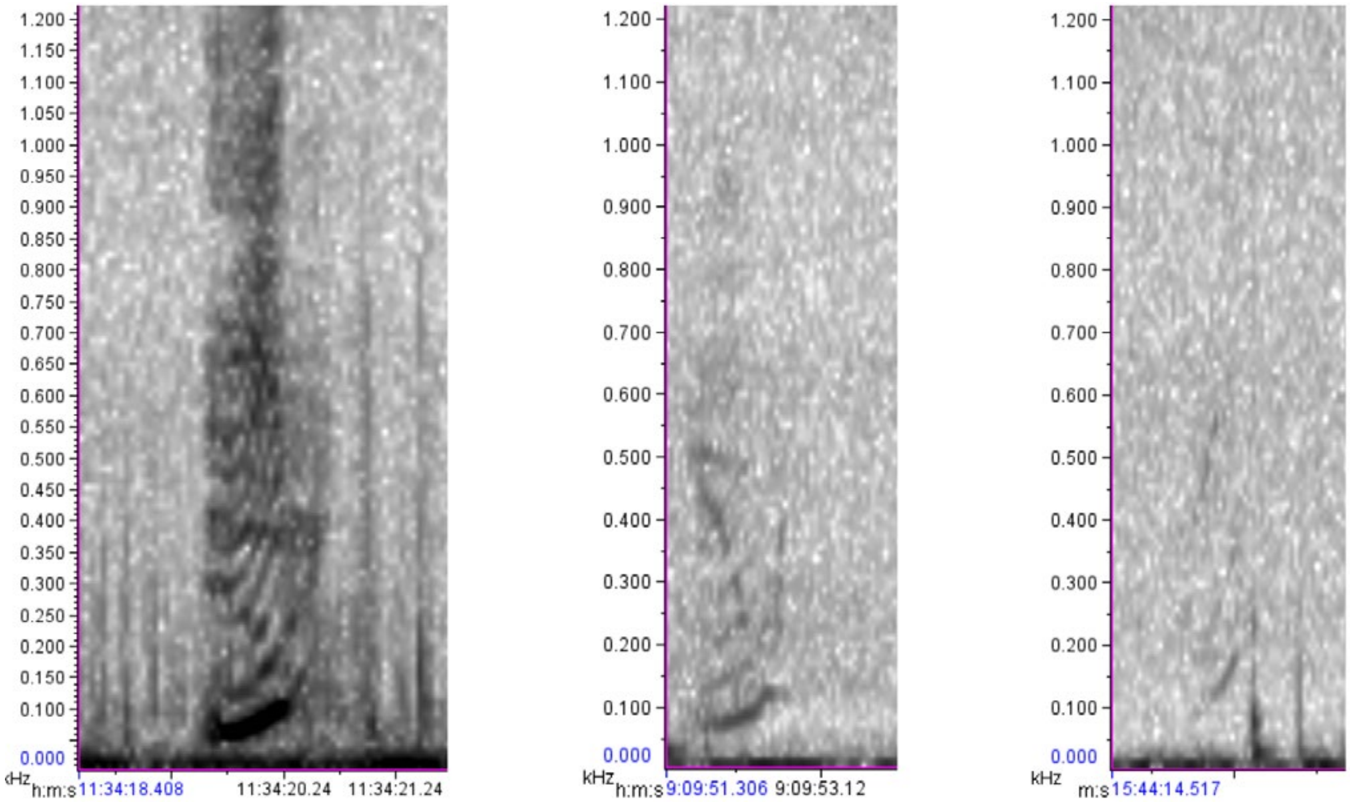
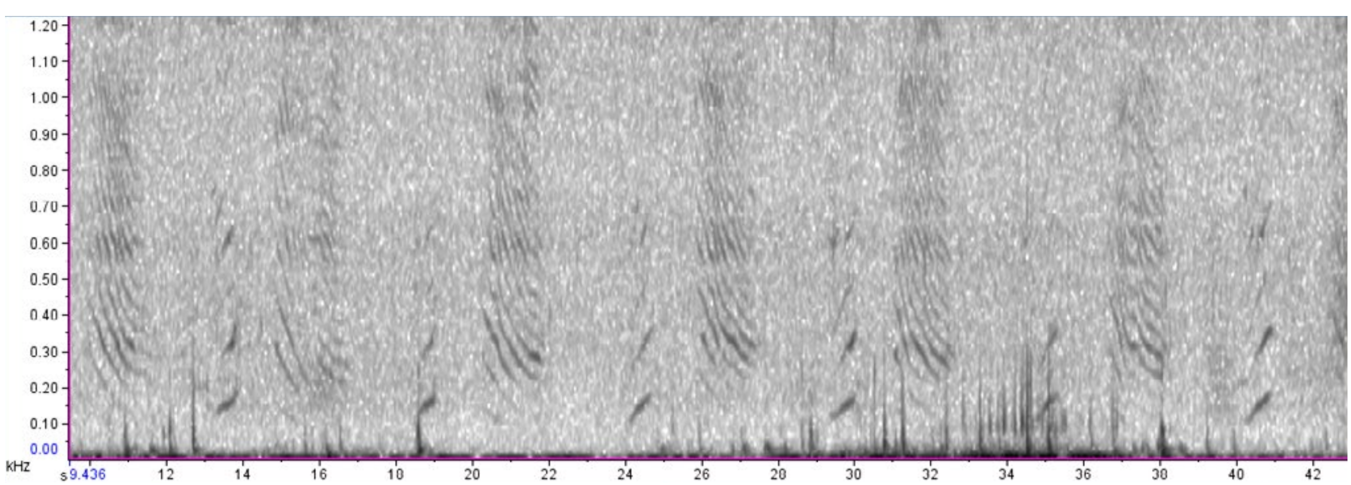


FIGURE 8
Part of a theme from humpback song with up-call units.



5.5.2 SIGNAL TO NOISE RATIO (SNR)

All calls were categorised in three SNR categories. Clear calls with a high SNR were categorised as “Excellent”, calls where the fundamental was clear enough to obtain measurements were categorised as “Potential”, and finally calls where it was impossible to obtain the contour of the call were categorised as “Poor” (Figure 7). Calls where the fundamental frequency was overlapped by other calls were excluded from the analysis.

5.5.3 HUMPBACK WHALE VOCALISATIONS

An unexpected discovery of humpback vocalisations was made during the manual logging of southern right whale calls. These vocalizations were only present in some of the recordings and complicated the logging of the southern right whale calls due to similarity in some of the vocalisations, notably up-calls. Songs of humpback whales containing themes, phrases and units were

Southern right whale and calf.

PHOTO CREDIT
KATJA VINDING PETERSEN

registered but a thorough analysis of the song characteristics is still to be conducted and is not the focus of this chapter. One of these themes contained up-call like sound units (Figure 8) and these humpback up-call units were analysed to obtain the characteristics of the up-calls and to investigate if it was possible to define species-specific up-calls for each of the two baleen whale species. The duration of the call, low, high, Q1, Q3, peak, centre, 5% and 95% frequency was measured.

5.5.4 LINKING ACOUSTIC AND VISUAL DATA

Hourly distribution scan data from the visual land-based observations conducted while the acoustic logger was recording were used in the analysis. The total number of SAGs, cc-pairs, and UAs were calculated per scan. The category “best” of the group size was used in the further analysis.

The hourly total number of individuals per group category (only the “best” estimate was used for SAG and cc-pairs was calculated and adjusted for effort (total number of visual observation hours varied between days).

5.6 Results

5.6.1 PASSIVE ACOUSTIC MONITORING

A total of 44 days of recordings were collected in 2014 (Table 3). Out of this, a total of 29 clock hours with sound recordings with simultaneous visual observations were available for comparison and 23 clock hours contained either or both up-calls and gunshots (79%) (Figure 9).

Gunshots and up-calls were recoded on the loggerhead throughout the visual observation period. The 3 September was the day with the most recorded gunshots and up-calls. Both call types decreased on 4 September and the number of gunshots declined hereafter. Up-calls showed a second peak in occurrence however on 13 September (Figure 9).

No correlation was found in any of the relationships between call types and group type present (Figure 10).

FIGURE 9
Total number of up-calls (NU) and gunshots (WG) recorded from the PAM station and the total number of southern right whale groups (SAG, CC-pairs, and UA) visually observed (per hour of day) during the 7 days of study period in September 2014 in Pearly Beach South Africa. The Y-axis represents the number of calls and number of sightings.

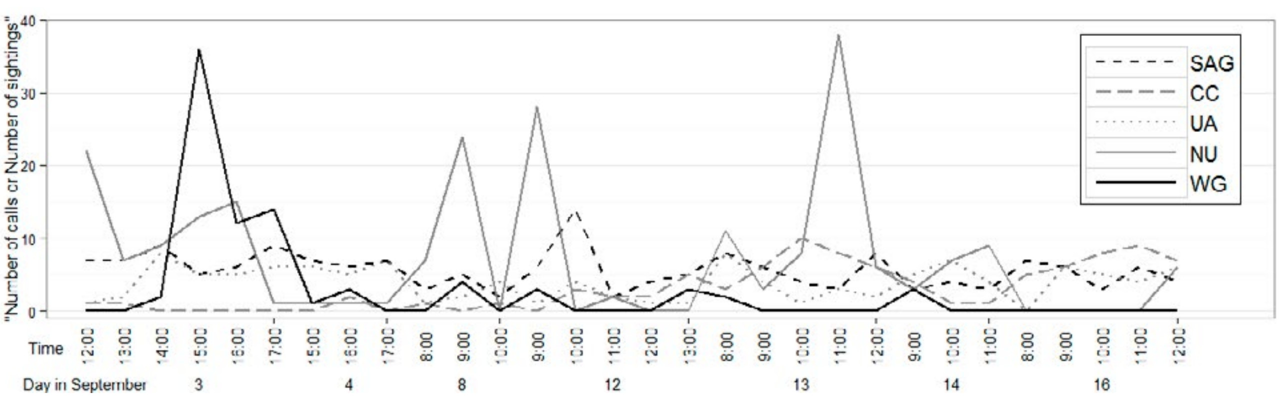
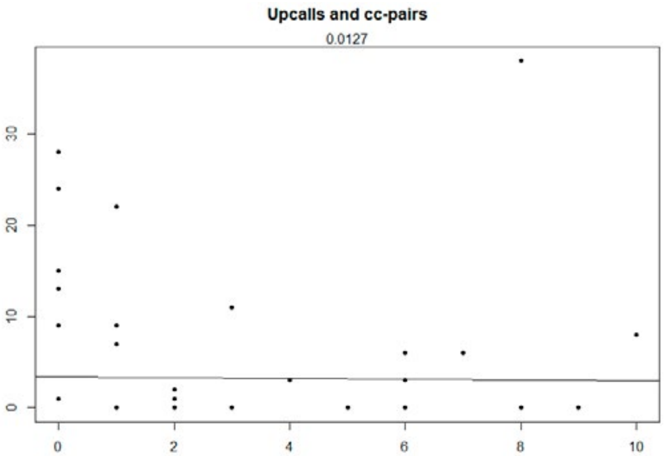


FIGURE 10

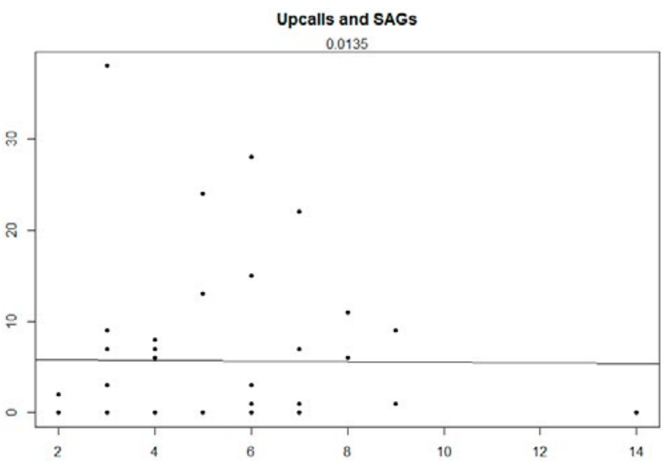
Test for correlation between the total number of Southern right whales per category (SAG, CC-pair, and UA) and total number of calls (up-calls and gunshots) per visual hour. No correlation was found in any of the relationships. The black line is the regression line. R^2 values are given above each scatterplot.

Relationship between up-calls and the three southern right whale group types. Total number of groups (x-axis) and total number of up-calls (y-axis) per visual hour.

A

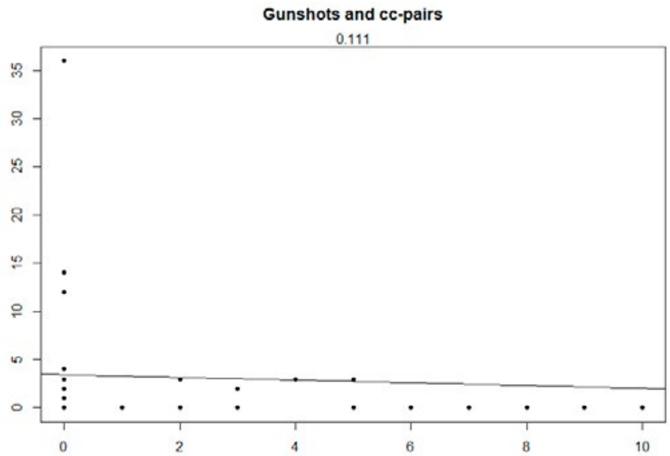


B



Relationship between gunshots and the three southern right whale group types. Total number of groups (x-axis) and total number of gunshots (y-axis) per visual hour.

C



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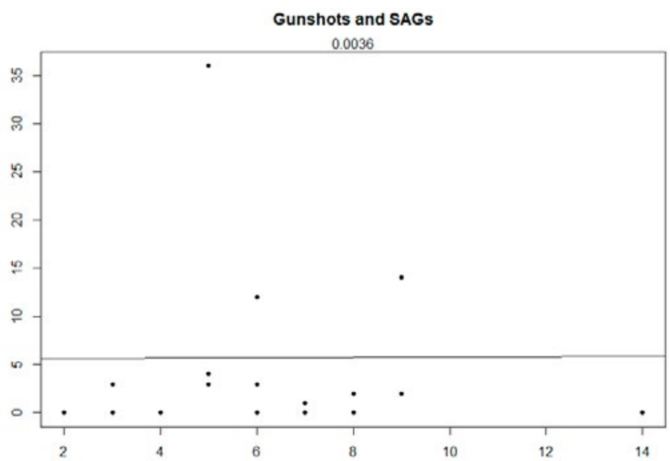


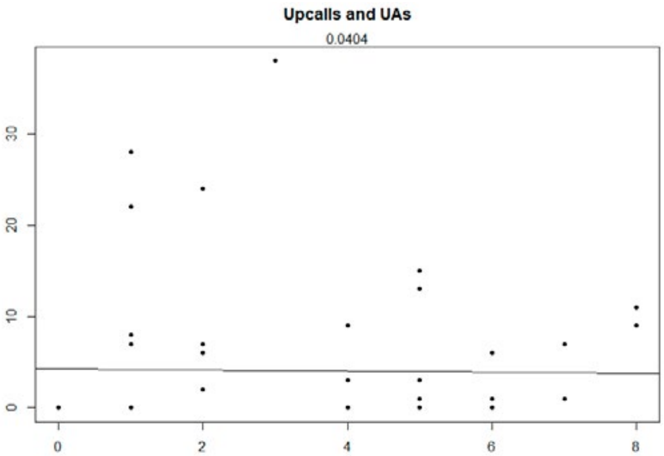
FIGURE 10

Test for correlation between the total number of Southern right whales per category (SAG, CC-pair, and UA) and total number of calls (up-calls and gunshots) per visual hour. No correlation was found in any of the relationships. The black line is the regression line. R^2 values are given above each scatterplot.

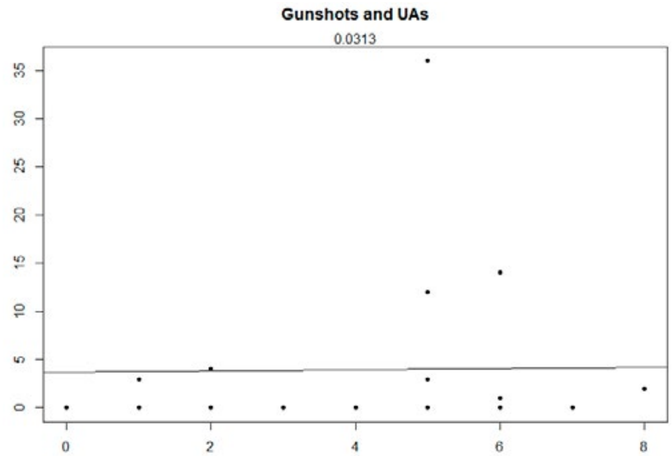
Relationship between up-calls and the three southern right whale group types. Total number of groups (x-axis) and total number of up-calls (y-axis) per visual hour.

Relationship between gunshots and the three southern right whale group types. Total number of groups (x-axis) and total number of gunshots (y-axis) per visual hour.

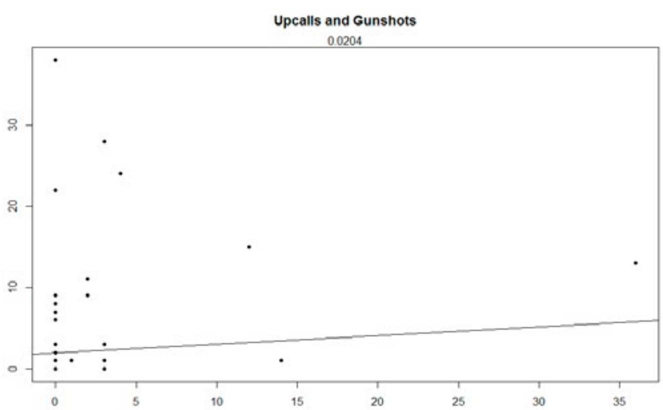
E



G



F



5.6.2 SOUTHERN RIGHT WHALE CALL ANALYSIS

A total of 255 southern right whale up-calls and 83 gunshots were recorded during the visual observation periods. Six gunshots were recorded at the maximum sampling rate of 80 kHz and the centre frequency of half of these gunshots was above 30 kHz.

Gunshots had a higher centre frequency than the up-calls of the southern right whales and were short in duration. The upper frequency bound of the gunshots extended to 5 714 ± 5 603 Hz (SD). A total of 77 gunshots were recorded at the low frequency sampling rate of 10 000 Hz. The centre frequency of these gunshots was 4 605 ± 954 Hz(SD) and hence limited by settings of the recording equipment. Six gunshots were recorded at the high frequency sampling rate of 80 kHz. This sampling rate captured the entire bandwidth of the gunshots: the centre frequency of half of these was above 30 kHz (centre frequency 1 426 ± 976 Hz (SD)) (Table 5).

The up-calls of southern right whales whales were tonal, frequency modulated up-sweep sounds with a mean centre frequency of 107 ± 16 Hz (SD), mean start frequency of 56 ± 13 Hz (SD), and mean duration of 0.92 ± 0.28 s (SD).

5.6.3 HUMPBACK WHALE CALL ANALYSIS

Song of humpback whales was frequently recorded on the acoustic logger. Some of the themes contained up-calls that were superficially similar to southern right whale up-calls (Figure 6 and 8). However, a comparison of 20 up-call units from the theme of a humpback song (Table 5) and 255 southern right whale up-calls showed that low frequency (two tailed unpaired student t-test,

TABLE 5 CALL CHARACTERISTICS OF SOUTHERN RIGHT WHALE GUNSHOTS, SOUTHERN RIGHT WHALE UP-CALLS, AND HUMPBACK WHALE UP-CALLS (MEAN ± STANDARD DEVIATION).

	Southern right whale Gunshots (n=83) Mean value ± SD	Southern right whale Gunshots (n=6) Sampling rate = 80kHz Mean value ± SD	Southern right whale Up-call (n=255) Mean value ± SD	Humpback Up calls (n=20) Mean value ± SD
Low Frequency (Hz)	80 ± 46	81 ± 16	56 ± 13	94 ± 12
High Frequency (Hz)	5 714 ± 5 603	19 941 ± 14 295	184 ± 54.5	198 ± 8
Duration (end - begin time) (s)	0.36 ± 0.15	0.19 ± 0.019	0.92 ± 0.28	0.63 ± 0.11
Centre time (s)	6526 ± 5089	520 ± 176	6477 ± 4782	7271 ± 41
Time 5%	6526 ± 5089	293 ± 30	6477 ± 4782	7271 ± 41
Time 95%	6526 ± 5089	7116 ± 2445	6478 ± 4782	7271 ± 41
Duration 90% (s)	0.11 ± 0.09	0.07 ± 0.07	0.55 ± 0.18	0.39 ± 0.03
Q1 time (s)	6526 ± 5089	520 ± 176	6477 ± 4782	7271 ± 41
Q3 time (s)	6526 ± 5089	520 ± 176	6477 ± 4782	7271 ± 41
Centre frequency (Hz)	833 ± 713	1 426 ± 976	107 ± 16	149 ± 6
Peak frequency (Hz)	564 ± 534	1 003 ± 1 075	107 ± 18	150 ± 9
Q1 frequency (Hz)	446 ± 233	508 ± 90	95 ± 15	140 ± 7
Q3 frequency (Hz)	1 961 ± 1 326	3 464 ± 1 141	122 ± 19	157 ± 8
Frequency 5% (Hz)	248 ± 88	293 ± 30	80 ± 14	122 ± 10
Frequency 95% (Hz)	4 035 ± 1 600	7 116 ± 2 445	146 ± 30	173 ± 8

t = 12.7, p < 0.001), high frequency (t = 3.8, p < 0.001), centre frequency (t = 12.241, p < 0.001), duration (t = 12.6, p < 0.001) and peak frequency (t = 18.1, p = < 0.001) differed significantly from southern right whale up-calls.

The hourly distribution of total call numbers (Figure 9) varied between days and time of the day and calls were found to be distributed in peaks, rather than evenly distributed throughout the day. No consistent pattern was observed in the time of day that vocalisations were recorded, and there was considerable variation in the number of vocalisations recorded on different days (Figure 9).

5.6.4 LAND-BASED THEODOLITE TRACKING

A total of 193 SAGs, 97 cc-pairs, and 124 sightings of UAs were observed. Additionally, 26 vessels were observed during this period. The largest SAG consisted of eight animals (best estimate) observed on 3rd September at 15:10. The group size of the SAG varied from minimum 2.4 ± 0.8 animals, best 2.8 ± 1 animals, and maximum 3.5 ± 1.1 animals. The day with the most observed vessels was 13 September with a total of seven vessels during 5 hours of observation.

The total number of individuals per visual observation hour per day was calculated (Figure 14). Days with the highest counts of animals (regardless of group category) were the 3, 13, and 16 September. The day with the lowest number of whales in the bay was 8 September (Figure 14). No individuals or groups of humpback whales were observed during any of visual observation periods.

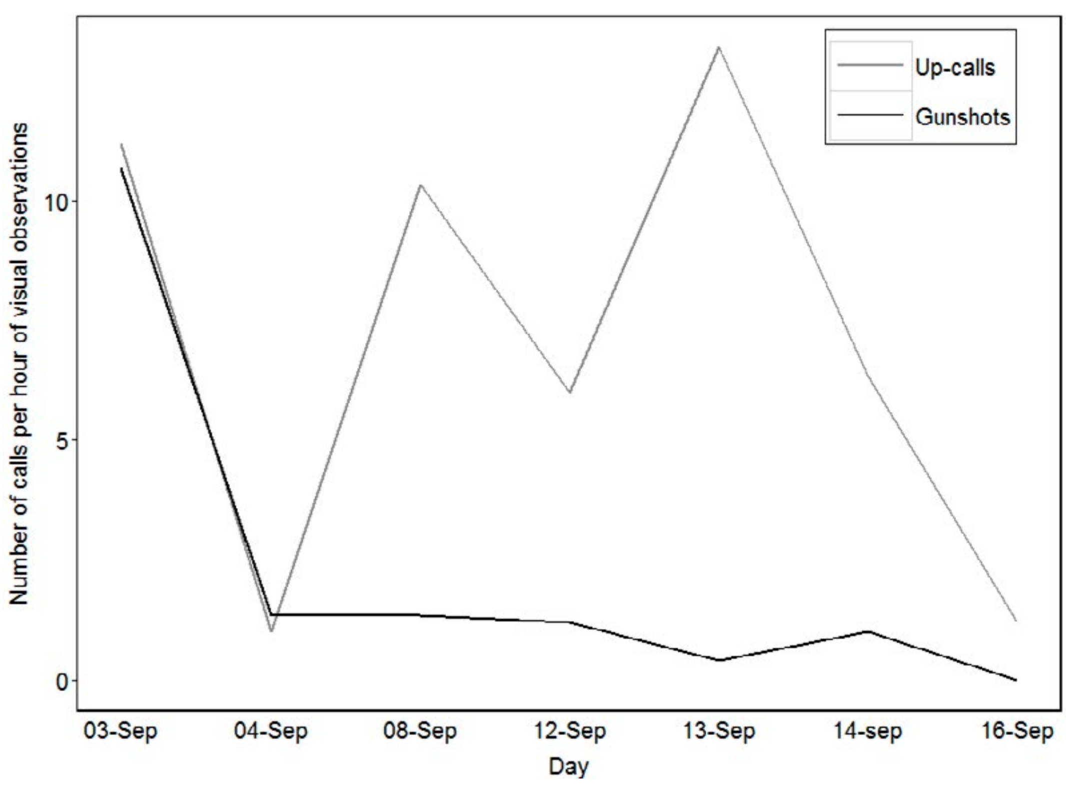


FIGURE 11
Total number of up-calls (NU) and gunshots (WG) per visual observation hours per day.

FIGURE 12

Cumulated best, minimum, max number of individuals in SAG groups per visual observation hours per day.

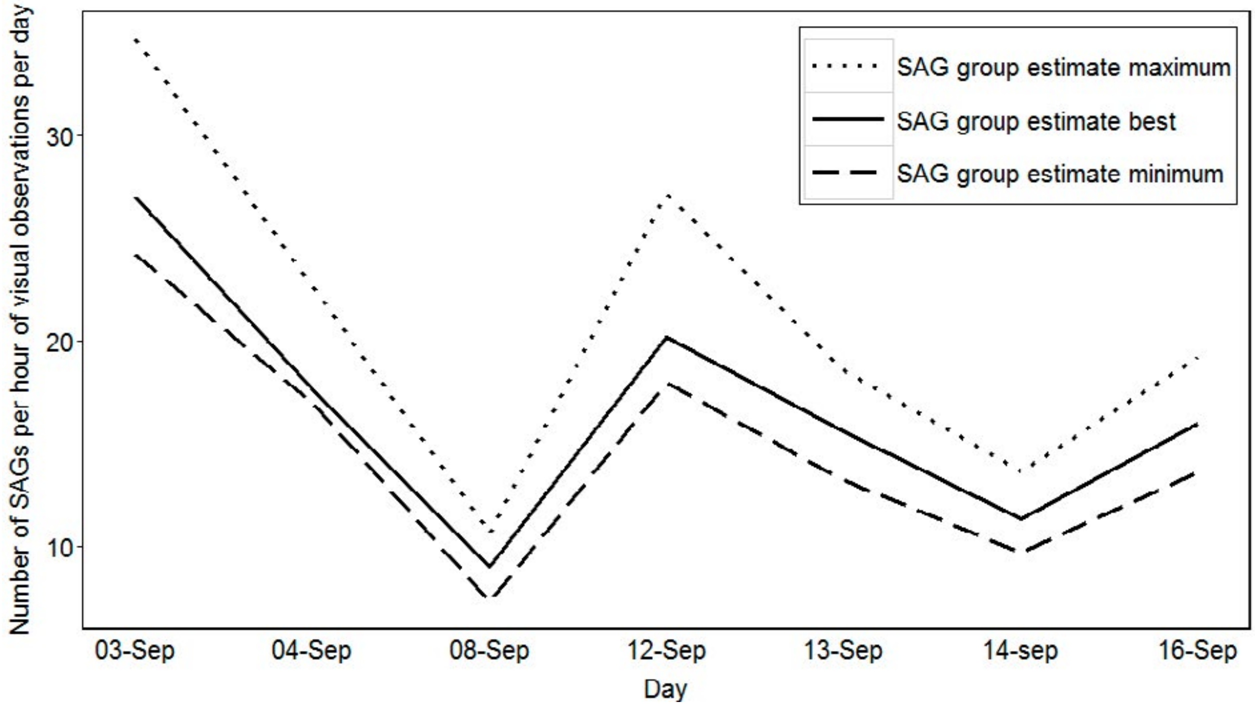


FIGURE 13

Total number of individuals of SAGs (best), cc-pairs (best), UAs, and vessels per visual observation hours per day.

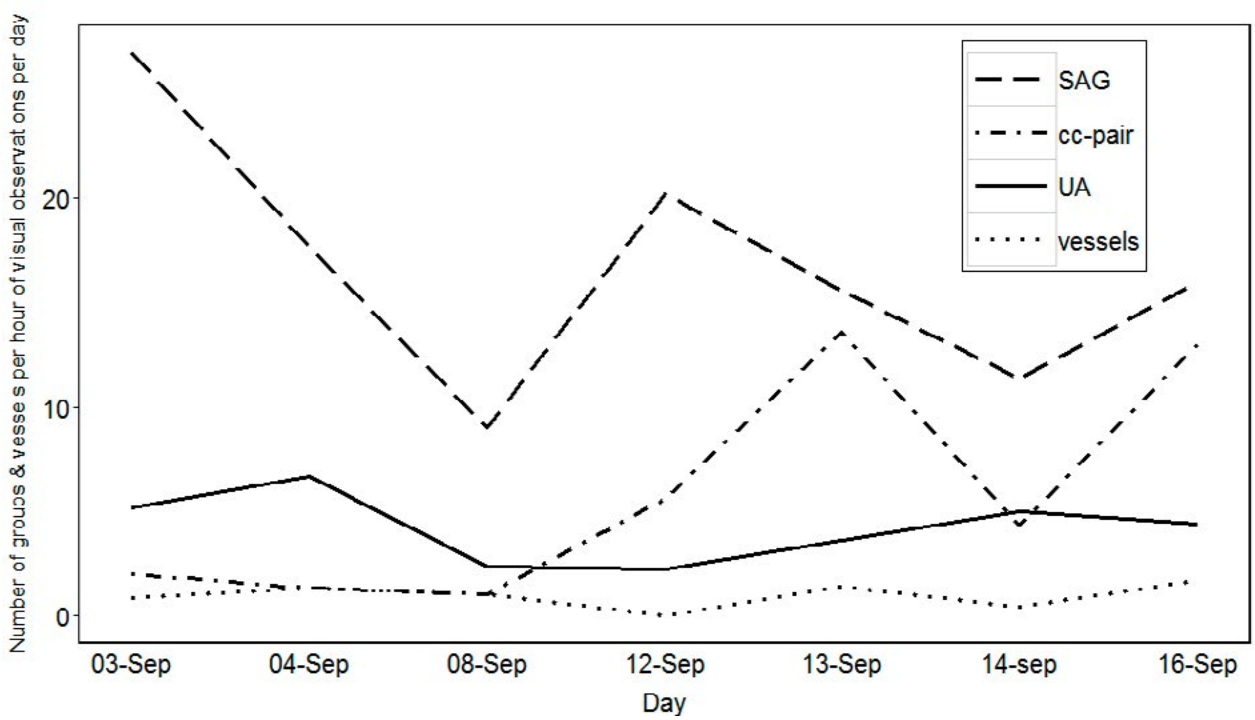
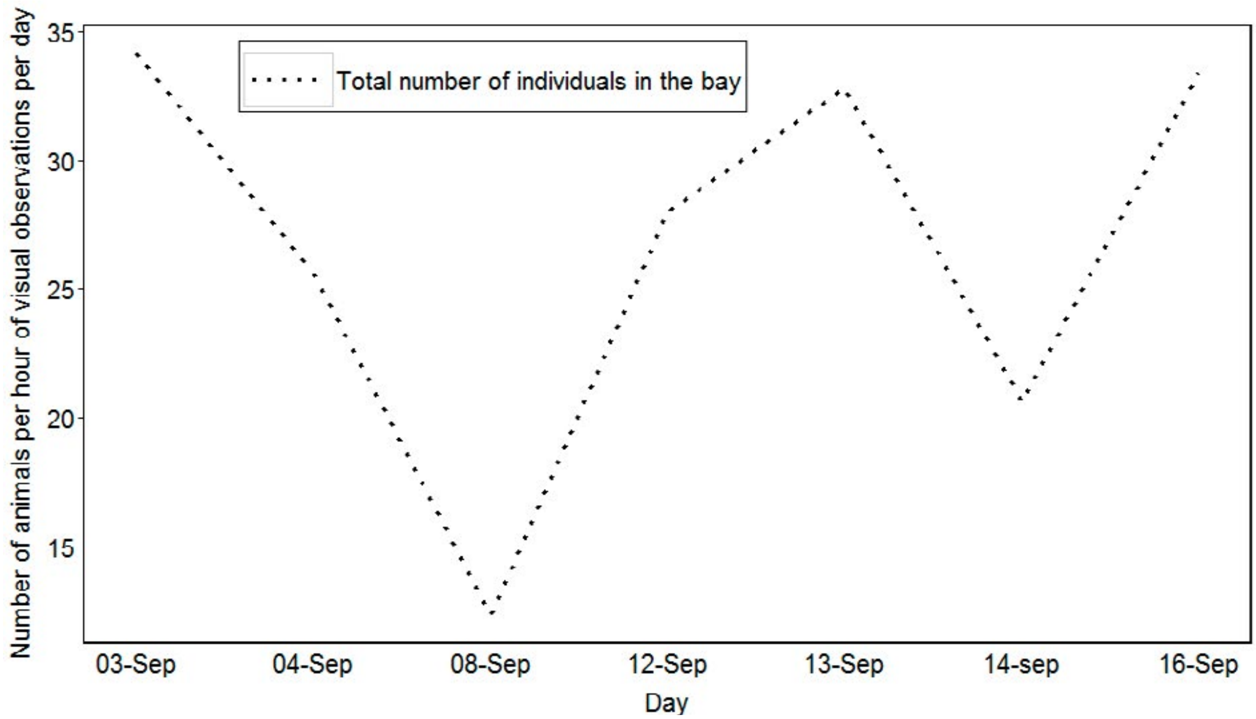


FIGURE 14
Total number of individuals across all groups: SAGs (best), cc-pairs (best), and UAs per visual observation hours per day.



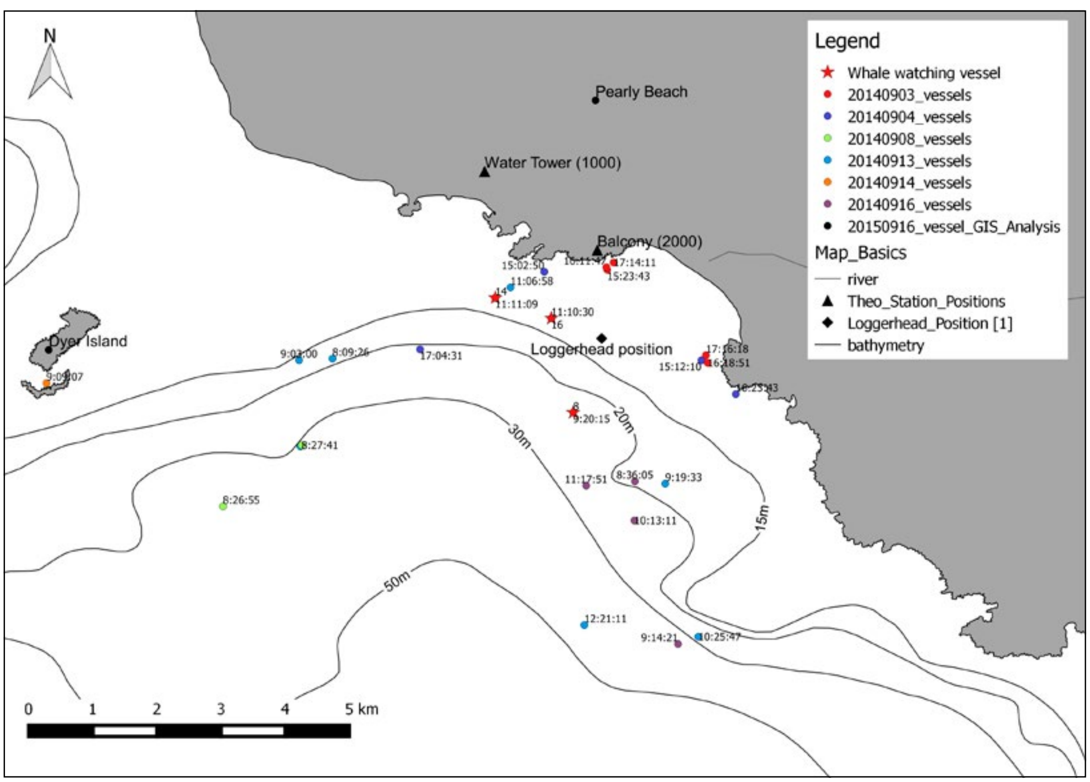


FIGURE 15
Positions of observed vessels per day with visual observations. The whale watching vessel was observed on 8, 14 and 16 September.

Vessels observed on 3 September were abalone fishermen, which also involved several divers in the water. Other vessels were leisure fishing vessels.

Retrieving the DSG-Ocean Loggerhead.

PHOTO CREDIT
HARRY STONE

5.6.5 PASSIVE ACOUSTIC MONITORING & LAND-BASED THEODOLITE TRACKING

Out of 29 hours of visual observations where animals were present, sounds attributable to southern right whales were recorded in 23 hours (78%). The sound recordings are combined with the visual observations in Figure 9. There were four periods with a high occurrence of up-calls (more than 20), but no clear association with a single group type:

1. A peak of up-calls on 3 September at 12:00 and high numbers of SAGs

2. A peak of up-calls and gunshots on 8 September at 9:00 and an increase of SAGs and UAs from the previous hour

3. A peak of up-call and gunshots on 12 September at 9:00 and high number of SAGs

4. A peak of up-call on 13 September at 11.00 and a high number of cc-pairs and an increase of UA from the previous hour but a decrease of SAGs from the hour before.

The peak in gunshots on 3 September at 15.00, 8 September at 9:00, and 12 September at 9:00 occurred at the same time as peaks in up-call and high numbers of SAGs (Figure 9). The three main peak days with up-calls were the 3, 8 and the 13 September with more than 10 up-calls (Figure 9). The total number of whales and individuals in SAGs were also high on these days, but on 8 September there was a decrease in the number of individuals. Thus, there was no clear association between group type present or total number of individuals observed and the rate at which vocalisation was recorded.

5.7 Discussion

5.7.1 PASSIVE ACOUSTIC MONITORING

When using PAM to detect vocalising cetaceans, it is important to take into account that it is not possible to detect silent animals (Matthews et al. 2001). In the study period southern right whale specific sounds (gunshots and up-calls) were detected in 23 out of the 29 hours of recording with simultaneous visual observations of right whales (79%), which indicate that PAM is a useful technique for monitoring the overall presence of southern right whales in an area. Southern right whales were visually present in all observation hours.

Up-calls recorded in this study were in the same frequency spectrum as up-calls recorded by Hofmeyr-Juritz and Best (2011) and generally had the same characteristics as the studies of up-calls of southern right whales from Argentina (Clark 1982), and New Zealand (Webster 2015). Up-calls from North Atlantic right whales are also similar to those of southern right whales: the peak frequency reported by Matthews et al. (2001) appeared to be slightly higher, whereas that reported by Parks and Tyack (2005) and Urazghildiiev and Parks (2014) is comparable to the present study. The up-calls of the North Pacific right whale is shorter in duration (0.7 s) and has a higher lowest frequency (90 to 150 Hz) than those described here (McDonald and Moore 2002). Gunshots recorded in this study were attributed to southern right whales and were found to be similar in duration (0.11 ± 0.09 s (SD)) to those of animals recorded in Argentina (Clark et al.1982), lasting 0.07 ± 0.04 s (SD) and New Zealand lasting 0.2 ± 001 s (SD) (range 0.1 - 0.4 s) (Webster 2015). Six gunshots were recorded using the maximum sampling rate of 80 kHz and the centre frequency of half of these gunshots were above 30 kHz. This shows that the gunshots extended far above the Nyquist frequency of recordings made at the lower sampling rates and that a relatively high sampling rate was required to capture the full bandwidth of these sounds.

There was no apparent relationship between either the group type or total number of whales in the area and the number of calls recorded. This could be caused by the relatively short sound sampling period, but is compatible with the previous finding of the complex relationship between the number of southern right whales, their group structure, and sound production (Hofmeyr-Juritz and Best 2011). Parks et al. (2011) found that the behavioural state was the primary factor determining the call rate for northern right whales and that the highest calling rates were detected from SAGs and travelling animals, and the lowest calling rates during logging and foraging. A problem with the present study was also that at any time at least two types of groups were present simultaneously. To be able to assign calls to specific groups or animals, future studies in this area would need to apply localisation (Hofmeyr-Juritz and Best 2011), use acoustic tags (Parks et al. 2005, Parks et al. 2011), or collect data in areas or times of lower animal density when overlap is likely to be less of an issue.

In this study, only two call types (gunshots and up-calls) were investigated. Although the complete sound repertoire of southern right whales is broader than these two call types (Hofmeyr-Juritz and Best 2011), they have been well described and used in several other studies for long term presence and behavioural monitoring (Matthews et al. 2001, Ildar R. Urazghildiiev et al. 2002, Parks et al. 2005, Laurinolli et al. 2006, Urazghildiiev and Clark 2006, Urazghildiiev and Clark 2007, Munger et al. 2008, Urazghildiiev et al. 2008, Clark et al. 2010, Hofmeyr-Juritz and Best 2011, Munger et al. 2011, Mussoline et al. 2012). Two other baleen whale species, Bryde's whales and humpback whales, frequent the study area (Chapter 11, Vinding et al. 2015b) which may reduce the certainty of species identification by acoustic means, as shown by similarity of up-calls in a humpback song (Figure 6 and 8). Analysis of frequency and duration of these calls showed that they could clearly be discriminated from those of southern right whale up-calls (Table 5). This result is promising regarding future species discrimination based on the characteristics of up-calls. Humpback whales are known to adjust their song and call types over time (Payne and Payne 1985), which might results in further convergence or overlap of call parameters with right whales over time, thus highlighting the importance of a thorough knowledge of vocalisation repertoire of the two different species. It is important to be able to distinguish species-specific calls when using PAM, and especially when using automatic call detectors (Munger et al. 2005, Mussoline et al. 2012). The use of PAM with North Atlantic right whales has proven very useful in the ability to detect whale presence in an area of high risk of ship strikes (Morano et al. 2012, Mussoline et al. 2012), it has also shown that the detection of animals increased compared to conventional visual observation techniques (Mussoline et al. 2012).

The recording of humpback whales in our study was unexpected, as no humpback whales were visually observed during any of the scans used in this analysis, there was a low number of humpback whales in the area overall (Vinding et al 2015), and those observed seemed to use the area predominantly for migration rather than mating (Vinding et al. 2015a). Additionally, no humpback whale songs were reported from a previous study on southern right whale sounds from Walker Bay during the late 1990s (Hofmeyr-Juritz and Best 2011, Hofmeyr-Juritz 2015. pers. comm. July.). This difference could possibly reflect a change in the presence of humpback whales in the two areas or an increase in the humpback whale populations (Findlay and Best 1996, Elwen et al. 2013). Studies on humpback whale vocalisation has described that songs and isolated social calls are not only associated with the mating grounds but also emitted during the southwards migration from Australia (Dunlop et al. 2008), and a number of studies have recorded humpback whale song at the feeding grounds (Stimpert et al. 2012, Garland et al. 2013).

The recording of humpback whales in this study shows that using PAM is a useful technique in this acoustically fairly unexplored environment and can provide new insight into the presence and behaviour of cetaceans here that are not necessarily possible through visual means. The use of a display song of the humpback whale (*Megaptera novaeangliae*), consisting of themes, phrases and units, is a well-known example of sound communication. The songs can last 5 to

Jean-Piere Bota from Shark Cage Diving Unlimited, retrieving the DSG-Ocean Loggerhead.

PHOTO CREDIT
HARRY STONE

20 minutes and consist of single units, which combined form phrases, repeated phrases form themes, and repeated themes form a song (Payne and McVay 1971, Payne 1995, Cholewiak et al. 2013). It is unknown which population these humpback whales belong to as the study area is situated at the verge of the migration routes of two breeding stocks; the population migrating up the east coast of Africa: Breeding Stock C (BSC1) (Best et al. 1998), and the other migrating up the west coast, sub-stock BSB2 (Barendse et al. 2011). Until now, it was also unknown that the humpback whales sing in the area and an analysis of the song pattern could possibly determine the affinity of the animals migrating through the area. The songs of the humpback whales occasionally overlapped with some of the calls of the southern right whales and hence masked the sound communication of the right whales and thereby potentially reduced their communication ability and audible range. Further studies are required to investigate if the presence of humpback song affects the communication and call rate of the southern right whales.

Human-related noise pollution was mainly associated with the local whale watching vessel, leisure fishing and “vessels of recreational divers”. There were no patterns in the presence of vessels (Figure 15) and the sample size of vessels was too small to ascertain any possible correlation with the number of up-calls and gunshots.

5.7.2 BIAS AND CONSIDERATIONS

Investigating the sound production of animals at sea can be challenging, particularly when visual confirmation of species, group structure, and behaviour is needed. The use of land-based theodolite stations for visual detection is a non-invasive technique, which does not impact the behaviour of the cetaceans, nor does it interfere with the sound recordings (engine noise). This technique also enables the observation team to survey a large area and obtain accurate positions of animals in the vicinity of the hydrophone. Observations conducted from a vessel are more restricted due to the low position of the observers, and it is only reliable to include observations of animals in close vicinity to the vessel.

5.8 Conclusion

It was possible to identify and monitor the presence of SRW acoustically from their up-calls and gunshots, although linking to group size or group type was not possible. The up-calls of southern right whales could be distinguished from the up-call units that were recorded as part of a theme of a humpback song and it should be possible to develop an automatic detector that can differentiation these species. Another area of future acoustic interest is the investigation of sound communications of cc-pairs and sound production development in calves. Future investigations of southern right whale vocalisation in South Africa are recommended based on bottom-moored acoustic arrays or/and D-tags.

5.9 Acknowledgement

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Research permit: This study was conducted under the permit of Mammal Research Institute, Whale Unit, approved by the South African Department of Environmental Affairs "Environmental research permit for the purpose of a scientific investigation or practical experiment in terms of section 83 of the marine living resources act, 1998 (Act no. 18 of 1998)" Permit number: RES2014/73. Research ethics granted by the "Animal use and care committee" University of Pretoria.

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6

6 Concluding remarks

6.1 Distribution, habitat use, and behaviour

The main aim of this study was to provide scientific evidence of the distribution, habitat use, and behaviour of cetaceans in the Greater Dyer Island area, Western Cape. It was documented that there are five cetacean species using the area frequently, whereof the dominant species was the southern right whale (*Eubalaena australis*) for which it appears to be an important nursing and socialising area. Two other baleen whale species were found to frequent the area; the humpback whale (*Megaptera novaeangliae*) migrating through the area and the endemic Bryde's whale (*Balaenoptera brydei*) which seemed to use the area as a summer feeding ground. Finally, two inshore species of dolphins were recorded in the area; the Indian Ocean humpback dolphin (*Sousa plumbea*), and the Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) who used the bay for various behaviours, feeding, resting, and socialising. Three additional species were rare visitors to the area. Common dolphins (*Delphinus* spp) were the most frequent of these visitors, whereas killer whales (*Orcinus orca*) and Heaviside´s dolphins (*Cephalorhynchus heavisidii*) were only observed twice over a 10-year period.

The area was populated year-round by the different cetacean species and the southern right whales were by far the most frequent species with a marked seasonal presence from August to December. They were recorded either unaccompanied or as part of either surface active groups or cow-calf pairs and they were predominantly located close to shore, as were the two main dolphin species which mainly occurred in the summer months. Bryde's whales and humpback whales were located further offshore. Humpback whales exhibited a primarily winter occurrence where as the Bryde's whales mainly were present in the summer and autumn months.

6.2 PAM

This study found that it is possible to use PAM as a monitoring tool for southern right whales based on up-calls and gunshots, which were recorded 79% of the time when animals were present. The analysis was based on these two sound types since it was difficult to distinguish between stand-alone calls from humpback whales and the southern right whale calls other than up-calls or gunshots. It is therefore recommended to include all call categories if possible (Urazghildiiev and Parks 2014), as it can result in a higher detection rate of whales.

Due to the simultaneous presence and large number of individuals in the bay from the three group categories, SAGs, cc-pairs and UAs, it was impossible to link a specific vocalisation pattern to any of the group types. Sound recordings from the shoulder seasons with only one of the group types and a few animals present in the bay would enable such an analysis. Instrument failure during a number of deployments resulted in a significant loss of sampling time and recordings during e.g. the important month of December, when primarily cc-pairs are present in the bay.

A next step of the analysis would be to investigate the obtained sound recordings for a diurnal pattern of up-calls and gunshots. Such a pattern was found in the study of Bort et al. (2015) of North Atlantic right whales, where there was a bimodal diurnal pattern with peaks in up-calls from 4:00 to 8:00 and 13:00 to 22:00 and a peak in gunshots from 16:00 to 22:00. Up calls from southern right whales were found to vary and it would be interesting to investigate the variation of up calls between different individuals. Establishment of an array of hydrophones (in a location with low background noise and away from the reef) or by using D-tags and accelerometer would enable such investigations. The same individuals of southern right whales are known to return to the coast of South Africa and it would be interesting to investigate if it is possible to determine the degree of kinship between individuals through their vocal communication.

The vocalisation pattern and the development of sound repertoire between southern right whale cow and calf should be investigated. Such investigations would only be possible with the deployment of D-tags and accelerometer, particularly as the density of cc-pairs in the area is very high and the animals move in and out of the area, and hence it would be difficult to follow the same cc-pair for a prolonged time period.

Songs from humpback whales were recorded in the months of September and October 2014. Based on the sound propagation model of the area ("Sound Propagation Modelling Report Gansbaai)" in Appendix 8, it is calculated that the song from the humpback whales could originate from animals more than 20 km off shore, which is at beyond the 50 m isobaths. This is at the edge of the visual range of the team at the land-based theodolite stations (Chapter 4) and beyond the normal limit of the route for the WWV. A low number of humpback whales were sighted visually in September and October from the WWV (Chapter 2) (2003 to 2012) and from the theodolite stations (Chapter 4) (2011 to 2014). These observations were recorded within 20 km from shore, but the fact that the humpback whales were singing in the area is novel. Hofmeyr-Juritz and Best (2011) did not record songs from humpback whales in 1999, whereas the recordings from the present study contained a considerable number of humpback songs. This difference could possibly reflect the increase in the populations of humpback whales (Findlay and Best 1996, Elwen et al. 2013) or a difference in the presence of humpback whales in the two areas (Walker Bay and Pearly Beach). The obtained recordings of humpback whale songs have not yet been analysed extensively, but during the southern right whale sound analysis it was clear that some of the frequencies of the song and the potential stand-alone sounds from the humpback whales were in the same frequency spectrum or slightly higher than the vocalisation sounds of the southern right whales. The singing of the humpback whales occasionally overlapped with some of the calls of the southern right whales and hence masked the sound communication of the right whales thereby potentially reducing the communication ability and range of them. Further studies are required to investigate if the presence of humpback song affects the communication and call rate of the southern right whale.

The next step in the sound analysis will be to identify the song pattern of the humpback whales and compare the themes and phrases of the songs with other humpback whale populations. Particularly the population associated with the East coast and the population associated with the West coast. Such an analysis could possibly shed light on the affinity of the animals migrating through the area, if it is possible to distinguish between the song patterns of the populations and assign the song pattern from the Greater Dyer Island area to one of these populations.

It is important to continue to record the sounds of cetacean species in the area. Recordings of baleen whales would allow to follow a potential change in the song patterns of the humpback whales and to further investigate the sound communication of southern right whales. The use of

PAM in monitoring of tooth whales is still in the developing stages in South Africa. Basic knowledge of species recognition based on whistle contours is currently being investigated and once such a tool is developed there will be multiple locations along the South African coastline where it would be beneficial to establish monitoring of delphinid species through the use of PAM. The area and the adjacent Walker Bay area is known for sardine and anchovy fishery and future investigations of the potential impacts of underwater noise from vessels on particularly the baleen whale species could be conducted.

The development of a custom designed mooring system, which was able to withstand the harsh local inshore conditions, remain in the same location, and not create noise when moving in the water column, became an important part of the PAM study. The knowledge obtained and the final design of the robust and yet flexible mooring system in this study can be used in future PAM studies and it is hoped that similar future projects can save costs, energy, and precious time by using this mooring design.

6.3 Platforms of opportunity

Two different platforms of opportunity were used during the study, the local whale watching vessel “Whale whisperer” and the local airplane “African wings”. Both platforms provided crucial important data on the cetacean species in the study area (Vinding et al. 2014, Best et al. 2015), which would not have been available otherwise. This confirms that collaboration between researchers and owners/operators of such platforms of opportunity can be of value when investigating the distribution, habitat use, and behaviour of cetacean species, particularly in otherwise data deficient areas and when obtaining long-term data sets (Vinding et al. 2014, Best et al. 2015).

The results of the analysis of the whale watching data revealed that there were certain areas of the data collection which could be improved to increase the outcome of the data analysis. The design of the data sheets, the use of simple behaviour categories, and spatial and temporal effort collection, in particular, were found to be key areas of which to improve the data quality (Vinding et al. 2014). The behaviour data collected from the WWV were discarded because the categories were too subjective and it was impossible to analyse the many different categories (Vinding et al. 2014). When collecting behavioural data in large amounts as for example from a whale watching vessel operating four trips a day, it would have been beneficial with fewer and stricter behaviour categories, which would have streamlined collection and hence enabled an analysis of the behavioural data. While using strict behavioural categories from platforms of opportunities it is important to leave space for descriptive comments, as was the case with the aerial observations of the orphaned calves. The results from observations from “African wings” of the behaviour of the orphaned calf and the different surrogate mothers, was novel and the most comprehensive of the four case stories of the southern right whale orphaned calves observed along the South African coast. The key-data in the study was the photographic evidence and the written descriptive observation notes of the behaviours of each of the different sightings. In such cases, it would be a disadvantage to have simple and strict behaviour categories, since the situation was complex and behaviours of all the involved animals over time were unpredictable and novel.

The two opportunistic sightings of Phocid seals, a leopard seal (*Hydrurga leptonyx*) (Vinding et al. 2013) and a crabeater seal (*Lobodon carcinophagus*) (Vinding et al. In prep) confirms the importance of the participation of the public and a well-established local stranding network. These two animals were discovered by locals who were patrolling the beach and knew whom to contact in case of washed up or stranded marine mammals. The local responsible stranding team knew how to respond, which samples to collect, and whom to inform at the governmental level.

Such opportunistic sightings are important to further understand the complexities and level of importance of different areas, and, as technology develops, it is possible to obtain opportunistic sighting data from an engaged public by using mobile phone apps such as "Coastal Walkabout" (Coastal-Walkabout 2015) and "Wild about whales" (Wild About Whales 2015). This is another dimension of opportunistic platforms, which will most likely increase in the future. The advantage of using these structured apps, is that it is possible to dictate strict criteria for the input and incorporate effort time, species, and simple behaviour categories, and provide photographic examples.

Chapter 3 and Vinding et al. (2014) both emphasise the need for world-wide guide lines regarding the design of the data sheet, data collection protocols, and data analysis protocols for platforms of opportunities. In some areas it could be beneficial to use the already designed mobile phone app when collecting data from, for example, a whale watching vessel.

When designing an observation sheet for a platform of opportunity it is important to consider the aim and the outcome of the data analysis. From the results of the analysis of the whale watching data it was evident that the following parameters should be included in an observation sheet (or app) if the aim is to obtain basic, temporal and spatial distribution pattern of the sighted species, and also be able to relate the sightings to group size and behaviour.

- Basic trip data per trip: Trip number, Spatial and temporal effort (to enable effort adjustment when analysing the data), and observer ID.

- Basic sighting data per sighting: Observation number, Sea state, water depth, water temperature, latitude and longitudinal position of sighting, species, group size, behaviour categories, comments, photographic material and reference ID to photos.

A simplified observation sheet for the local WWV in Kleinbaai could be designed as presented in Chapter 3.

6.4 Conservation and management

This study has shown that the area has a year-round presence of cetacean species and more than half of these are reliant on the inshore habitat, including the endangered Indian Ocean humpback dolphin and the seasonal southern right whales, which potentially makes them more exposed to human impacts. The main human impacts in the study area at the moment are related to tourism through whale-watching, shark cage diving vessels, high speed-boat training, or participating in the yearly 5-day Trans Agulhas race, and other vessel traffic such as abalone fishing (legal and illegal), and seasonal small vessel activity (particularly during holiday periods). The area could function as a corridor between locations for the two inshore dolphin species and increased underwater noise (from vessels and construction) could potentially function as a barrier and hence prohibit the animals from using the area and from moving between locations.

6.5 Literature

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Stranded southern right whale calf.

PHOTO CREDIT
HARRY STONE

Appendices

7 Appendix 1

7.1 The use of data from a platform of opportunity (whale watching) to study coastal cetaceans on the south west coast of South Africa

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THE USE OF DATA FROM A PLATFORM OF OPPORTUNITY (WHALE WATCHING) TO STUDY COASTAL CETACEANS ON THE SOUTHWEST COAST OF SOUTH AFRICA

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Effective conservation management requires information on wildlife abundance and distribution. Platforms of opportunity, including whale-watching vessels (WWV), can provide inexpensive and valuable information particularly in data deficient areas. This study analyzed over 5,500 cetacean encounters from more than 2,500 trips over 10 years by a WWV in the Western Cape, South Africa. Results were twofold: 1) providing spatial and temporal distribution patterns of the five main cetacean species for the area (southern right, humpback, and Bryde's whales, Indo-Pacific bottlenose and Indian Ocean humpback dolphins) and the first long-term, year-round data for this area; 2) showing that regularly recorded opportunistic encounters from a WWV constitute an important source of baseline information. Caveats and limitations of data from WWV are discussed and advice regarding data collection from platforms of opportunity is provided. Particularly, the lack of effort data and of clearly defined behavioral categories is emphasized and standardization of guidelines for data collection methods worldwide is suggested.

Key words: *Balaenoptera brydei*; Cow–calf pairs; Distribution; Ecotourism; *Eubalaena australis*, Guidelines; Human impacts; *Megaptera novaeangliae*; Monitoring cetaceans; *Tursiops aduncus*, Seasonality; *Sousa plumbea*

Introduction

Southern Africa has a diverse cetacean fauna with 38 species known to occur (Best, 2007; Findlay, Best, Ross, & Cockcroft, 1992), including two endemic species: Heaviside's dolphin (*Cephalorhynchus heavisidii)* found on the west coast and an isolated and endemic "inshore" population of Bryde's whales (*Balaenoptera brydei spp*) (Best, 2007). The high diversity is partly due to the

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varied oceanography around the coast with the warm south-westward flowing Agulhas current in the Indian Ocean passing along the south coast of South Africa and the cold northward flowing Benguela upwelling current along the Atlantic coast (Ansorge & Lutjeharms in Best, 2007). Different marine mammal fauna are associated with each ecosystem; the furthest eastward or westward range extent of several species occurring in an area of overlap in the south-western corner of South Africa between approximately Saint Helena Bay in the west and Cape Agulhas in the east (Findlay et al., 1992). Apart from information from museum-housed specimens and stranding records, long-term research along this part of the coastline has targeted only the southern right whale (*Eubalaena australis*) (see Elwen, Findlay, Kiszka, & Weir, 2011, for review) identifying the right whale "season" as June–December along the Cape south coast (Best & Scott, 1993). Long-term or year-round studies are unavailable for the other cetacean species known to occur along this section of the South African coast and it is unknown how they are affected by human impacts. There are multiple anthropogenic threats to marine life along the southern African coast including physical changes to the coastline (Sink et al., 2012), pollution (Atkinson & Sink, 2008; Cockcroft, de Kock, Lord, & Ross, 1989; de Kock, Best, Cockcroft, & Bosma, 1994), potential establishment of nuclear power stations (Griffiths & Robinson, 2011), effects of fisheries including depletion of prey (Atkinson & Sink, 2008), entanglement in fishing gear (Atkinson & Sink, 2008; Meÿer et al., 2011), boat traffic including recreational, ecotourism, and fishing vessels (Elwen & Leeney, 2010; Meÿer et al., 2011; Turpie, Savy, Clark, & Atkinson, 2005; Waerebeek et al., 2006), and tourism in a broader sense (Sink et al., 2012). However, whereas knowledge of the abundance of animals, their distribution, genetic variability, and behavior is a basic requirement for effective conservation of species and ecosystems (Caughley & Sinclair, 1994), acquiring such data for cetaceans is difficult and costly (Redfern et al., 2006). Structured scientific studies rely on specialized and expensive staff, and intensive monitoring methods such as ship-based or aerial line transects, passive acoustic monitoring, or mark recapture studies (Hauser, VanBlaricom, Holmes, & Osborne, 2007). This makes it challenging to obtain the baseline information needed to assess population health and impacts of environmental changes or anthropogenic threats to cetaceans, or identifying key areas and seasons of cetacean activity to provide a basis for spatial or temporal management plans, potentially useful tools for the protection of cetacean species (Hoyt, 2011).

Observations from platforms of opportunity, such as whale-watching operations (Ingram, Walshe, Johnston, & Rogan, 2007), seismic survey vessels (de Boer, 2010; Weir, 2011), cruise ships (Williams et al. 2006), or ferries (Kiszka, Macleod, Van Canneyt, Walker, & Ridoux, 2007; Weir, Stokes, Martin, & Cermeño, 2004) have been used to provide alternative sources of data on cetaceans, especially in developing countries (Koslovsky, Halpin, & Read, 2008), and information on spatial distribution, temporal patterns in abundance, and behavior have been acquired (Hoyt, 2001; Koslovsky et al., 2008). However, such data need to be interpreted with caution, especially given spatial or temporal differences in effort or variation in observer ability to correctly identify species (Evans & Hammond, 2004; Hauser et al., 2007). In 1998, an estimated 9 million participants took part in commercial whale-watching activities in 87 countries. This number has increased annually by approximately 12.1% since 1991 (Hoyt, 2001). By 2008, the industry had increased to an estimated 13 million whale watchers in 119 countries (O'Connor, Campbell, Cortez, & Knowles, 2009). This increase in numbers and geographic coverage broadens the potential scope for collection of scientific information from this type of platform.

In South Africa, commercial whale and dolphin watching has been permitted by government since 1998 [Marine Living Resources Act (MLRA), 2008], regulated by the Department of Environmental Affairs (DEA). Regulation began in 1998 when 20 license-holder areas were designated along the approximately 3,000 km coastline, increasing to 25 areas in 2002 (Turpie et al., 2005). Each license area has one to three (maximum) operating whale-watching vessels (WWV). By law, the WWV may not approach cetaceans closer than 50 m, not spend more than 20 minutes at any encounter, nor spend time with cow–calf pairs, and operators must collect information on trip statistics including the species, number, and behavior of animals encountered, to submit to the DEA. In the absence of other studies, observations from WWVs operating along the south-western Cape coast offer a potentially valuable source of information on cetacean presence, distribution, and seasonality. In this study, data collected from a single WWV for the period 2003–2012 were used to assess the distribution and seasonality of all observed cetacean species between Danger Point and Quoin Point in the south-western Cape, after assessing the veracity and consistency of the data. Based on the findings, recommendations are provided as to how data collection by WWV can be improved in the interests of providing valuable scientific information for cetacean research or monitoring.

The Study

Study Area

The study area, from Danger Point in the west to Quoin Point in the east (Fig. 1), is whale-watching license area 10 (Turpie et al., 2005), where the company "Dyer Island Cruises" (DIC) has been the sole license holder since 2000, until 2010 when "Geyser Rock Tours" (GRT) started as the second whale-watching company. GRT conducted similar tours but operated far less frequently and stopped in 2013. Data from GRT have not been included in this study. The study area consists of two main bays with sandy beaches, namely Franskraal and Pearly Beach, which are separated by a rocky, kelp covered reef extending out to Dyer Island and Geyser Rock, approximately 10 km offshore. Both bays are characterized by a

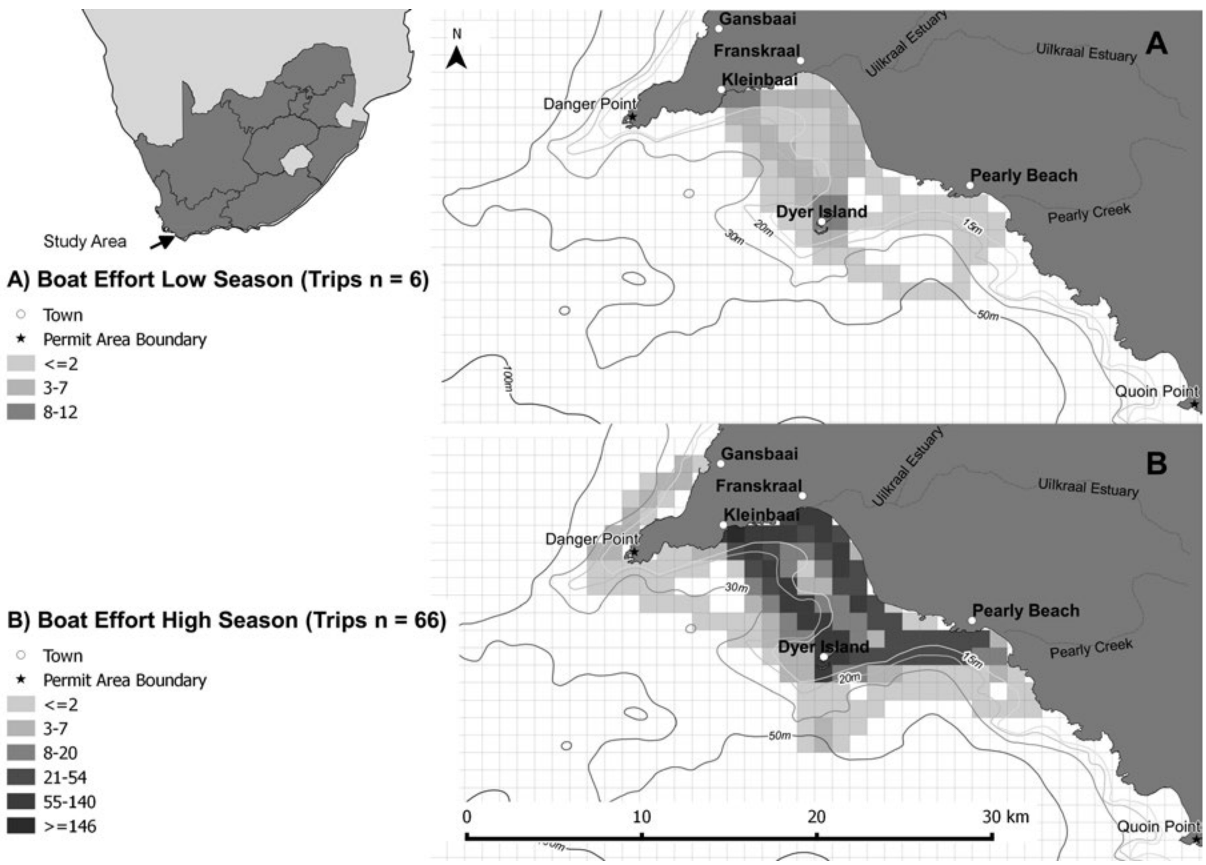


Figure 1. Map of the study area between Danger Point and Quoin Point, Western Cape, South Africa showing spatial effort of the whale watching vessel based on GPS tracks in the low season (January–June) (A) and in the high season (July–December) (B) collected between September 2011 and September 2012.

mixture of gently sloping sandy bottoms, a few shallow reefs, and kelp forests. Water depth in the study area does not exceed 100 m and the most frequently visited area is less than 30 m deep. Two small rivers flow into each of the main bays, Pearly Beach Bay (Pearly Creek) and Franskraal Bay (Uilkraal estuary). Pearly Creek is the smaller of the two, and is only open in the summer period. Since 2009, closure of the mouth of the Uilkraal estuary occurred periodically (Anchor Environmental, 2010). The estuary was closed during the following periods: January–July 2009, December 2009–October 2010, December 2010–July 2011, and October 2011–June 2012 and was manually opened each time (Anchor Environmental, 2010). Sea surface temperature in the study area has been described by Towner, Underhill, Jewell, & Smale (2013), who showed that the annual mean SST was 14.9°C (mean monthly temperatures ranging from 13.5°C to 16.2°C) without any strong seasonal patterns, but with short periods of cold water fluctuation due to upwelling in summer driven by the south-easterly winds (Roberts, 2005). The prevailing wind direction shifts throughout the year: in December–February (summer) winds are predominantly southerly or south-easterly, in March–May (autumn) they are southerly, south-easterly, or north-westerly, in June–August (winter) they are north-westerly, south-easterly, or south-westerly, and in September–November (spring) they are south-easterly, southerly, or south-westerly (Law, 1999). The study area is situated inshore of the Agulhas Bank, which forms the southern boundary of the Benguela upwelling system, and displays characteristics of both an upwelling system and a temperate shallow shelf system (Hutchings et al., 2009).

Data Collection and Validation

Throughout the 13 years of observations from the WWV (2000–2012), 14 persons were responsible for data collection as either skippers or biologists/guides on board (see Acknowledgments). In 2000 there were whale-watching trips only during October–December and in 2001–2002 only during July–October, whereas trips were conducted year round from 2003 to 2012. For consistency, only 10 years of data from 2003 to 2012 were included in this study.

On each trip, the following data were collected: date, daily trip number, departure time, and weather conditions including wind speed, wind direction, and sea state or category. When cetaceans were encountered, the location (latitude and longitude), species, number of groups and individuals, presence of calves, animal behavior, and photo documentation were recorded.

The probability of sighting a cetacean at sea is reduced with increased sea state (Bailey, Corkrey, Cheney, & Thompson, 2013; Redfern, Barlow, Ballance, Gerrodette, & Becker, 2008). Whereas for larger whales it is possible to conduct scientific surveys in up to sea state 5 (Thiele, Chester, & Gill, 2000), for dolphins a sea state of <3 is recommended (Reeves & Brownell, 2009). The WWV trips in this study occurred in a wider range of weather conditions than those normally considered suitable for scientific surveys. Only a single value of sea state was recorded per trip with insufficient record of wind strength or direction, thus, it was not possible to account for variation in sighting conditions within a trip. Sea state conditions within the study area can vary owing to location and prevailing wind direction, thus sheltered areas can have calm seas at the same time as the exposed locations undergo rough seas. For instance, Pearly Beach is exposed to the southerly winds and fairly protected from the northerly winds while the waters around Dyer Island are exposed to all wind directions. The relationship was investigated between weather conditions and number of encounters for each of the five main species encountered by comparing the number of encounters of each species in each sea state at Beaufort 1 to 5 and the categories "calm" and "choppy" (Table 1). For each of these species, the number of encounters dropped at Beaufort ≥4, indicating as expected that there were fewer encounters in rougher conditions. Therefore, all trips in conditions of Beaufort ≥4, or described as "rough" on the simpler scale, were removed to reduce the influence of sea conditions on observations. Trips and encounters for which weather data or trip date were missing were also removed. Not only wind strength (affecting sea state) but also wind direction to some extent affects the sightability of dolphins and could influence seasonal differences in encounters. Wind direction was infrequently recorded and the data available were not considered reliable, thus the potential effects of wind direction could not be determined retrospectively. However, the two seasons of the year for which results are

Table 1
Number of Encounters for the Five Most Frequently Encountered Cetacean Species Under Different Sea Conditions

Species	Calm, Choppy and Sea State ≤2	Calm, Choppy, and Sea State = 3	Calm, Choppy, and Sea State = 4	Calm, Choppy, and Sea State = 5
Humpback whales	93	9	5	1
Bryde's whales	93	8	4	1
Indo-Pacific humpback dolphins	269	76	38	11
Indo-Pacific bottlenose dolphins	153	52	27	4
Southern right whales	3,534	1,138	791	188

As expected the encounter number decreased with increasing seas state, but encounters were still reasonable high at sea state 3 and therefore included in the data analysis.

presented separately (see Data Analysis) based on the availability of right whales are broadly different in terms of the prevailing wind directions. Low season, which generally coincides with summer–autumn, is characterized by southerly or south-easterly winds with an increase in north-westerlies towards the end, whereas the prevalence of north-westerly and south-westerly winds increases during winter and spring. Seasonal differences reported in the encounters of the different species may therefore be affected by differences in prevailing wind direction, wind strength (represented by sea state), behavior of animals including seasonal migrations, and different routes of the WWV between seasons.

Recorded GPS positions of encounters were vetted by mapping them using ArcGIS 9.3 (ESRI), projection UTM 34S, and datum WGS84. Of 5,431 available encounter positions 118 (1.5%) occurred either on land or well outside of the permit area. All these records were cross-checked against the original data sheets; those that could not be corrected were likely caused by clerical errors during initial recording at sea. Records containing these obvious errors were discarded, with no further attempt at correcting them, and encounters that lacked latitude and longitude positions were excluded from spatial analyses (but included in temporal analyses).

Species identification was validated by comparing written field records with photographs taken during the following encounters: 80 encounters with southern right whales (*Eubalaena australis*), 21 with humpback whales (*Megaptera novaeangliae*), 5 with Bryde's whale (*Balaenoptera brydei*), 65 with Indian Ocean humpback dolphins (*Sousa plumbea*), 187 with Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), 7 with common dolphins (*Delphinus* spp), a single encounter with Heaviside's dolphins (*Cephalorhynchus heavisidii*), and 2 encounters with killer whales (*Orcinus orca*). For all encounters there was 100% agreement between the field identification and associated photographs.

Where the number of animals in a group was recorded as a range, a conservative approach was used for analysis and only the minimum was considered. Cow–calf pairs of southern right whales were regularly approached by the WWV because calves were difficult to see from a distance; cow–calf pairs therefore reflect in the observations. Behavior data were not included in the analysis due to subjectivity and inconsistency in reporting. Many of the 25 predefined behavioral categories provided in the forms were subjective and difficult to distinguish. For example, "tail slapping" was only defined within the main category "aggressive behavior" and would hence only be categorized as aggressive behavior. Another main category was "attraction/interactive behavior" with a subcategory "relaxed behavior," whereas a similar subcategory "relaxed, no approach" was categorized in another main category "calm/undisturbed behavior." Also, in addition to the predefined categories, there were more than 50 different descriptions of behaviors recorded in the completed forms, many of which were impossible to categorize or recategorize into simpler, more functional categories such as "resting, traveling, socializing, and feeding" (Lusseau, 2004).

Data Analysis

When determining patterns of seasonal or spatial distribution of populations, it is essential that any spatial or temporal variation in search effort is taken into account (Daniel et al., 2010; Vigness-Raposa, Kenney, Gonzalez, & August, 2009). The South African government does not require WWVs to record or report trip routes; hence, no direct measure of spatial search effort was available for the data set. To provide an index of spatial search effort by the WWV, the tracks of 72 trips between September 2011 and September 2012 were recorded. These routes were typical of the routes followed since 2003 according to author W.C., the owner of the WWV company since its inception in 2000. The routes of the trips were influenced by local experience of the availability and distribution of the cetacean species and the distributions of other attractions including seabirds [e.g., African penguins (*Spheniscus demersus*)], Cape fur seals (*Arctocephalus pusillus*), and great white sharks (*Carcharodon carcharias*), which may vary between seasons and the time constraints of the trips (cost efficiency and back-to-back trips). Track data were collected using a Garmin Dakota 20 GPS receiver recording at 1-minute intervals, downloaded to computer, converted to a polyline, and overlaid on a 1 km × 1 km grid [Koslovsky et al., 2008; National Oceanic and Atmospheric Administration (NOAA), 2006] using QGIS 2.1.0, projection UTM 34S, and datum WGS84. Temporal search effort (i.e., trip duration) was only recorded intermittently by the WWV; therefore, records held by the local harbor master for 1,007 trips conducted between 2010 and 2012 were used to estimate a standard trip duration (see Results). Difference in trip duration led to a division of the data set into high (July–December) and low (January–June) seasons, and data is presented separately in the analyses as encounters per trip (number of groups encountered per trip). Temporal patterns in encounter rates were investigated for years and months.

For species with more than 20 encounters, groups containing calves were included in the overall encounters per trip but also presented separately. For southern right whales, for which more data were available, the data set was further subdivided into cow–calf pairs, single individuals, two adults, and three or more adults. The presence of mating groups or surface active groups (SAG) was recorded in some data sheets, but it was not possible to determine from the data sheets if this category was recorded consistently by all observers, so they were not presented separately, but are included in groups of three or more right whales. SAGs are defined as groups with high levels of social interaction at the surface with physical interaction between individuals, where most attention is directed towards a focal animal (or animals) (Best, Schaeffer, Reeb, & Palsbøll, 2003; Kraus & Hatch, 2001).

Results

Search Effort

From 2003 to 2012 DIC conducted 3,914 trips. Cetaceans were encountered on 3,390 trips (524 trips without encounters) and 7,492 cetacean encounters were recorded in total. After exclusion of trips and encounters that occurred under poor weather conditions, there were 5,920 encounters during 2,876 trips (475 trips without encounters) available for analysis. All data were suitable for temporal analysis and 5,838 encounters were suitable for spatial analysis (82 encounters were discarded because of missing or invalid positions). The number of trips varied between the seasons; during the low season January–June, 708 trips (mean = 118 per year, SD = 41.8) were conducted and 2,168 were conducted during the high season July–December (mean per year = 361.3, SD = 127.3) (Fig. 2). Typical search effort is shown in Figure 1 as the number of times the WWV track passed through each grid cell with high and low season presented separately. Trip duration was significantly longer (Students t test $t = 1{,}287$, $p > 0.001$) in high season (mean $= 145.4 \pm 14.6$ minutes) than low season (mean $= 99.2 \pm 14.8$ minutes) based on the records from the local harbor master.

The spatial search effort differed between low and high seasons, with effort during low season focusing mainly in the Franskraal area with only rare visits to the Pearly Beach area or the deeper waters beyond Dyer Island (Fig. 1). During the high season, the typical route included Pearly Beach more frequently. Visits to water deeper than 30 m and to the west of Dyer Island were rare and with no predictable pattern. Visits to the southernmost part of the license area Quoin Point were never recorded. Trips starting from Gansbaai harbor only happened when the tide was too low for boat launching from Kleinbaai harbor—this area is beyond the permit area and approaches were therefore not allowed.

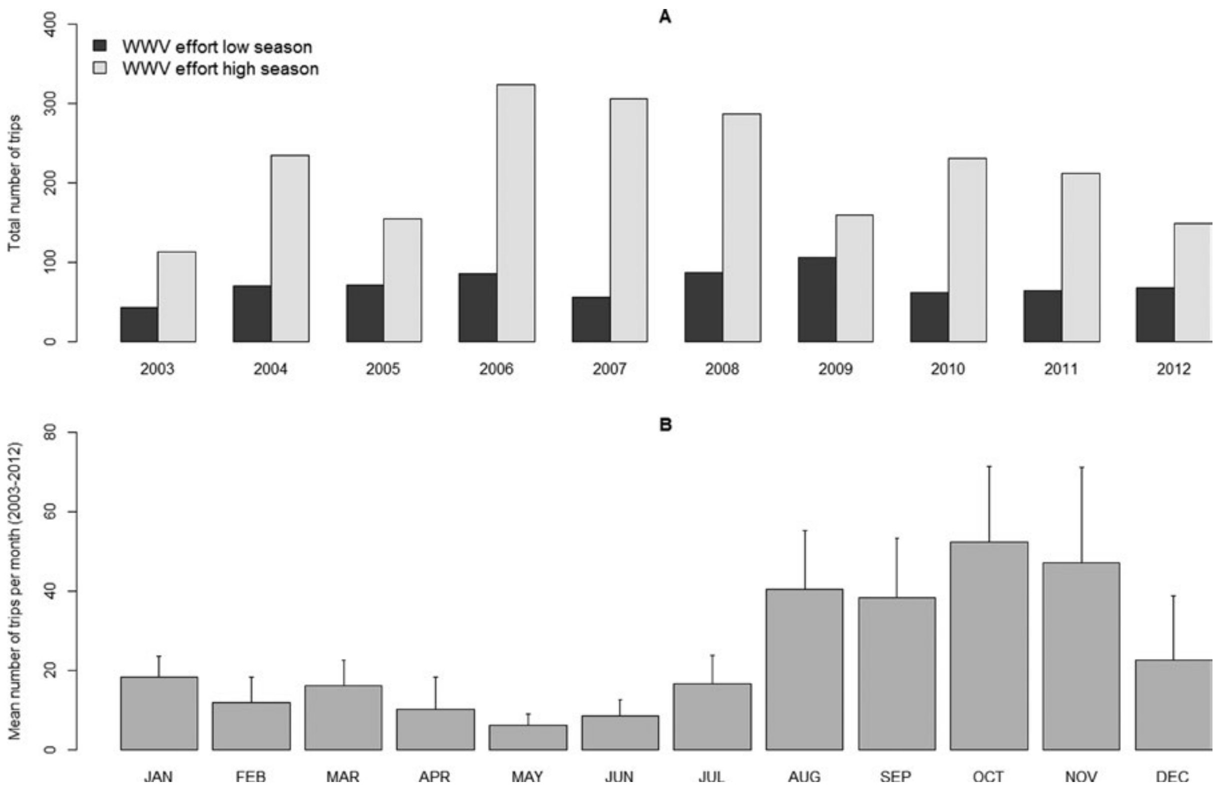


Figure 2. Total number of trips per year (A) and mean number of trips per month (B), conducted by the whale-watching vessel for the period 2003–2012. Error bars indicate the standard deviation of the mean value.

Cetacean Occurrence and Seasonal Distribution

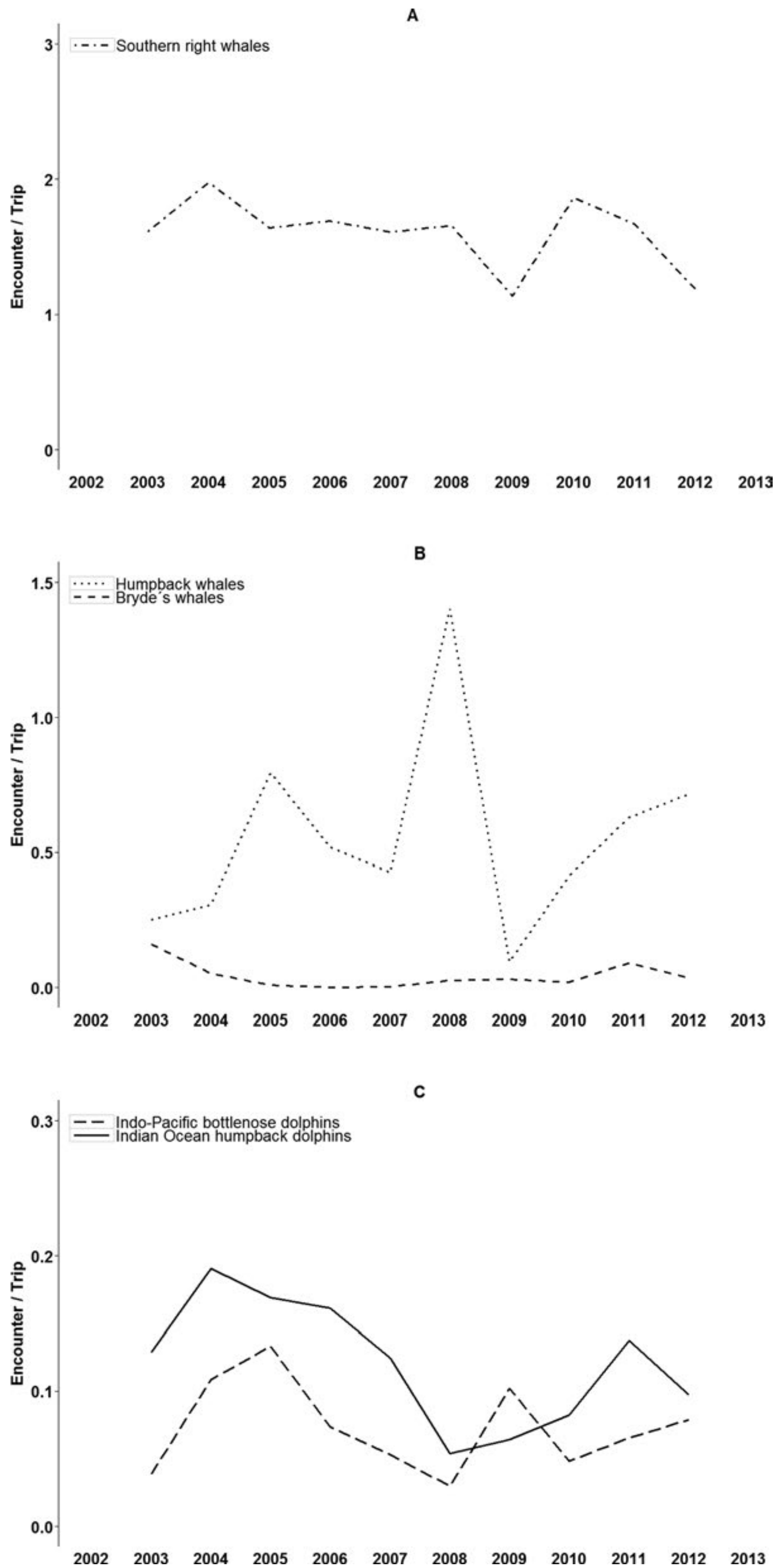
Five species of whales and dolphins were encountered regularly: southern right whales, humpback whales, Bryde's whales, Indian Ocean humpback dolphins, and Indo-Pacific bottlenose dolphins. Three additional species were seen on fewer than 20 occasions: 2 encounters of killer whales, 2 of Heaviside's dolphin, and 14 of common dolphins.

Temporal Patterns

Annual encounters of the five main cetacean species varied considerably between years and among the species (Fig. 3), while monthly encounters showed more consistent trends across years (Figs. 4 and 5).

Bryde's whales were encountered on 101 occasions (145 individuals, of which 125 were adults and 20 calves). Most encounters were of solitary animals (mode = 1). This species was most frequently encountered (74 times) in low season, with the highest encounters between March and May (Fig. 5), and rarely (27 times) during high season. Bryde's whale calves were encountered year round. Bryde's whales were observed in all years, except 2006. The highest number of encounters occurred during 2003 ($n = 25$), dropped to 0 in 2006, and then slowly increased at 1% per annum after 2006 (Fig. 3).

Humpback whales were encountered on 102 occasions (233 individuals, of which 218 were adults and 15 calves). The modal group size encountered was 1, the maximum was 10, and from the 102 encounters 73% were either solitary individuals or groups of two or three individuals. Humpback whales showed two peaks in seasonality: the majority of animals were encountered in June (last month of low season), July, and August, with a much smaller peak in late November and December (Fig. 5). Most encounters with humpback whale cow–calf pairs occurred during October–December. Humpback whale encounters varied considerably from year to year, with most encounters in 2008 ($n = 28$), 2011 ($n = 15$), and 2012 ($n = 12$) (Fig. 3), but showed a slow average increase at 0.4% per annum.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Southern right whales were encountered on 4,672 occasions (13,091 individuals, of which 10,154 were adults and 2,937 calves). Numbers peaked consistently between June and January (Fig. 4) each year and only a single encounter was recorded between January 31 and May 26 (two animals on March 18, 2011) in the entire data set. Single right whales were more commonly encountered at the beginning of high season (June–September) while groups of two or more were most commonly encountered in the middle of the season (July–September) and the modal group size was two. Cow–calf pairs were encountered most frequently late in the season with highest encounters in October–December (Fig. 4). The earliest observation of a cow–calf pair was on June 26, 2011, and only a total of six cow–calf pairs were observed during July throughout the study. The latest encounter of a cow–calf pair was on January 26, 2009. Annual trends in encounters varied considerably between social categories. Encounters of all non-cow–calf groups showed a decrease over the duration of the study period (single = −9.8% pa, pairs = −11.8% pa, >3 = −11.1% pa.) (Fig. 4A). Conversely, the encounters of cow–calf pairs increased almost linearly between 2003 and 2010 at 9.9 % pa, but declined substantially by −45% pa subsequently. This trend is evident in all months of the year, although there is some indication of an earlier shift in the timing of cow–calf pairs, with encounters peaking in November/December from 2004–2009 and in October from 2010–2011 and 2003; data for comparison were not available for November and December 2012.

Indian Ocean humpback dolphins were encountered on 345 occasions (1,521 individuals, of which 1,386 were adults and 135 calves). Humpback dolphin groups ranged from 1 to 12 individuals (mode = 1, mean = 4). Encounters were more frequent during summer months (Fig. 5), and most encounters occurred in 2003–2007 and in 2011 (Fig. 3), a slightly negative annual trend existed (0.9%). Calves were recorded in 97 encounters with most calf encounters occurring in December ($n = 25$) and January ($n = 12$) (Fig. 5); a maximum of three calves in a group was noted.

Indo-Pacific bottlenose dolphins were encountered on 205 occasions (4,271 individuals, of which 4,085 were adults and 186 calves). Group size ranged from 1 to 200 individuals (mode = 10, mean = 20). Groups larger than 40 individuals were only encountered 28 times. A clear seasonal peak occurred from December to April (Fig. 5) and most encounters occurred in 2004–2006 and in 2009 (Fig. 3) with a slightly negative annual trend over time (0.2%). Calves were observed in groups on 109 occasions, with 10 being the highest recorded number of calves in any group. Seasonality of calves followed the same pattern as for adults.

Spatial Patterns

Bryde's whales were observed in predominantly deeper waters throughout the surveyed area with most encounters occurring between Dyer Island and the Kleinbaai harbor (Fig. 6). The furthest observed Bryde's whale was 9.3 km from shore, and only a single encounter occurred within 1 km of shore. Cow–calf pairs were observed in the same areas as groups and single individuals. Most of the encounters occurred between 20 m and 30 m water depth.

Humpback whales were observed throughout the study area, with areas of higher concentration around Dyer Island and in the bay at Franskraal (Fig. 6), which coincides with the most frequently searched areas (Fig. 1). The furthest from shore that a humpback whale was encountered was 8.3 km. Animals were observed less than 1 km from the shore during the high season. Cow–calf pairs were observed in the same areas as non-calf groups and single individuals. Most of the encounters in low season occurred between 15 m and 50 m water depth. Encounters in high season were similar to low season, but covering a larger area with some encounters close to shore.

Southern right whales were seen throughout the license area, although the majority of encounters occurred in near-shore waters and bay areas, mainly in less than 20 m depth of water (Fig. 6). Cow–calf pairs and groups of animals were found close to

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Figure 3. Annual mean encounter rate of southern right whales (A) and baleen whales (B, C) and dolphins (D, E) per year by the whale-watching vessel operating from Kleinbaai Harbour, South Africa. Notice the higher *y*-axis for southern right whales and Bryde's whales, due to the high sighting rate of this species in the area. Error bars indicate the standard deviation of the mean value.

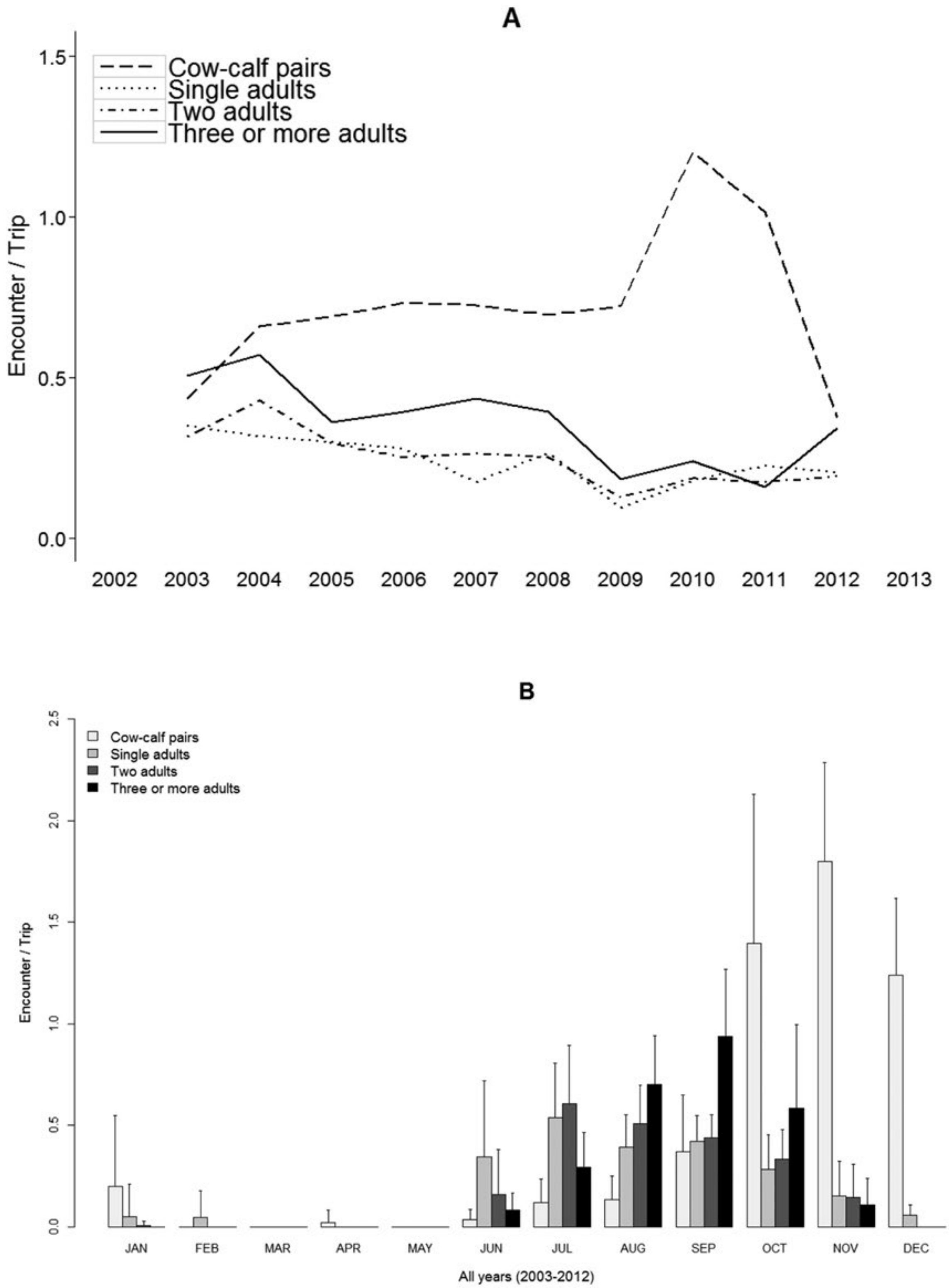

Figure 4. Mean monthly sighting rates (sightings per trip) of different southern right whale group types. Error bars indicate the standard deviation of the mean value.

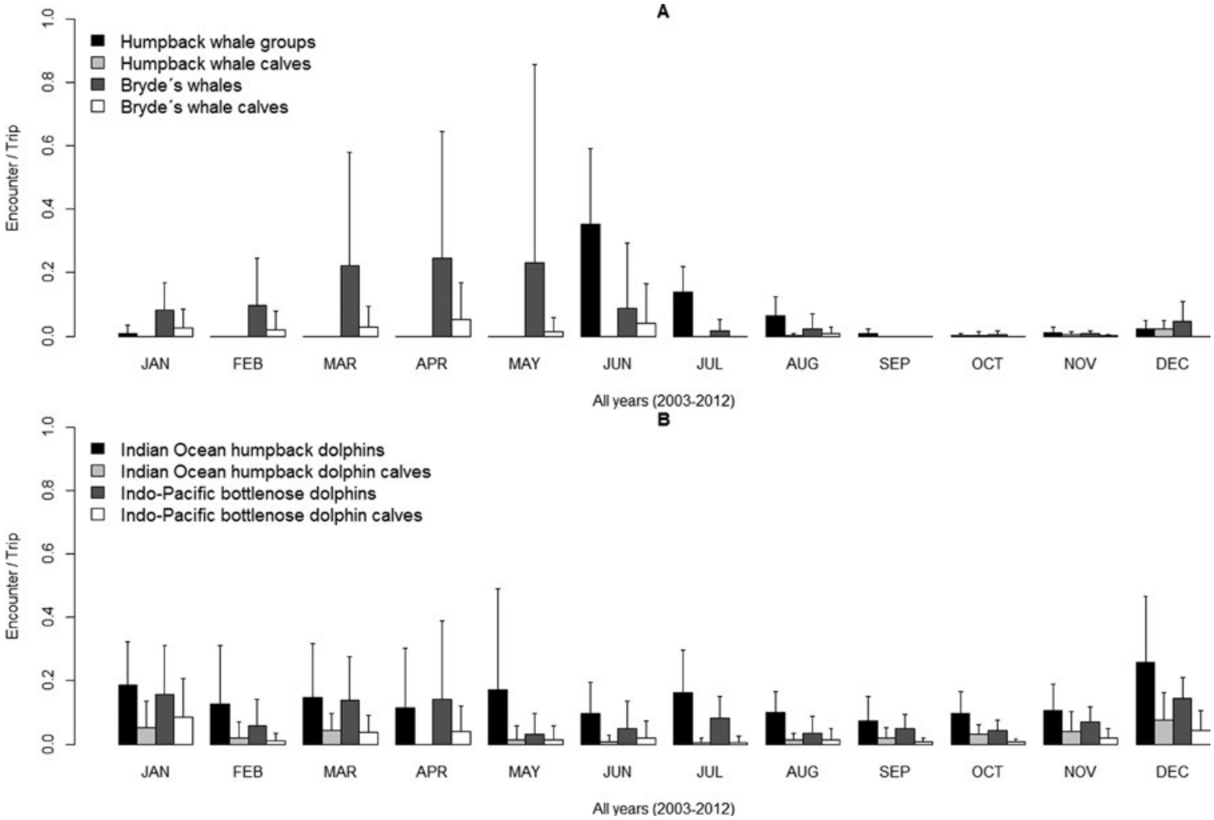

Figure 5. Mean monthly sighting rate (sightings per trip) of humpback and Bryde's whales (A) and Indo-Pacific bottlenose dolphins and Indo-Pacific humpback dolphins (B). Error bars indicate the standard deviation of the mean value.

shore and always in less than 30 m of depth. Most encounters were less than 2 km from shore. The furthest from shore that southern right whales were recorded was 9.3 km. Encounters of the first and last animals in June and December were mainly recorded in Pearly Beach and in the months of December and January cow–calf pairs were most frequently observed in the Pearly Beach area (Fig. 7).

Indian Ocean humpback dolphin distribution was restricted to very shallow water (Fig. 8). Encounters were most regular within 1 km from shore along the sandy beaches in the vicinity of the well searched areas of Uilkraal estuary in less than 15 m of water, although a few encounters were recorded near Dyer Island and up to 5.9 km off shore at a depth of more than 50 m. No spatial difference was observed in the patterns for low and high season.

Indo-Pacific bottlenose dolphins were predominantly encountered in waters less than 15 m deep. Most encounters were observed less than 2 km from the coast, with a maximum distance of 5.8 km from the coast (Fig. 8). Encounters were most frequent in both of the sandy beach areas near Franskraal and Pearly Beach. No spatial difference was observed in the patterns for low and high season.

Rarely Seen Species

The locations of common dolphin, killer whale, and Heaviside's dolphin encounters are shown in Figure 9. Common dolphins were encountered on 15 occasions: in October ($n = 4$), September ($n = 2$), April ($n = 1$), June ($n = 1$), July ($n = 2$), August ($n = 4$), and January ($n = 1$). Their group sizes ranged from 6 to 1,000 individuals (mode = 200), the largest group size for any of the cetacean species observed in the area. Common dolphins were encountered at depths from 15 m and beyond with four encounters beyond 50 m of water depth. Killer whales were only observed twice. In April 2011 two animals were encountered to the west of the Danger Point peninsula, at the western boundary of the permitted

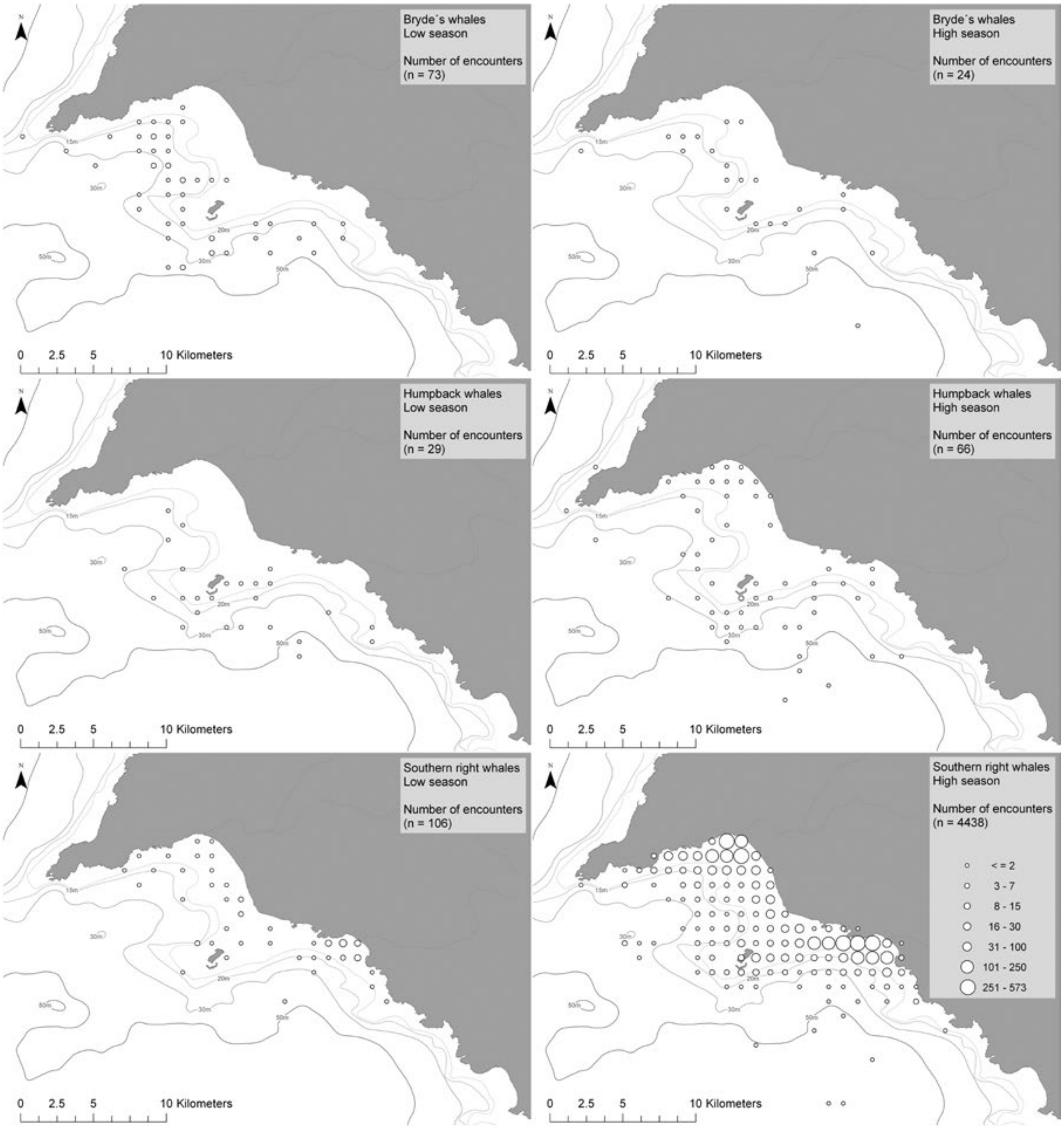

Figure 6. Spatial distribution of encounters of Bryde's whales, humpback whales, and southern right whales by the whale watching vessel operating from Kleinbaai Harbour, South Africa. Size of circles represents numbers of encounters per 1 km × 1 km grid square.

area. On August 24, 2012, six killer whales were observed hunting a school of approximately 1,000 common dolphins. Heaviside's dolphins were also observed twice. On November 23, 2007, two were encountered very close to shore at Pearly Beach on two occasions within 6 hours on the same day.

Discussion

Seasonality and Distribution of Cetacean Species

Five species (southern right whale, humpback whale, Bryde's whale, Indian Ocean humpback dolphin, and Indo-Pacific bottlenose dolphin) were

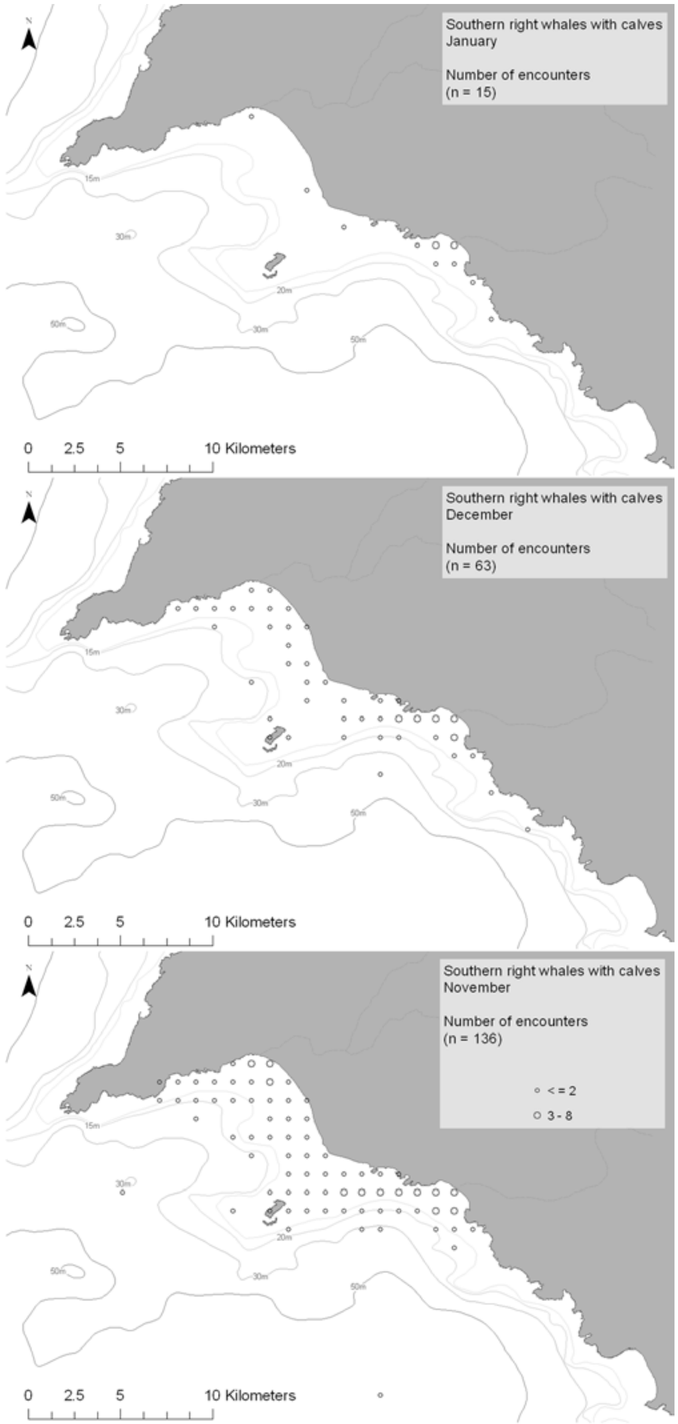

Figure 7. Encounters of southern right whale mother–calf pairs (2003–2012) in January, December, and November. Size of circles represents numbers of encounters per 1 km × 1 km grid square.

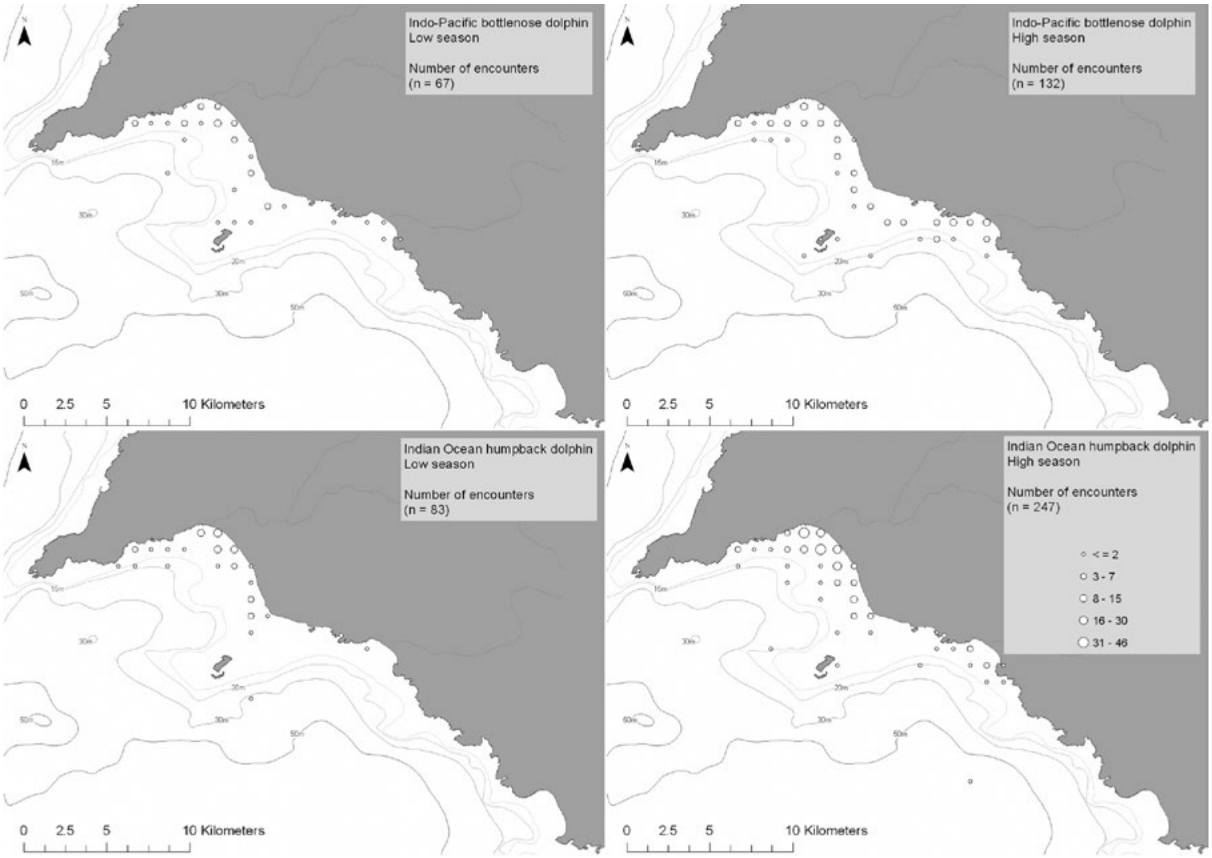

Figure 8. Spatial distribution of encounters of the two main dolphin species. Size of circles represents numbers of encounters per 1 km × 1 km grid square.

found to use the study area regularly and a further three species (common dolphin, killer whale, and Heaviside's dolphin) were occasionally encountered.

Southern right whales were the most frequently encountered cetacean species in the study area and the majority of encounters occurred within 2 km of shore in the two sheltered, sandy-bottomed bays of Franskraal and Pearly Beach. Changes in group composition throughout the season were consistent with the seasonal patterns previously described for right whales in South Africa by Best et al. (2003). The results also show that the season extended until January when predominantly cow–calf pairs were encountered and finally a shift in distribution between the bays was found, with Pearly Beach Bay as the preferred area (Fig. 7). Several changes in the encounters of different social categories were detected over the study period. The encounters of adults without calves (single, pairs, and groups of more than 3 including SAGs) declined almost linearly over the study period, while the encounters of cow–calf pairs showed a general increase, at least until 2010. This corresponds with a decrease in non-cow–calf pair right whales along the southern Cape coast that has been observed in annual aerial surveys since 2009 (Roux, Braby, & Best, 2015). These trends may be related to increased use of the feeding ground off Saldanha Bay on the South African west coast since at least 2000, and increased use of the Namibian coast to the north of this (Barendse & Best, 2014; Peters, Best, & Thornton, 2011; Roux et al., 2015).

The sighting rate of Bryde's whales in this study (145 individuals in 10 years, of which 20 were calves) was considerably lower than that reported by Penry, Cockcroft, and Hammond (2011) for Plettenberg Bay (146 individuals in 4 years, of which 38 were calves) during a study that also used WWV as

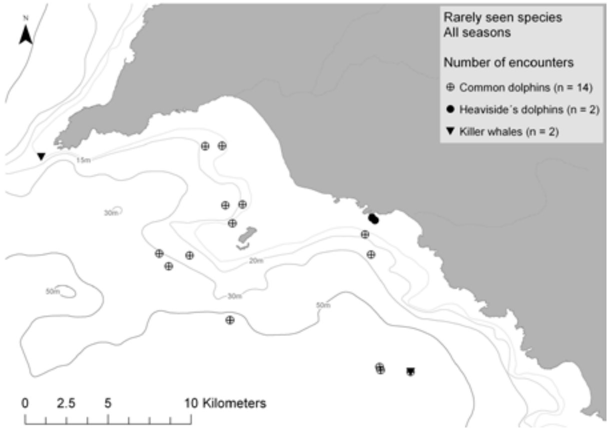

Figure 9. Spatial distribution of rare species in the research area.

the observation platform. Seasonality was similar in both study sites with most encounters occurring in autumn (March–May), peaking in April, and the highest encounter of calves also occurring in this season. The drop in Bryde's whale numbers in the study area after May could be linked to the increased sightings of this species during winter on the east coast, where they are known to follow the "sardine run" and are regularly seen feeding in association with common dolphins and gannets (Best, 2001; Best, Butterworth, & Rickett, 1984; O'Donoghue, Whittington, Dyer, & Peddemors, 2010).

The peak in abundance of humpback whales in the study area during winter was coincident with the timing of the northward migrations of humpback whales up the east and west coasts of South Africa. The population migrating up the east coast is en route to breeding grounds referred to as Breeding Stock C (BSC1) by the International Whaling Commission (IWC) (Best et al., 1998), while those passing the west coast are part of Breeding Stock B (BSB), which consists of a large breeding population (BSB1) off tropical West Africa, and a much smaller substock BSB2 (estimated at approximately 500 individuals in 2010) (Barendse et al., 2011), which feeds off west South Africa in spring and summer (Barendse et al., 2010). The study area is located between the western most area predicted to be used by BSC whales, namely Cape Agulhas (Cerchio et al., 2008), and the south-eastern most location where BSB humpback whales have been identified, namely Cape Point (Barendse et al., 2011). Therefore, the affinity of the humpback whales sighted in the study area is uncertain and evidence from genetic, acoustic, or photographic matches is needed. Certainly the low overall number of sightings in the current study (233 individuals over 10 years) suggest that the study area is not part of a main migration route (cf., Findlay, Best, & Meÿer, 2011), and the whales sighted may have miscued their point of arrival at the continent on their northward migration. There were relatively few encounters from September to January during the expected southward migration period. This likely reflects the tendency of humpback whales from both BSB and BSC to migrate fairly directly, rather than coastwise, between their breeding grounds and sub-Antarctic feeding grounds (Fossette et al., 2014; Rosenbaum, Maxwell, Kershaw, & Mate, 2014), except for the small group that uses a more coastal route from tropical West Africa, which forms BSB2 (Carvalho et al., 2014; Elwen et al., 2014). Those that were encountered late in the year were mainly cows with calves, corresponding with the findings of Banks (2013) at Plettenberg Bay and Knysna for this period (460 km to the east of Kleinbaai). The increase in humpback whale encounters over the study period, albeit only slight, was not unexpected given the recovering trend of this species from past overexploitation.

Throughout their range humpback dolphins are known to prefer highly coastal habitats and are usually found within 1 km of the shore (Findlay, Best, Ross, & Cockcroft, 1992; Saayman & Tayler, 1979). This was the case in this study where they were only encountered close to shore. The small group sizes (maximum 12 individuals) and the seasonality of encounters were similar to findings of Karczmarski and Cockcroft (1999) at Algoa Bay on the southeast coast. Habitat preference of this species seems to change with environment; off KZN they prefer estuarine areas (Atkins, Pillay, & Peddemors, 2004) whereas in Algoa Bay they prefer rocky reef areas (Karczmarski, Cockcroft, & McLachlan, 2000; Saayman & Tayler, 1979). The majority of encounters in this study occurred near the frequently searched sandy beach regions of Franskraal and Uilkraal estuary mouth, the largest river within the study area. Encounters dropped during the low season in 2010, 2011, and 2012, corresponding with three of four summers when the estuary mouth was closed (2009–2012) (Anchor Environmental, 2010). These patterns suggest a general preference for sandy substrates and river mouths as reported for humpback dolphins in KZN (Atkins et al., 2004). Annual encounters showed a slight decrease since 2007 (peak year). Concern has been expressed regarding the conservation status of this species especially considering the multifarious anthropogenic threats associated with its inshore habitat (Elwen et al., 2011) and in the Plettenberg Bay area the provisional results of a population study indicates a considerable decline in numbers over a 10-year period [personal communication with P. A. Pistorius, 2015: Preliminary results from the study of "Population changes and spatial distribution of humpback dolphins (*Sousa chinensis*) within the Plettenberg Bay area"]. Indeed, a recent reassessment of the species during the South African National Red list assessment reduced its conservation status from Vulnerable to Endangered due to the small population, indications of population decrease, increased habitat loss, and unknown levels of interchange between existing sites from which abundance levels are available (Atkins et al., in press). Therefore, while trends, especially of such non-target species of WWV need to be regarded with caution, the observed decline is not improbable.

Indo-Pacific bottlenose dolphin adults and calves were observed year round with no obvious peaks in seasonality, suggesting a year-round residency in the area despite the proximity to the western end of the species range (Findlay et al., 1992) and relatively high seasonal variation in water temperature (Rouault, Pohl, & Penven, 2010). However, group sizes were considerably smaller (mean = 20) than the mean size previously recorded for this species in South Africa (i.e., 76.2 ± 84.98) (Findlay et al., 1992). The largest group of any cetacean species encountered was of common dolphins with a group of approximately 1,000 animals recorded. This species was primarily observed in offshore waters (>15 km from shore) but it was not possible to determine their seasonal distribution because encounters were too few. A rare encounter of a group of 6–8 killer whales hunting a pod of common dolphins was the first record for this event in the study area. Around the coast of South Africa, killer whales are present year round in low numbers. They are more common in offshore waters and mainly feed on marine mammals including common dolphins (Best, Meÿer, & Lockyer, 2010; Findlay et al., 1992). Two Heaviside's dolphins were encountered twice on a single day during the study period, and therefore these animals must be considered vagrants. The species is endemic to the cold waters of the Benguela ecosystem between Cape Point and southern Angola (Elwen et al., 2006), and the only other record to the east of Cape Point is a single sighting in Plettenberg Bay (Best, 2007).

Caveats and Recommendations

When using data collected from commercial WWVs there are certain caveats that need to be considered. An inherent problem with WWV data is the unavoidable interaction between the vessel and the cetaceans, where for example underwater noise from time spent in close proximity to animals and number of vessels (Bejder et al., 2006) can result in an antipredator type response from the cetaceans including change in the type of behaviors observed and avoidance of high vessel impact areas (Bejder, Samuels, Whitehead, & Gales, 2006; Bejder et al., 2006). Such responses have been documented to have both short and long-term effects (Bejder et al., 2006; Lundquist, Gemmell, Würsig, & Markowitz, 2013) in the form of measurable changes in ecology and behavior (Christiansen & Lusseau, 2014; Stensland & Berggren, 2007). Thus, the collected data have the potential of being biased particularly with respect to avoidance of high vessel impact areas. It is therefore important when interpreting

WWV data to consider information regarding the specific local legislation and WWV conditions. The data used in this study were collected from a single vessel operating under South Africa's fairly strict laws, which currently allow for limited vessels per license area, restrict the approach distance and time allowed with animals, specifically to minimize impacts. Enforcement of these laws currently depends on public complaints to the DEA, as no in situ enforcement from DEA exist.

Another challenge is the influence of sea state and wind direction on the sightability, distribution, and behavior of cetaceans. Sea state values are crucial for the exclusion of data for the analysis and wind direction can affect the presence of cetaceans, with indications that feeding dolphins (Elwen, Best, Reeb, & Thornton, 2009) and southern right whale cow–calf pairs in particular are affected (Elwen & Best, 2004a, 2004b). The WWV data on wind direction were only collected once per trip so it was not possible to filter out sightings or periods within trips where conditions were too poor for reliable observations. However, entire trips were removed from the analysis when sea state conditions exceeded Beaufort 4. Furthermore, the separation of results into two seasons (low and high) based on changes in trip duration associated with the availability of southern right whales, coincidently distinguished two periods within which the wind patterns were generally consistent. It is recommended for future efforts that wind direction and sea state information is collected for each encounter and not only per trip.

One of the most difficult tasks for observers is to objectively assess the behavior of animals, which may itself be altered by the presence of the WWV. To obtain reliable data it is necessary to define behavior into clear, mutually exclusive categories. The behavioral data collected from the WWV in this study were not analyzed due to inconsistencies within the data set. It is recommended that future log sheets consist of restricted and simple tick boxes with only a few main behavior types, depending on the main species of interest [e.g., socializing, feeding, traveling, and resting (Lusseau, 2004) with clear descriptions of typical behaviors observed in each category and a comment box for further details].

A lack of spatial and temporal effort data complicated the analysis to some extent. Temporal and spatial effort information was not adequately recorded by the WWV, because it is not currently a requirement for data entry. For the analyses we addressed this by obtaining information from the harbor master's office (trip duration), and an index of spatial search effort from 72 representative trips. Recording of trip duration, animal encounter times and duration, and vessel track data through GPS tracking or vessel monitoring systems (VMS), would improve the accuracy of results. It is recommended that such effort data are part of a basic standard for data collection from any type of platform of opportunity such as sea, land, and air. Equipping WWV with VMS would also assist government in monitoring and regulating the behavior and spatial use of restricted areas by WWV.

Another challenge for describing seasonality and space use patterns is that low density areas are likely to be underrepresented. Encounters are likely to be skewed in favor of species that are easiest to locate or are of greatest interest to tourists. In the study area, southern right whales are the main target species of commercial operators due to their regular and predictable occurrence close to shore (Turpie et al., 2005), their preference for protected waters (Elwen & Best, 2004a, 2004b), near shore distribution and slow movements along the coast (Mate, Best, Lagerquist, & Winsor, 2011), and relatively "boat-friendly" behavior. Thus, during high season, which largely coincides with the presence of southern right whales in vast numbers, encounters by WWVs are potentially skewed towards this species at the expense of all other species. Moreover, if suitable animals were encountered early in a trip, there would be no motivation for the WWV to survey the entire license area. Despite this potential bias, seasonal trends in occurrence were clear for several species in the study area and the seasonality of humpback whales and Bryde's whales corresponded with what has been observed in other areas for these species. Annual trends in right whale encounters in the study area could be masked by several factors. During the high season the number of right whales in the license area is sufficient that encounters per trip would reach a saturation level of between two and three encounters in a 2-hour trip. Resightings of animals during the same trip, especially during periods of lower numbers, June–July and December–January would result in overestimation of animals which could positively bias numbers. Additionally, the Pearly Beach area has the characteristics of a preferred area for right whales (Elwen & Best, 2004a, 2004b) and numbers in the area may effectively be saturated during high season and therefore not changing correspondingly with the growth rate of the population as the whole. The lack of a pronounced positive annual trend in humpback whale encounters likely reflects the license area's location between the migration paths of the east (BSC) and west (BSB) coast populations, with most whales encountered being at the border of their known range.

The collection of photographic material of a sufficient quality to allow for identification of individual animals would increase the number of questions that could be asked from this type of opportunistic data, including matching the encounters within and between trips and reducing the number of reencounters within a data set. However, this would be dependent upon complete coverage of the groups encountered, which is generally impracticable for WWV personnel to achieve given the required high level of simultaneous interaction with clients, the relatively high staff turnover, issues of data storage and management, and allowable approach distances to animals. Therefore, WWV's are not an optimal platform for collecting individual photographic identification data, unless there is at least one person aboard dedicated to this task (e.g., scientist or trained volunteer). Apart from individual recognition, collection of photographic images can be extremely useful for species identification and recording of rare species, behaviors, or other events (e.g., injuries or entanglements), and is thus encouraged.

The whale-watching industry is increasing worldwide, and potentially also in South Africa, and it is strongly recommended that guidelines at a regional and/or worldwide level are developed to secure the collection of high quality data from different categories of platforms of opportunity. Consistency of countrywide or even worldwide data collection methods (Robbins & Frost, 2009) would generate a powerful and versatile data set for a broad scale comparison of results. Data collection is mandatory for South African WWV, and although crew members may make concerted efforts to follow the rules, it becomes a futile exercise for them, and any officials processing the data, if the data collected are not consistent, useful, or logical. In order to maximize the usefulness of the data, the structure of the data log sheets must enable behavioral, temporal, and spatial distribution analyses (Vinding, Christiansen, & Rose, 2014). Currently in South Africa there is a lack of any enforcement regarding the compliance to the data collection; it is highly recommended that the boats are either inspected or dedicated observers are placed on board the WWVs for the benefit of better quality and reliability of collected data.

Conclusion

The data set used in this study provides a unique insight into the presence, seasonality, and distribution of cetaceans in an area of the south-western Cape. The data showed that cetacean species are distributed throughout the study area and present year round, although there was clear seasonality in both species and group composition present. The baseline provided may enable early recognition of adverse effects from human impacts on cetaceans or natural changes in the measured parameters, for example the different patterns in annual trends observed here for cow–calf pairs and non-calf groups of right whales in the study area. Moreover, at least within the extent of the area surveyed, the data are potentially useful for informing of spatial management measures, for example in prioritizing areas or times for protection or more detailed research. However, certain shortcomings were identified in the data collection methods, which had impacts upon analysis and interpretability of the data. Changes to data collection protocols to secure efficient and precise data collection from WWV are recommended and the development of regional and/or worldwide guidelines is strongly encouraged.

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Biographical Notes

Katja Vinding Petersen, Ph.D. student, is originally from Denmark, but has lived and worked as a marine mammologist in South Africa since 2010. She has studied the species occurrence and spatial and temporal distribution of cetaceans in the Dyer Island area. Her particular interest is the acoustic and social characteristics of southern right whales.

Prof. Marthán Bester specializes in trophodynamics of pinnipeds, in particular prey identity and consumption. He has published extensively on the numerical abundance and population trends of Antarctic seals. A particular interest is the body growth patterns of pups, reflecting availability of food within the at-sea foraging range of their mothers. He started the seal program on Marion Island three decades ago and remains actively involved as coinvestigator.

Dr. Stephen P. Kirkman is a scientist and marine biodiversity specialist at South Africa's Department of Environmental Affairs, Branch Oceans and Coasts. His research interests include the ecology of marine top predators, responses of marine ecosystems to global changes, research of relevance to achieving biodiversity targets, and ethics in management of marine animals.

Wilfred Chivell is the CEO of Marine Dynamics and Dyer Island Cruises and founder of the Dyer Island Conservation Trust. He has lived in the area since childhood and is a well-known wreck diver and spear fisherman. It is his drive and dedication to providing an excellent tourism experience while conserving the wildlife of the area that have earned Wilfred and his companies several awards through the years, most recently Marine Dynamics the African Responsible Tourism Award 2015-Best for Wildlife Conservation.

Dr. Simon H. Elwen is interested in a broad range of ecological and behavioral aspects of cetacean biology. His core interests relate to the interaction of cetaceans with human activities such as coastal development and tourism as well as the behavioral adaptations that these top predators can make to different environmental conditions.

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8 Appendix 2

8.1 Data collection from commercial whale watching vessel: the need for international guidelines and systematic quality control

J. CETACEAN RES. MANAGE. SC/65b/WW07

Data collection from commercial whale watching vessels: the need for international guidelines and systematic quality control

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Introduction

The conservation of cetaceans is coming more into focus worldwide. Managing conservation is of great significance both for species and ecosystems in general (Caughley and Sinclair 1994). It is, however, often difficult and expensive to obtain the necessary abundance, distribution, and behavioural data that are essential to pursue an effective conservation effort (Redfern et al. 2006; Perrin et al. 2007).

Platforms of opportunity, such as whale-watching operations (Ingram et al. 2007), seismic survey vessels (de Boer 2010, Weir 2011), cruise ships (Williams et al. 2006) or ferries (Weir et al. 2004, Kiszka et al. 2007), have been used as alternative sources of data on cetaceans, especially in developing countries (Koslovsky et al. 2008). In this way, data on spatial distribution, temporal patterns in abundance, and behaviour have been acquired (Hoyt 2001, Koslovsky et al. 2008).

Whale watching has become an increasingly popular activity and often leads to local economic benefits. The whale-watching industry is fast-growing, with a global increase in activity of 12.1% annually since 1991 (Hoyt 2001, O'Connor et al. 2009). The industry was established in 87 countries world-wide in 1998 (Hoyt 2001) and this number had increased to 119 countries in 2008 (O'Connor et al. 2009).

The whale watching industry has become a billion dollar industry, often contributing greatly to the economy and development of the geographic locations where such activities occur. However, the whale-watching industry has potential impacts of both a conservation and societal nature ((Higham et al. 2014) and should be carefully monitored.

Whale watching vessels constitute platforms of opportunity for collection of data on targeted cetaceans. Historic data obtained from such platforms of opportunity are already used in data deficient areas, particularly in developing countries (Koslovsky et al. 2008). However, data from whale-watching vessels (WWV) are subject to several types of bias.

Firstly, the purpose of commercial WWVs is to showcase the cetaceans and focus is on fulfilling the guests' desire to encounter the animals. The collection of research data is not the primary purpose and the WWV's transit is not in scientific line transects. The behaviour of the WWV influences particularly the search effort, which often is restricted to localized high abundance areas, sometimes seasonally dependent and species specific. To be able to correct for the spatial and seasonal effort of the WWV, it is crucial that spatial and sighting effort data are collected as well.

Secondly, the quality of data acquisition is a potential source of bias. Guides and skippers have to perform many tasks on the boat and registering data and taking photographs are sometimes least priority. However, the use of qualified guides, e.g. experienced biologists, has great potential for improving collection of valuable but fairly inexpensive data, particularly in areas where funding is scarce. The observers´ skills and training levels vary with respect to their ability to perform correct species identification and behaviour classification and assess weather conditions (Evans and Hammond 2004, Hauser et al. 2007).

Thirdly, the WWV will only spend time with a limited number of animals and not always approach and identify all individuals and groups in an area. There may also be a tendency for the WWV to approach calm and easily approachable animals. This will lead to non-representative sampling.

Despite it being compulsory in many countries for WWVs to register and report information to a central authority on the activity of the vessel, as well as observations and opportunistic sightings, such information is not collected according to international guidelines and it may be difficult to assess the significance of bias. A recent survey of WWV data collected from 2000 – 2012 off the south coast of South Africa (Vinding et al. unpublished) noted considerable shortcomings, particularly with respect to behavioural data and spatial as well as sighting effort data, whereas the seasonal distribution and species presence data were reasonably well reported. Thus, WWV data do constitute a source of valuable and valid information on the presence of specific cetacean species. However, the scientific value, as well as the significance for conservation efforts and tourism management decisions, of the data could be increased by changes in the definition of which data to report and how to do so. If such changes could be implemented internationally it would enable a direct comparison of data. To date, there are no world-wide guidelines regarding the type and standard of WWV data.

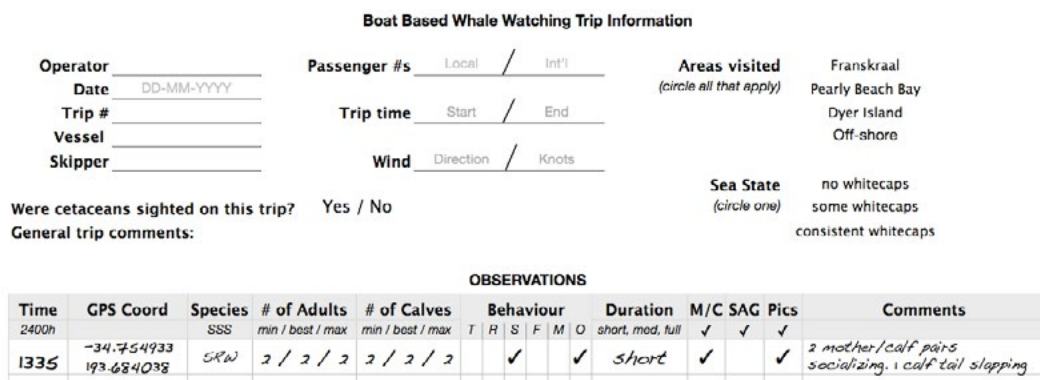
IWC (2005) reported on a prototype "data recording system" (DRS), an effort by the Sub-Committee on Whalewatching to standardize data collection from WWVs/platforms of opportunity (Simmonds et al. 2002; de Boer and Simmonds 2004). The DRS was web-based and had several features that would allow customising for various circumstances (e.g., species, type of vessel, habitat). Although the sub-committee requested further development of the DRS, the project has not progressed beyond the prototype stage. In the interim, efforts to develop standardized WWV data collection methods have been pursued by other organizations and researchers and such methods are in limited use (e.g., Stelle and Melodi 2014).

To enable a reliable scientific outcome and support a high standard of data, we suggest implementing a set of guidelines for a data collection protocol for WWVs. As originally proposed by Simmonds (2004), a standardized data sheet could be hosted by the IWC as guidance for current and future whale-watching operations. This paper presents a basic data collection protocol and data sheet that can be applied world-wide.

As discussed by the Scientific Committee (IWC, 2005), we also suggest implementing a quality control system for the WWV. Such a system should be established and operated be an independent, international organization or professional association.

Guidelines for data collection protocol and data sheet for WWVs

WWVs in different regions have different demands and challenges related to data collection. It is therefore important that international guidelines for any data collection protocol explain the importance of collecting basic data parameters. To be able to meet the different demands of the users, it is important to design the data sheet so it can be customised, e.g., for the species and conditions of an area, since different operators have different capacities. An ideal way to do this would be to have an online data sheet, where the most important parameters were subject to mandatory reporting and users could, in addition, choose relevant parameters for their area and thus customise their own data sheet. For a few parameters, it might also be possible for the user to type in information before a trip, e.g., "Areas visited" (see Fig. 1).


Boat Based Whale Watching Trip Information

Operator
Date DD-MM-YYYY
Trip #
Vessel
Skipper

Passenger #s Local / Int'l
Trip time Start / End
Wind Direction / Knots

Areas visited (circle all that apply): Franskraal, Pearly Beach Bay, Dyer Island, Off-shore

Sea State (circle one): no whitecaps, some whitecaps, consistent whitecaps

Were cetaceans sighted on this trip? Yes / No
General trip comments:

OBSERVATIONS

Time	GPS Coord	Species	# of Adults	# of Calves	Behaviour						Duration	M/C	SAG	Pics	Comments
2400h		SSS	min / best / max	min / best / max	T	R	S	F	M	O	short, med, full	✓	✓	✓	
1335	-34.754933 193.684038	SRW	2 / 2 / 2	2 / 2 / 2			✓			✓	short	✓		✓	2 mother/calf pairs socializing. 1 calf tail slapping

Figure 1. An example of a basic data collection sheet

From a research point of view, the data collected must be valid and consistent to be useful. Since the focus of WWVs is on the passengers and not always on the data, it is important to simplify the data sheet as well as prioritise the required information.

Content of the data sheet

The data sheet should at a minimum include the following parameters (Fig. 1):

Trip information:

1. Date
2. Trip number
3. Departure time from harbour
4. Return time from harbour

5. GPS track of the route taken (if possible) or a tick box with the main "Areas visited"
6. Name(s) of the person(s) responsible of data collection
7. Name of the skipper and the operation
8. Weather information. Wind direction and wind speed (No white caps, Some white caps or Many white caps or Beaufort scale)
9. Sightings of animals Yes/No

Sighting information

10. Time of encounter
11. Latitude position
12. Longitude position
13. Water temperature
14. Water depth
15. Species
16. Number of adults
17. Number of calves
18. Information about photo documentation
19. Behaviour comments
20. Small comment box

Protocol

The protocol should explain why the different data parameters are included in the data sheet.

1. Date
2. Trip number

Information about the trip number and the date is important when analysing the data. Each trip will be given an ID-number before data can be analysed and it is important to distinguish the different trips from each other. Some operators have more than one trip a day and the trips should have consecutive numbers reflecting the date and time they were conducted.

3. Departure time from harbour
4. Return time from harbour

The total time spent at sea is necessary to calculate sighting effort. This is important information when data are analysed (see below regarding spatial effort).

5. GPS track of the route taken (if possible)

It is crucial to be able to account for the effort spend at sea searching for cetaceans. Time and spatial effort is important reference data when calculating the spatial distribution of a species. Simple notation of start and end time of the trip can increase the quality and usefulness of the data collected. The optimal way to determine effort is to collect GPS tracks of the boat's location, which will also give precise data of the spatial route. Of crucial importance is the collection of information about trips where no cetaceans are sighted (see below). The effort of the boat can be biased toward areas with whales and where whales would have been observed previously. On days with more than one trip, animals in the area have a high chance of being sighted consecutive times. If observers are experienced, they can make notes from trip to trip of individual re-sightings.

6. Name(s) of the person(s) responsible for data collection

The quality of the obtained data is dependent on an observer's skills. The quality of observations can be subject to bias when many different observers are involved in data collection.

7. Name of the skipper and the operation
8. Wind category (No white caps, Some white caps or Many white caps)

Sighting probability is reduced as weather becomes increasingly rough. To be able to adjust for this in data analysis, it is important for weather conditions to be noted. A suitable cut-off at, say, Beaufort 2 (i.e., all data collected at or below Sea State 2 are included in analyses) can be applied to the dataset before conducting the analysis (Fig. 2).

Scientific Name	Common Name	Code
Eubalaena australis	Southern Right Whale	SRW
Megaptera novaengliae	Humpback Whale	HBW
Balaenoptera edeni	Bryde's Whale	BRW
Balaenoptera acutorostrata	Minke Whale	MKW
Delphinus delphis	Common Dolphin	COD
Sousa plumbea	Humpback Dolphin	HBD
Tursiops aduncus	Bottlenose Dolphin	BND
Cephalorhynchus heavisidii	Heavisides Dolphin	HSD

MPH	Beaufort	Knots	Km/h	Code
> 1 mph	0	> 1 kn	> 1 km/h	no whitecaps
1 - 3 mph	1	1 - 2 kn	1.1 - 5.5 km/h	
4 - 7 mph	2	3 - 6 kn	5.6 - 11 km/h	some whitecaps
8 - 12 mph	3	7 - 10 kn	12 - 19 km/h	
13 - 17 mph	4	11 - 15 kn	20 - 28 km/h	consistent whitecaps
18 - 24 mph	5	16 - 20 kn	29 - 38 km/h	
25 - 30 mph	6	21 - 26 kn	39 - 49 km/h	
31 - 38 mph	7	27 - 33 kn	50 - 61 km/h	
39 - 46 mph	8	34 - 40 kn	62 - 74 km/h	

Behaviour	Description	Code
Travelling	Swimming in one direction for an extended period of time. Moving more quickly than the idle speed of the vessel.	T
Resting/Logging	Motionless in same spot except to breathe. If moving, then moving more slowly than the idle speed of the vessel.	R
Socializing	Diverse interactive behavior such a body contact, flipper caressing, tail swipes, genital inspections. Dive intervals may vary.	S
Feeding	May be surface apparent in some species (mouth open, baleen rattle). Otherwise indicated by long-term group synchronous diving. Arched backs may indicate deep dives.	F
Milling	Non-directional swimming. Individuals are surfacing in different directions. No net movement.	M
Other	Make a note in the Comments. Examples include spyhopping, breaching, pectoral slapping, tail slapping, and sailing.	O

Figure 2. An example of categories chosen for the data collection sheet.

9. Sightings of animals Yes/No

To be able to account for effort, it is important to have a reference for the number of trips with no sightings, since even with no sightings, effort has been expended searching for animals. Weather data on trips where no animals are sighted are also important.

Sighting information

10. Time of encounter

It is important to distinguish between search and sighting time. By logging the time at each sighting, it will be possible to calculate search effort and sighting effort.

11. Latitude position
12. Longitude position

It is crucial to obtain location positions of the animals sighted to determine if animals have preferred habitat.

13. Water temperature
14. Water depth

Water temperature and depth are important factors to record, particularly in data deficient areas since bathymetric data often don't exist in such areas. In order to analyse data in relation to spatial and physical factors, it is important to record such parameters.

15. Species

Simple codes should be used for the relevant species (Fig. 2).

16. Number of adults
17. Number of calves

The number of adults and calves is important, as it may reveal whether there are, for example, specific areas used as nursery grounds.

18. Information about photo documentation

For photographic material to be useful, it should be catalogued the same day and the frame of the photographs should be noted for each sighting where photographic evidence is collected. Setting date and time stamps on the camera is crucial as well. Photos of sightings should be divided with blanks between observations (e.g., a photo of the WWV life raft). A GPS linked to the camera can be a great help during later analysis.

19. Behaviour categories

To enable an efficient and consistent analysis of behavioural data, the data sheet should consist of restricted and simple tick boxes with 4-5 main behaviour types, e.g. mating, feeding, travelling, and resting, and a comment box for further qualitative details (Fig. 2).

20. Small comment box

Comments should be minimised. Subjective comments can be very difficult to categorise and analyse.

Layout of the data sheet and data recording

The data sheet should be simple and easy to fill in.

A basic yet important factor concerning the data collected during the South African study (Vinding et al. unpublished) was that it was sometimes difficult to digitise the data from hard copies; in some cases it was either impossible or highly difficult to read the handwriting of the observer. This could be due to people having to write during rough sea conditions. Ideally the observer who writes the notes should also enter the data the same day or within a few days from the trip. This factor clarifies why tick-box observation sheets are more user-friendly, less time consuming, and provide more accurate data, e.g., when taking behavioural notes.

The data sheet must be filled in at sea in situ and should ideally be digitised the same day by the observer. Photographs should be sorted the same day as well and linked to the relevant observations. The process of linking photographs to specific observations is very time consuming and almost impossible if done retrospectively by more than a few days.

Quality control

In order to ensure the quality of WWV data, a systematic control effort is necessary. Such a system should ideally be multi-layered, with the first layer being the use of a well-structured and well-explained data sheet that is easy to fill in. An important part of the system would be the inclusion of explanations for each data field, e.g. behavioural categories. The second layer should be an online submission system for data collected in the field, where each operator is assigned an ID-number and can log in to their account and enter their data and upload pictures from each trip. Each operator's data should be then available to download either as an Excel sheet or Access database. A third level is the systematic evaluation of the reported data by a qualified researcher with feedback to the reporting vessels. Finally, an onsite inspection of data collection for as many WWVs as possible should improve quality. Another potential quality control mechanism is a mandatory exam for individuals who intend to observe and report WWV data. Such an exam could be downloaded from a website and evaluated by qualified researchers.

Blue Flag (http://blueflag.org.za/) is an accreditation organization for beaches, boats, and marinas in South Africa and now inspects whale-watching vessels that have applied for Blue Flag accreditation. Since Blue Flag already has a global network of officers and is independent, it is ideal to take on the task of assessing WWVs. One limitation is that Blue Flag will monitor only accredited vessels and at least initially these vessels will be in the minority

Conclusion

In order to improve the quality of WWV data collection, we recommend international guidelines, hosted by the IWC, comprising at a minimum a standardised data sheet, advice on how to ensure data quality by providing explanations, analysis and feedback to WWVs submitting data, and accreditation of WWVs by an independent organisation such as Blue Flag, to maximise compliance with guidelines. Such readily accessible guidelines will help ensure that accurate and useful platform-of-opportunity data (e.g., spatial and sighting effort) will be collected by more WWVs and that data will be comparable on a global scale.

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9 Appendix 3

9.1 Occurrence of vagrant leopard seals, *Hydrurga leptonyx*, along the South African coast

Occurrence of vagrant leopard seals, *Hydrurga leptonyx*, along the South African coast

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[5]CKD boats, Hout Bay, South Africa

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Leopard seals inhabit the pack-ice rim of Antarctica, and they regularly haul out on Antarctic and Sub-antarctic islands. Occasionally, vagrants are sighted further north in South America, Australia, New Zealand, and very rarely in southern Africa and Oceania. Here we report on an observation made on the 15th of July 2010 of a single 3-m-long juvenile leopard seal at 'Die Dam' in the Western Cape, South Africa (34°45.772′S, 19°42.582′E). We searched historical records and found details of four observations of leopard seals along the coast of South Africa since 1946. All of these sightings were of juvenile animals. The relative scarcity of observations is a likely reflection of the great distance from Antarctica and the Subantarctic to South Africa.

Keywords: leopard seal, distribution, vagrancy.

Leopard seals are distributed along the outer fringes of the Antarctic pack ice during the austral spring (Bester *et al.* 1995; Gilbert & Ericson 1977; Rogers 2009). They infrequently haul out on Subantarctic islands such as Marion Island (Bester *et al.* 2006), seasonally at Macquarie Island (Rounsevell & Pemberton 1994), and year-round on higher latitude Îles Kerguelen (Bester & Roux 1986, Borsa 1990) and Heard Island (Gwynn 1953). Leopard seals breed on the pack ice (Southwell *et al.* 2003), and primarily feed on krill, penguins and other seals (Schulz & Menkhorst 1984; Hall-Aspland & Rogers 2004).

Occasionally, leopard seals are found north of the Subantarctic (Jefferson *et al.* 1993). In Australia they have been seen as far north as Fraser Island in Queensland, but are most frequently seen in Tasmania, which is considered to be part of their foraging distribution (Rounsevell & Pemberton 1994). Even further north in the Pacific Ocean, they have been encountered on the Cook Islands (McCormack 2007). They are likewise often seen in Argentina and Chile (Rodriguez *et al.* 2003). Many of the extralimital sightings are of single juvenile males that are exhausted and emaciated (Elliot 1982; Mawson & Coughran 1999). We describe a single sighting of a leopard seal in the Western Cape, South Africa, and review published and reported sightings of leopard seals along the South African coast.

Historical data were obtained from a literature search, using Web of Science, PubMed, Biosis, Yahoo and Google with the search words 'leopard seal' and 'South Africa'. Unpublished records of sightings were retrieved from the files of the Mammal Research Institute, University of Pretoria and Port Elizabeth Museum at Bayworld, Port Elizabeth.

A leopard seal was sighted on 15 July 2010 on the beach at 'Die Dam', Western Cape (34°45.772′ S,19°42.582′ E). The animal was lying on dry sand in the sun. It was lethargic and in poor condition, but reacted when touched. No signs of physical injury were seen, except a small amount of blood in mucus from the nostril, and what appeared to be a shallow small cut on the upper lip. There were no other wounds and the teeth and gums appeared healthy and there were no indications that it had been entangled in fishing gear. The seal had departed by the next day during which it was seen from a distance by local fishermen.

Confirmed records of leopard seal sightings in South Africa (Table 1) are rare, with less than one observation per decade.

The leopard seal in this study was in poor condition, apparently fatigued and hauled out in an area close to Cape fur seal (*Arctocephalus pusillus pusillus*) colonies, about 3 km from Geyser Rock and 700 m from Quoin Point (Kirkman *et al.* 2007). Leopard seals are thought to haul out to rest, digest a meal, or when injured or in poor condition (Rounsevell & Pemberton 1994). The presence of the animal in the vicinity of Cape fur seal colonies may be related to feeding, as leopard seals take Antarctic fur seal pups (*A. p. doriferus*) at Bird Island, South Georgia (Walker *et al.* 1998). It is, however, unlikely that the immature individual reported here was capable of taking the relatively

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Table 1. Reported sightings of leopard seals along the coast of South Africa.

Date	Location	Observer	Reference	Collected	Notes
Sep 1946	60 km north of East London		Roberts (1951)	East London Museum	
23 Oct 1969	Hout Bay, Western Cape	Peter Best	Best (1971)	Iziko South African Museum	Died in captivity in Tygerberg Zoo
9 Aug 1994	East London	Carolyn Stewardson	P.E. Museum unpublished records. Dewes (1994)	Port Elizabeth Museum	Yearling. P.E. Museum accession number N2244
17 Aug 2005	Hout Bay	Roy McBride	Hardaker (2005)	This study	Juvenile individual resting
15 Jul 2010	Die Dam, Western Cape	This study	This study		See text

large fur seal pups, which would have been approximately seven months old at the time (*cf.* Walker *et al.* 1998).

Inexperience in prey capturing in leopard seals has been reported to result in fractured mandibles when larger prey has been involved (Elliott 1982). The blood in the mucus in the nostril and the cut lip in the present case is most likely an injury sustained during feeding as such wounds are known from leopard seals viziting Tasmania where stingray spikes have been isolated from the heads of such animals (Elliott 1982).

The movement of leopard seals to continents abutting the Southern Ocean is thought to be facilitated by the northward extension of the pack ice in winter (Gwynn 1953; Rounsevell & Eberhard 1980; Bester & Roux 1986; Jessopp *et al.* 2004; Bester *et al.* 2006; Gray *et al.* 2009). Tagging of leopard seals in Prydz Bay (Rogers *et al.* 2005) indicate a substantial difference in the movement patterns of juvenile and adult seals. In Australia, the highest proportion of juvenile males was seen farthest to the north (Rounsevell & Pemberton 1994).

Four of the leopard seal sightings for South Africa were between August and October, the same period during which the majority of leopard seal sightings were recorded over a period of 25 years at Marion Island (Bester *et al.* 2006).

The observed leopard seal stayed in the area for two days only. This is a typical pattern for reported sightings of vagrant leopard seals. It is, however, unknown whether these animals return to Antarctica or succumb.

Most likely, the combination of the great distance from Antarctica to continental South Africa, the need to pass through the east-moving Antarctic circumpolar and Agulhas retroflection currents are the major reasons for the relative scarcity of leopard seals on the South African coast compared to Tasmania.

Honorary Fishing Inspector, Rob Lobb, is acknowledged for alerting us to his sighting of the leopard seal.

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10 Appendix 4

10.1 Possible non-offspring nursing in the southern right whale, *Eubalaena australis*

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Possible non-offspring nursing in the southern right whale, *Eubalaena australis*

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During the austral winter, adult female southern right whales *Eubalaena australis* enter the South African coastal waters to give birth and raise their young. Most births take place over a 4-month period, when the females congregate in specific coastal areas or nursery grounds for up to a recorded maximum of 105 days. At this time, the density of cow–calf pairs in nursery areas can reach as high as 3.2 pairs/km^2 over 26 km of coastline. Although a single young is born and suckled exclusively for 7 months to a year, recent observations on nursery grounds include 3 incidents where apparently abandoned/orphaned calves-of-the-year have been seen associating with a minimum of 2–3 different cow–calf pairs over periods of 11–38 days. Attempts to suckle from these females have been noted in 2 of the cases, with the response of the female varying from extreme avoidance to apparent tolerance. In one instance where the observations of the same trio extended over 21 days, the non-offspring appeared to compete at least equally with the offspring, even though the mother directed her evasive tactics more at the non-offspring than her own calf. At the same time, both of the calves exhibited some growth in length when compared with the size of the adult female: their subsequent survival is unknown. Non-offspring nursing in monotocous species is generally rare, and the costs to the female potentially high: this is certainly the case for seasonally feeding mysticetes such as the right whale, where the costs of lactation cannot be recovered until the cow resumes feeding about 4 months after parturition. Hence, it is perhaps not surprising that these are the first recorded observations of contemporaneous nursing attempts by offspring and non-offspring calves of any mysticete.

Key words: *Eubalaena australis*, non-offspring, nursing, South Africa, southern right whale

Female southern right whales *Eubalaena australis* visit nearshore waters along the South African coast between June and December each year to give birth and raise their young. Most births occur over a 4-month period between mid-June and mid-October, with a peak in August (Best 1994). After giving birth, females reside in these waters for up to 105 days nursing their young, moving between favored nursery areas but only leaving the coastline for higher latitudes once the calf has reached a certain size (Best 2000). At this time each year, a number of neonatal right whales strand on the South African coast, approximately 15% are live when found (Best et al. 2001b): the stranded calves are generally smaller than the calves seen alive at sea, possibly because they are mainly first-born calves (Best and Rüther 1992). Nevertheless, sightings of abandoned calves at sea are rare, and the circumstances surrounding the separation of mother and calf (and their subsequent behavior) are unknown.

The length of lactation in southern right whales is not well established. Some calves have been seen attempting to skim feed next to their mothers at an estimated age of 6 months (Best 2007), while some females return to coastal nursery areas in the following year with their yearling calf still in attendance: these pairs apparently separate or disappear by about mid-August (Thomas and Taber 1984; Best et al. 2003). If these latter calves are still nursing, then lactation would have lasted about 12 months: Hamilton and Cooper (2010) have documented mother–calf associations in North Atlantic whales lasting up to 14 months. Before separation, the yearling takes the initiative in maintaining contact with its mother, nurses more frequently, and appears to be obtaining as much nourishment as possible before weaning (Taber and Thomas 1982). Some of these yearlings then remain on the coast through September, October, and November, where they socialize with adults and other subadults (Taber and Thomas 1982; Thomas and Taber 1984).

Like most large whales, right whales normally give birth to a single calf. Twin fetuses have been recorded in 0.5% of southern right whale pregnancies (n = 220—Best 1994), but these were relatively small (1.13 and 1.18 m long) and whether both would have been carried to term or survived long after birth is unknown. Documented observations of twin births or neonates in right whales (i.e., with accompanying genetic evidence) are unknown, and although killer whales *Orcinus orca* are said to be the only cetacean species in which viable multiplets have been recorded (Baird 2000), this assertion appears erroneous (Ford and Ellis 1999).

Nevertheless, occasional sightings of southern right whales accompanied by 2 calves have been reported along the South African coast. Most of these observations of "twin" calves are short term and opportunistic in nature, with little supporting documentation in the form of photographs, etc. However, since 1997, there have been 3 occasions where the incidents have been more protracted and the observations more fully documented. In this paper, we provide details of these 3 instances, together with one at-sea observation of an interaction between an adult female and an apparently abandoned calf, and attempt to interpret the behaviors observed.

Materials and Methods

Annual aerial surveys along the south coast of South Africa between Muizenberg and Plettenberg Bay (Fig. 1) were undertaken in mid-October annually since 1979, their purpose being photo-identification of all cow–calf pairs of right whales seen. Methods used in field photography and subsequent laboratory matching of individuals have been provided by Best (2011), but a relevant aspect of these surveys is that they were wide in spatial extent but narrow in seasonal coverage. Currently (up to 2012), the Mammal Research Institute (MRI) right whale catalog includes images of 1,318 adult females and 599 of their calves that were conspicuously marked dorsally (some of which also eventually appear in the catalog as adults).

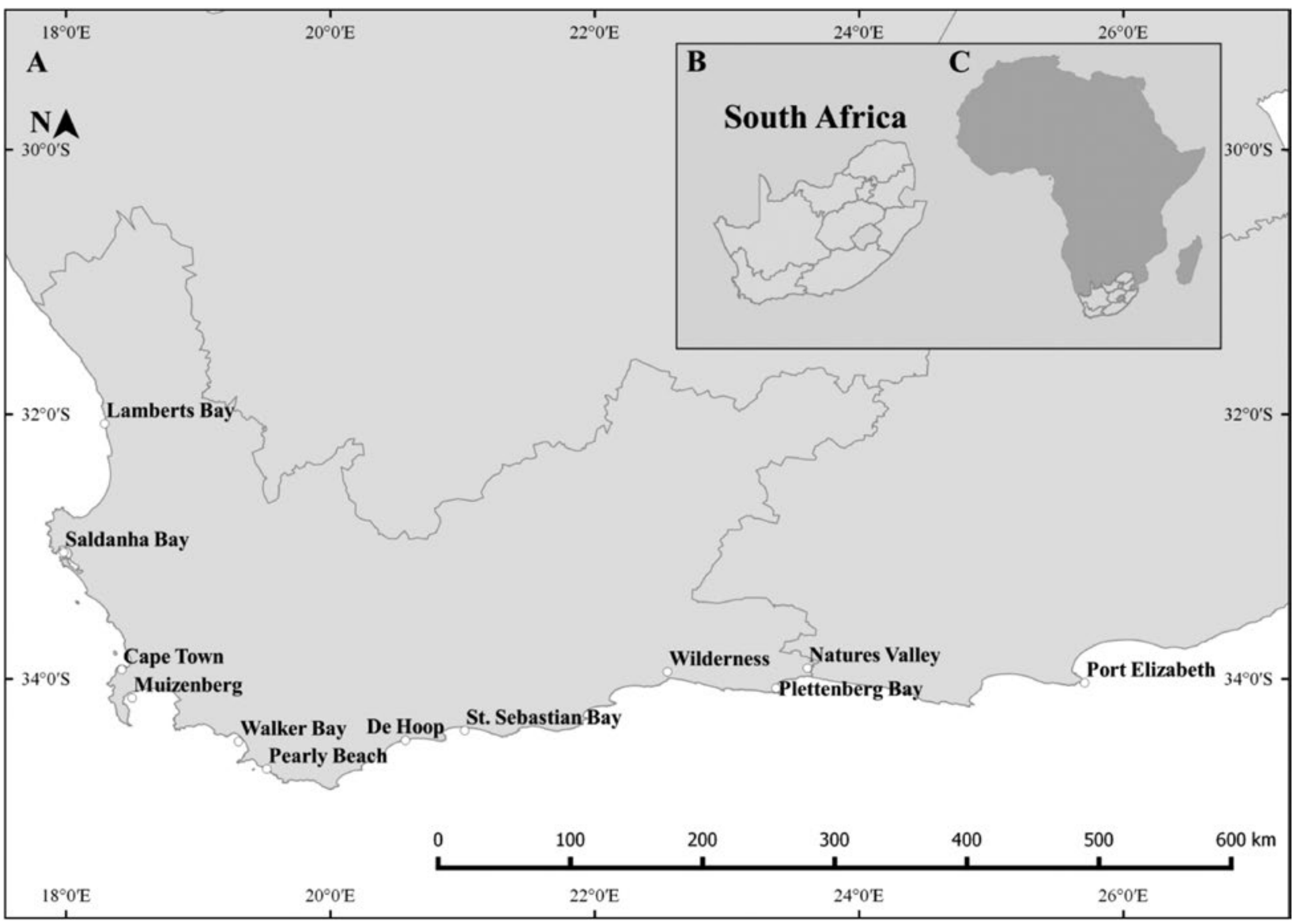

Fig. 1.—South African coastline showing localities mentioned in the text.

From 1995 to 1997, a boat-based program of biopsy sampling right whales was carried out annually between July and November in the South African coastal waters, from Lamberts Bay on the west coast to Wilderness on the south coast (Fig. 1). In total, some 343 groups of right whales were intercepted and 906 biopsy attempts made: details of the methods used are given by Best et al. (2005). Individual identification photographs taken of each group intercepted were compared with each other and where possible with the contemporary aerial right whale catalog. Of relevance is that these surveys were wide in both temporal and spatial coverage.

Since 2005, commercial whale-watching flights over Walker Bay and the adjacent Pearly Beach area (Fig. 1) have been undertaken on a daily basis during the whale season (approximately June to December), weather and tourist demand permitting. Incidental photographs have been taken of groups seen from a circling fixed-wing aircraft, both by the pilot (using a Pentax K20D) and various passengers (including KV using a Canon 40D with 200-mm lens or a 5D with 100–400-mm lens), from a minimum altitude of 305 m as dictated by permit conditions. Appropriate images have been cropped and compared with the MRI catalog using the Hiby–Lovell matching system (Hiby and Lovell 2001). These opportunistic data are obviously circumscribed in spatial coverage but extensive seasonally: at the same time, they are nonsystematic in nature so that only whales of interest were photographed.

Nursing in right whales normally takes place with the mother lying level at the surface. The calf commences suckling by arching its back and submerging, then turning in toward its mother's side. During suckling, the head remains beneath the mother's genital region, while the back is arched and the tail raised close to the surface (sometimes with the tips of the flukes exposed): suckling bouts last less than 1.5–4.5 min, depending on age (Thomas and Taber 1984). Because the calf's head is hidden beneath its mother, it is essentially impossible to ascertain from above-surface observations whether suckling is successful, so in this paper, the term "suckling attempt" has been adopted for occasions when the calf has adopted a typical suckling posture.

In boat-based observations, the duration of observations was recorded as part of the normal protocol (as encounter time), but in aerial observations was not. In annual aerial surveys the duration of observations has been deduced (as a maximum) from the time between the start of photography of successive groups. In commercial whale-watching flights, durations were derived from the time of the first and last frames as recorded in the time stamp metadata associated with each photographic image: where no photographs were taken there is no record of the duration of observations. In the commercial whale-watching data, each daily flight was considered a separate encounter ("observation").

We have used photographic frames as instantaneous samples of behavior, but have treated each photographic session as a separate sample and expressed the incidence of a behavior as the proportion of the number of frames in each session in which it occurred. Because the photographs were taken ad libitum, we have not attempted to calculate absolute rates of behavior but only assumed that there was no selection for recording behavior by the calf or non-offspring, so that the relative incidence of behaviors shown by the 2 should be unbiased.

Relative measurements of calves against adults have been made on the same image when both are at the surface with both extremities visible and in the same approximate orientation, after enlargement on a 55-cm monitor.

The distribution of observed ages at 1st parturition for 122 right whales off South Africa has been used to estimate a possible minimum age for mature females seen for the first time with a calf. Although 1.6% of females have been observed with their 1st calf at age 5, animals at age 6 comprise 9% of observed ages at 1st parturition. The latter age has therefore been selected as a more appropriate minimum age.

Results

Case 1: interaction of near-term female with abandoned calf.—On 10 July 1996, a lone adult right whale (A) was encountered at sea off De Hoop Nature Reserve (Fig. 1), travelling west. Almost immediately thereafter a 2nd adult (B) was seen approaching very fast from the west: the 2 animals joined up and began traveling fast westward. Both animals, but especially B, appeared highly agitated, with the head being thrust high out of the water at each surfacing. After the boat closed with the group, the whales reversed direction and began swimming eastward. As the boat followed the group, a very small grayish calf (C) was encountered, swimming slowly at the surface. At that stage, both adults were about 100 m away from C. When the boat stopped to inspect the calf, both adults approached. Behavioral interactions between C and the adults then took place, but the adults left without C following. The calf then swam slowly round the boat, bumping it once, causing a large piece of skin to become detached. The animal was clearly newborn, with loose grayish skin indicative of an animal undergoing postnatal ecdysis that is completed on average within 1 week of birth (Reeb et al. 2005). The sex of the calf was determined genetically as female (Bérubé and Palsbøll 1996). The boat then left C to follow the adults, which after moving about 200 m away reversed direction and returned to C. Whale B then interacted quite strongly with the calf, surfacing right next to it, and the calf began swimming alongside her in the normal mother–calf position, with whale A also in attendance. Whale B was biopsied and proved to be female. Shortly after B had been biopsied, the calf was abandoned again, the adults moving off several hundred meters. When the boat followed them, they reversed direction and returned to C. When the boat approached again, the adults swam off without the calf. This was the last time that C was seen. Adult B continued to swim in an agitated manner backward and forward, mainly inshore/offshore, sometimes accompanied by whale A. Eventually A and B separated, causing loss of visual contact with whale A. Whale B was then seen to associate with a smaller whale that possibly could have been whale A. After biopsying the latter individual (determined genetically to be male), the boat left the area. The total period of observations was 1 h 44 min. It is possible that the observed behavior of the adults was influenced by the presence of the boat, particularly following the biopsy darting of B.

Whale B was photographed again on 30 September 1996 off De Hoop, about 7.5 nautical miles west of (and 82 days following) its July location, with a calf (D). Both animals were biopsied, and the calf molecularly sexed as male. The cow was later identified as MRI catalog number R99/11A, which had not been seen previously in 17 annual surveys suggesting that D was likely to have been its first recorded calf, making R99/11A at least 6 years old in 1996.

Whales B and R99/11A had identical genotypes at 14 microsatellite loci, confirming that they were the same adult female: R99/11A also shared at a minimum 1 allele at all 14 microsatellite loci with calf D, confirming that it was its biological offspring. The microsatellite data from calves C and D, however, proved these to be 2 different individuals, confirming the findings from gender determination.

This incident can be characterized as an interaction between a near-term female and an abandoned/orphaned non-offspring neonate, in which the adult seemed to be the active partner, at least briefly.

Case 2: association between lone calf and different mother–calf pairs.—On 19 October 1997, during the annual photographic survey for right whales, a group consisting of a cow and 2 apparent calves was encountered off De Hoop Nature Reserve: one of the calves left the group almost as soon as photography began but was relocated about 5 min later and photographed on its own; the total duration of observations was about 6 min. This was considered a highly unusual occurrence at the time, as usually a calf on its own will be rapidly rejoined by its mother once the helicopter targets the calf for photography. The cow was identified as MRI catalog number R89/16A, a female first photographed with a calf in 1989 and with subsequent calves in 1994 and 1997. Given a minimum age at first parturition of 6 years, R89/16A was presumably at least 14 years old in 1997. The lone calf was readily identifiable from a large white dorsal blaze and was assigned the MRI catalog number R97/72c.

On 29 October 1997, the same calf was encountered at sea off De Hoop about 2 km from the sighting 10 days earlier. About 200 m away was another cow–calf pair, the adult of which proved to be MRI catalog number R97/56A, a female photographed for the first time with a calf (and so presumably about 6 years old): it was photographed 3 years later with a 2nd calf. All 3 animals were biopsied: the calf with the white blaze was molecularly sexed as male and seemed in good condition. The period of contact with the whole group lasted 25 min, during which time no 2nd adult arrived to claim this calf.

Although no attempts at suckling were observed, this was the first incident in which an apparently lone calf was observed associating with different cow–calf pairs several days apart.

Case 3: attempted non-offspring nursing.—On 8 December 2012, a solitary calf was seen from the air off Pearly Beach (Fig. 1): it did not seem to associate with any of several cow–calf pairs in the bay. The next day a cow was seen off Pearly Beach with 2 apparent calves in attendance. While 1 calf was calmly swimming in the vicinity of the female, the other was actively attempting to access the cow's genital area. The cow was twisting her body and attempting to avoid the second, very persistent calf: observations continued for about 15 min before the aircraft had to leave for passenger exchange. On a 2nd trip the same day, 2 calves were observed together but no female was seen in the vicinity.

Thereafter, a cow with 2 calves in apparent attendance was seen 6 times between 16 December and 26 December in Walker Bay, about 30 km to the NW of Pearly Beach (Table 1). On 4 of these occasions, the cows involved could be photo-identified, proving to be 3 different individuals:

> R09/162A, first seen with a calf in 2009 and seen on 18 October 2012 during the aerial survey with a single calf about 60 km to the southeast of Walker Bay; comparisons of photographs showed that this calf was still present on 16 December;
> R97/113A, seen with calves in 1997, 2000, 2003, 2006, and 2009, and on the aerial survey on 4 November 2012 in Walker Bay as escort to a 2nd adult female (R86/09A) with a calf;
> R09/335A, first seen with a calf in 2009 and only photographed by the whale-watch operation in 2012, not by the annual aerial survey that year.

Assuming these cows all had their 1st calf at a minimum age of 6 years, they would have been at least 9, 21, and 9 years old, respectively, in 2012.

One calf was photo-identified on 3 occasions (16, 21, and 26 December) as the same individual (E) and was observed making suckling attempts on 2 different cows; if it was assumed that it was the same non-offspring observed on all occasions that year, then it was seen on 9 occasions, with at least 3 different cows on 5 different days and alone on one day (Table 1).

Evasive reactions by the mother were recorded 3 times on 2 different days. For example, when first encountered on 21 December, the cow R97/113A was lying in an area of white water and disturbed substrate, interacting with E while its own calf lay about 2 (adult) body lengths distant. E was attempting to dive beneath the genital region of the cow, which responded by lying on its back, a tactic sometimes used by mothers to terminate nursing by their own calf (Thomas and Taber 1984). When encountered 90 min later, the same cow was found still lying on its back in a patch of disturbed water, with E attempting to access its genital area (Fig. 2A). There was initially no sign of the cow's own calf, but after 2 min, E seemed to finish harassing the cow and started to move away. The cow then rolled upright, turned more than 90°, and headed inshore (Fig. 2B). Zooming out, the camera showed that the cow was headed toward a 2nd calf (Fig. 2C). Assuming the cow was about 14 m long (Best and Rüther 1992), this 2nd calf is estimated to have been about 200 m distant from the cow at the time the interaction with E ended. Given the time elapsed from the image time stamps, the cow must have covered the intervening distance at a speed of 10.3 km/h, faster than any leg swimming speed recorded for

Table 1.—Observations of non-offspring involvement with cow–calf pairs of right whales (*Eubalaena australis*), South Africa, 2012, 2013: all aerial sightings made from commercial whale-watching operation (sightings made on separate flights on the same day listed separately). Letter codes are as follows: N = non-offspring, MC = mother + calf, MCN = mother + calf + non-offspring. ? = no photographs available for individual identification.

Encounter no.	Date	Location	Seen from	Group type	Identity of non-offspring	Identity of mother	Attempted suckling by	Remarks
2012								
1	8 Dec.	Pearly Beach	Air	N	?			
2	9 Dec.	Pearly Beach	Air	MCN	?	?	N	Mother evasive to N
3	9 Dec.	Pearly Beach	Air	CN	?	?		
4	16 Dec.	Walker Bay	Air	MCN	?	?	C, N	
5	16 Dec.	Walker Bay	Air	MCN	E	R09/162A		Trio relaxed
6	17 Dec.	Walker Bay	Air	MCN	?	?		
7	21 Dec.	Walker Bay	Air	MCN	?	R97/113A	N	Mother evasive to N, calf stands by—Fig. 2
8	21 Dec.	Walker Bay	Air	MCN	E	R97/113A	N	Mother evasive to N, calf stands by—Fig. 2
9	26 Dec.	Walker Bay	Air	MCN	E	R09/335A	C, N	Calves possibly competing for access
10	30 Dec.	Walker Bay	Air	MC		R97/113A		No sign of N
2013								
11	24 Nov.	Pearly Beach	Air	MCN	F	R13/375A		No sign of a cow without calf
12	24 Nov.	Pearly Beach	Air	MCN	F	R13/375A		
13	25 Nov.	Pearly Beach	Air	N	?			
14	25 Nov.	Pearly Beach	Air	N	?			
15	25 Nov.	Pearly Beach	Air	MCN	?	?	N	Mother evasive to N, calf stands by
16	27 Nov.	Pearly Beach	Air	MCN	?	?	N	Mother evasive to N
17	27 Nov.	Pearly Beach	Air	MCN	?	?		
18	28 Nov.	Pearly Beach	Air	MCN	?	?		N moving between c/c pairs, mothers evasive
19	28 Nov.	Pearly Beach	Air	MCN	?	?		N moving between c/c pairs, mothers evasive
20	28 Nov.	Pearly Beach	Air	MCN	?	?		N moving between c/c pairs, mothers evasive
21	2 Dec.	Pearly Beach	Air	N	?			Further out in bay
22	2 Dec.	Pearly Beach	Air	MCN	F	R13/376A	N, C	
23	2 Dec.	Pearly Beach	Air	MCN	F	R13/376A	N	Calves possibly competing for access
24	2 Dec.	Pearly Beach	Air	MCN	F	R13/376A	N, C	See Fig. 3
25	3 Dec.	Pearly Beach	Air	N	F			Breaching. Only seen on 1 of 3 flights
26	4 Dec.	Pearly Beach	Air	MCN	?	?		N originally alone then joined MC
27	5 Dec.	Pearly Beach	Air	N	?			
28	8 Dec.	Pearly Beach	Air	N	?			In vicinity of 5 MCs
29	8 Dec.	Pearly Beach	Air	N	?		N	Joined MC for 10 min, mother evasive
30	9 Dec.	Pearly Beach	Air	MCN	?	?	N	Mother relaxed
31	11 Dec.	Pearly Beach	Air	MCN	F	R91/55A	N, C	Simultaneous suckling attempts
32	13 Dec.	Pearly Beach	Air	MCN	F	R91/55A	N, C	Alternate and simultaneous suckling
33	13 Dec.	Pearly Beach	Air	MCN	F	R91/55A	N, C	Mother evasive initially
34	13 Dec.	Pearly Beach	Air	MCN	F	R91/55A		Mother relaxed
35	14 Dec.	Pearly Beach	Air	MCN	?	R91/55A	N	See Fig. 3
36	17 Dec.	Pearly Beach	Air	MCN	?	R91/55A	N, C	Simultaneous attempted suckling
37	19 Dec.	Pearly Beach	Shore	MCN	?	?		Mother evasive
38	19 Dec.	Pearly Beach	Air	MCN	F	R91/55A	C	
39	20 Dec.	Pearly Beach	Air	MCN	?	R91/55A	N	(Mother recorded as evasive off camera)
40	21 Dec.	Pearly Beach	Air	MCN	F	R91/55A		Mother initially evasive
41	22 Dec.	Pearly Beach	Shore	MCN	?	?		Mother evasive
42	23 Dec.	Pearly Beach	Air	MCN	?	R91/55A	N	Mother evasive
43	30 Dec.	Pearly Beach	Air	MCN	F	R91/55A	N	
44	30 Dec.	Pearly Beach	Air	N	?	?		N left behind by MC pair
45	31 Dec.	Pearly Beach	Air	MCN	F	R91/55A	N	

362 right whale groups tracked by theodolite from the shore (Barendse and Best 2014). Observations ceased after 6 min, with the cow–calf pair swimming together and E following them at an estimated distance of 95 m (Fig. 2D).

At other times (e.g., 26 December), the cow was not seen to make any attempt to dissuade either calf from suckling in 8 min of observations: rather the 2 calves dove beneath the female to access the genital area, often from separate sides, and seemed to be jostling for position.

To summarize, assuming only a single individual was involved, an apparently abandoned or orphaned calf interacted with at least 3 different mother–calf pairs over a period of 19 days. Apparent attempts to suckle by the non-offspring were seen on 4 days and from at least 2 different mothers.

Fig. 2.—A) Female (*Eubalaena australis*) R97/113A lies on back evading intentions of non-offspring, B) leaves non-offspring to locate calf, C) swims quickly and directly to calf, and D) swims off with calf with non-offspring following; Walker Bay, 21 December 2012.

Case 4: attempted non-offspring nursing.—On 24 November 2013, an apparently lone calf (F) was spotted from the air close to a mother–calf pair, in a bay to the east of Pearly Beach. From the amount of sediment stirred up between them, it was inferred that F had been trying to suckle from the cow. The pilot searched the immediate vicinity and located a total of 12 mother–calf pairs and the lone calf, but no unaccompanied adults. The situation was essentially unchanged on a 2nd flight 72 min later.

Thereafter a cow with 2 calves in apparent association was encountered on 25 occasions on 17 different days in the Pearly Beach area, over a total time period of 37 days (Table 1). In total, 3 different cows were identified:

R13/375A, first seen with a calf in 2013;
R13/376A, first seen with a calf in 2013;
R91/55A, seen 5 times before on the South African coast: in 1991 and 2007 as an escort to a cow–calf pair, in 2001 and 2009 as a single animal, and on 4 October 2013 as a mother with a newborn calf, approximately 120 km (coastwise) to the east of Pearly Beach.

Fig. 3.—Same non-offspring attempting to suckle from (upper) R13/376A accompanied by calf (*Eubalaena australis*), 2 December 2013, and (lower) R91/55A accompanied by calf, 14 December 2013.

Assuming a minimum age at first parturition of 6 years, the first 2 females would have been about 6 years old. The minimum age for R91/55A would be 22 years, but as it was recorded as an "adult" when first seen a more realistic minimum age might be 25 years. Her calf in 2013 would have been at least 68 days old when their first encounter with the non-offspring was recorded.

One calf was photo-identified on 14 occasions over 9 days (24 November; 2, 3, 11, 13, 19, 21, 30, and 31 December) as the same individual (F): on the remaining occasions, there were no suitable images for matching. Suckling attempts by F were seen on 8 occasions on 5 different days with 2 different cows (Table 1). If it is assumed that the same non-offspring was observed on all occasions, then it was seen on 27 occasions on 18 days with 3 different cows: it was also recorded alone, moving between, joining, or leaving cow–calf pairs on 11 occasions, indicating considerable fluidity of association.

The reaction of the mothers varied, as with case 3. On 12 occasions on 10 days, evasive behavior was recorded, probably involving at least 2 different mothers: the most common reaction was to lie in an inverted position so that access to the mammary gland area was denied. On 3 of these occasions, the behavior was only temporary, and on another 5 occasions, the cow was recorded as relaxed and/or permitted simultaneous or alternate suckling attempts by the offspring and non-offspring calves (Table 1).

The observation of 31 December was the last of this group in the area by both whale-watching boats and the aircraft. A flight on 2 January 2014 found no whales at all along the coast within 20 km either side of Hermanus.

Assuming only a single individual was involved, this episode can be characterized as an apparently abandoned or orphaned calf interacting with at least 3 different cow–calf pairs over a total period of 38 days, with the interactions being confined to the same cow–calf pair over the last 21 days. Attempted suckling by the non-offspring was photographically recorded on 10 days and noted on another 3 days and involved at least 3 different mothers.

Classification of non-offspring as calf or yearling.—Assignment of juveniles as calves or yearlings has usually been based on size. Taber and Thomas (1982) assigned calves-of-the-year to 4 size categories: < 25% mother's length, 25–50% mother's length, approximately 50% mother's length, and > 50% mother's length. Although their size estimates were based on the visible portion (from a 46-m cliff) of the calf during a normal surfacing relative to the overall length of the mother, and so not completely comparable with the photographic method used here, Best and Rüther (1992) provided photogrammetric measurements which tentatively agreed with Taber and Thomas' classifications in that no calf exceeded 60% of its mother's length by mid-November. Taber and Thomas (1982) defined yearlings as 75% of their mother's length, while North Atlantic right whales at 1 year of age reach 76% on average of their asymptotic length (Fortune et al. 2012). Taking the lower 99% confidence interval around the latter measurement would suggest most yearlings would be at least 74% of their asymptotic length. Assuming the asymptotic length is equivalent to the average length of an adult female, these proportions provide some criteria for distinguishing between calves (< 60% mother's length) and yearlings (> 74% mother's length) in the field.

Other meristic criteria that might be used to distinguish calves from yearlings, such as relative head size or fluke width, have not proved as reliable. Nine known yearlings on the South African coast had head lengths ranging from 15% to 20.7% of body length (average 17.2% ± 2%): this compared with an average of 15.8% ± 0.9% in 115 calf measurements (Best and Rüther 1992). Fluke widths could be estimated in 5 known yearlings, ranging from 34.4% to 41.6% (average 38.1% ± 3.1%): fluke width in calves showed significant positive allometry, increasing from 34.1% to 40.8% of body length over body lengths of 3.41–8.5 m (Best and Rüther 1992). Thus, although yearlings overall might have relatively larger heads and wider flukes than calves, there was insufficient discriminatory power in either case to make unequivocal assignments to age class. Other nonmeristic criteria, such as head shape or callosity development (Patrician et al. 2009), are less applicable for aerial images and when taken late in the calving season (about 4 months after the mean date of birth).

Relative sizes of non-offspring and calves compared to the accompanying adult are given in Table 2. They indicate that all 3 non-offspring should be classified as size 4 calves and

Table 2.—Size of right whale *Eubalaena australis* calves and non-offspring relative to that of the mother, South Africa, with their classifications according to the criteria of Taber and Thomas (1982).

Date	Non-offspring identity	% Mother's length	Classified as	Associated calf	% Mother's length	Classified as
19 Oct. 1997	R97/72c	< 60	Size 4 calf			
16 Dec. 2012	E	53	Size 4 calf	R09/162c	54	Size 4 calf
26 Dec. 2012	E	53	Size 4 calf	R09/335c	57	Size 4 calf
30 Dec. 2012	E			R97/113c	41	Size 2 calf
2 Dec. 2013	F	57	Size 4 calf	R13/352c	51	Size 4 calf
11 Dec. 2013	F			R91/55c	42	Size 2 calf
13 Dec. 2013	F	52	Size 4 calf	R91/55c		
30 Dec. 2013	F	54	Size 4 calf	R91/55c	43	Size 2 calf

5 of the accompanying calves would be either size 2 or size 4 calves. As all but one of the measurements were made in December, or about 4 months after birth, these size classifications are consistent with the overall pattern of calf growth. In the case of R97/72c, an inspection of the catalog of white-blazed calves from the previous season failed to reveal a match: as the efficiency of detecting calves on aerial surveys from 1995 to 1997 was 71.4–76.9% (Brandão et al. 2011), there seems a high probability that this individual was not born the previous year.

Non-offspring F was subsequently matched with a calf accompanying a cow photographed on 1 October 2013, approximately 330 km coastwise to the east of Pearly Beach: from its callosity development and cyamid infestation, the calf was clearly recently born. This match would mean that F was at least 55 days old when first seen attempting suckling from a nonmaternal cow (and given the mean date of birth more likely 3–4 months old). The cow was R79/02A, previously seen with a calf on the South African coast in 1979, 1981, 1984, 1990, 1993, 1999, and 2005: if 1979 was its first calving, then the female would have been a minimum of 40 years old in 2013.

Discussion

These observations suggest that the individuals responsible for the attempted non-offspring suckling in cases 2, 3, and especially 4 were all calves-of-the-year, rather than yearlings. In cases 2 and 3, this conclusion is strongly dependent on their relative sizes: if there are particularly diminutive or late-born individuals, these might not fit the average growth curve and could appear smaller as yearlings.

Although actual observations of suckling were not made (and in any case are extremely difficult to detect, given that the cow normally maintains its dorsal-up posture when nursing), there seems little doubt that cases 2, 3, and 4 provide evidence of a non-offspring attempting to associate with and/or suckle from more than 1 (and up to at least 3) lactating females. In cases 3 and 4, such interactions continued over 11–38 days, and all 3 cases were confined to a limited geographic area.

Reactions of the adult females to the attempted suckling differed. Some seemed to tolerate the presence of a non-offspring calf, to the extent that observers felt successful suckling by both calves might have taken place. At the other extreme, R97/113A (and the unknown female on 9 December 2012) reacted violently, twisting and/or inverting the body (presumably to prevent access to the mammary area by the non-offspring calf). At such times, the cow's offspring seemingly retreated temporarily to a safe distance from the fray. Reasons for the different reactions are difficult to establish: in the case of R97/113A, her calf was substantially smaller (and probably younger) than those of other cows approached and for which the relative size of the calf could be established, possibly eliciting a more protective response by the mother to preserve her milk resources.

An analysis of available photographic frames suggests that the non-offspring calf may have been at least as competitive as R91/55A's calf for access to the genital area (Table 3). During 11 encounters made over 10 days, the non-offspring calf was photographed more often in a suckling position than the mother's calf on 7 occasions, an equal proportion of time on 2 occasions and less often on 2 encounters; these proportions do not reject the null hypothesis of equal access by both calves (sign test, critical values for $n = 9$, $P = 0.5$, being 1 and 8). This excludes periods when the mother lay inverted preventing any suckling: R91/55A's calf made no recorded suckling attempts at all in the 3 encounters when this behavior occurred, while the non-offspring calf was recorded in a potential suckling position in 36–100% of the images. This would suggest that the cow's evasive tactics were directed mainly toward the non-offspring calf.

It is difficult to conclude whether any of the non-offspring calves obtained sufficient nourishment from these interactions to survive or even whether the survival of the true calves was compromised. No stranded calves were reported subsequently in the vicinity, but the conspicuously marked R97/72c from case 2 has not been photographed on 15 subsequent aerial surveys (up to and including 2012). However, these surveys were largely directed at cow–calf pairs (and white-blazed animals can be of either sex—Schaeff et al. 1999), and hence the absence of sightings cannot be taken as unequivocal evidence of nonsurvival. There was some evidence of growth in both the calves associated with R91/55A. Even assuming the mother was 15.2 m long (the upper 95% confidence interval for 57 adult females measured photogrammetrically by Best and Rüther 1992), the changes in proportion would correspond to overall increases in length of about 15 cm for the calf and 30 cm for the non-offspring over 19 and 17 days, respectively, or 0.8 cm/day growth for the calf and 1.8 cm/day for the

Table 3.—Proportions of time spent in a suckling position versus at or on the surface for the right whale *Eubalaena australis* calves of R13/376A and 91/55A and the associated non-offspring, as judged from successive photographic images, December 2013.

Date	Duration of obs. (min)	No. of frames	Calf		Non-offspring	
			Suckling	Surface	Suckling	Surface
R13/376A						
2 Dec. a	~3	18	33.3	66.7	44.4	55.6
2 Dec. b	8.3	41	4.9	95.1	92.7	7.3
2 Dec. c	10.5	57	42.1	57.9	24.6	75.4
R91/55A—in normal position						
11 Dec.	9.6	50	66.7	33.3	95.7	4.3
13 Dec. a	4.9	23	87.0	13.0	78.3	21.7
13 Dec. b	5	28	28.6	71.4	85.7	14.3
14 Dec.	0.3	5	0	100	100	0
17 Dec.	1.4	26	100	0	100	0
19 Dec.	3.4	11	87.5	12.5	0	100
20 Dec.	2	7	0	100	100	0
21 Dec.	7.9	11	0	100	9.1	90.9
23 Dec.	3.7	3	0	100	0	100
30 Dec.	8	18	0	100	72.2	27.7
31 Dec.	11.5	42	7.1	92.9	40	60
R91/55A—in inverted position						
13 Dec. b	5	10	0	100	100	0
21 Dec.	7.9	11	0	100	36.4	63.6
23 Dec.	3.7	24	0	100	100	0

non-offspring. These rates are well below that of 2.78 ± 0.71 cm/day recorded photogrammetrically for calves between July and November by Best and Rüther (1992). If the mother was indeed feeding both calves, then such impaired growth would not be unexpected. Nevertheless, the data are limited and the interpretations based on unproven assumptions.

In a review of non-offspring nursing in mammals, Packer et al. (1992) have shown that in monotocous taxa such as Cetacea, it is relatively more common where taxa form larger groups, it is generally associated with "milk theft," and it is also more common in taxa where a relatively high proportion of the behavior involves females that have lost their own offspring. Although baleen whales are not generally considered as particularly social animals, with group sizes usually small (mean group size range 1–9) and impermanent (Whitehead and Mann 2000), southern right whales are seasonally "social." The females give birth in, or bring their newly born calves into, coastal nursery areas, for reasons that are not entirely clear but seem to include shelter from swell, protection from predators, and possible avoidance of males and other whales without calves (Elwen and Best 2004a, 2004b, 2004c). Such areas are consistent in location from year to year and quite circumscribed in extent, so that cow–calf pairs tend to aggregate within them. These aggregations can reach very high densities: in 2012, for instance, 75 cow–calf pairs were photographed along 26 km of coastline in the main nursery area off De Hoop, South Africa. As most pairs are within about 0.9 km from the coast (Best 1990), this is equivalent to an overall density of 3.2 pairs/km^2. While such aggregations are not strictly social units, as there is a constant flux of individuals, females tend to linger in these areas (Mate et al. 2011), with average residence times estimated as 59 ± 3.9 days (Best 2000). This provides plenty of opportunities for cow–calf pairs to interact (and seems to meet Packer's 1st criterion).

In this aspect, the nursery areas almost represent the cetacean equivalents of pinniped rookeries, where adult females congregate seasonally for parturition and early care of their young. Within such rookeries, milk theft is often the most frequent mode of non-offspring nursing, being recorded as such by Packer et al. (1992) in 5 of the 7 species for which non-offspring nursing was recorded (*Arctocephalus galapagoensis*, *Eumetopias jubatus*, *Zalophus californianus*, *Leptonychotes weddellii*, and *Mirounga angustirostris*). Given the similar juxtaposition of cows with newborn calves in right whale nursery areas, it is perhaps not surprising that instances of milk theft by southern right whales should occur. Such instances are likely uncommon, given that the 1997 observation of a lone calf was the first in photography of 1,337 cow–calf pairs over 19 years of surveys (acknowledging that milk theft by an unabandoned calf would go undetected in such data). The recent occurrence of instances in 2 successive years is intriguing but is most likely an artifact reflecting greater observer awareness or coverage (especially by commercial aerial whale-watching operations).

All the instances of potential non-offspring suckling recorded to date seem to have been initiated by the calves themselves, i.e., milk theft, rather than by females that have lost a calf. Instances of the latter phenomenon might present as a 2nd adult associating or interacting with a cow–calf pair (as an "escort"). Between 2005 and 2012, there were 135 such incidents recorded on aerial surveys, usually (84%) involving a single individual but occasionally up to 6. In 71 (53%) of the incidents, no photographs were taken of the escorts, presumably because they were only loosely associated with or left the cow–calf pair before any frames could be exposed or were deliberately not photographed as part of the survey protocol. In the remaining 64 incidents, 43 involved individuals not photographed previously or subsequently ("new" individuals), while another 12 were photographed earlier or later but unaccompanied by a calf, 2 of them on more than 1 occasion. Given the nature of the catalog (targeted at cow–calf pairs), this lack of resightings suggests that these individuals were either immature individuals of either sex or more likely males. In the other 9 cases, the "escort" had a previous or subsequent sighting history that included being seen with a calf, and so these were most likely females. In 8 of these cases, the individual had either last calved 3 years previously ($n = 5$) or calved 3 years later ($n = 2$) or both ($n = 1$): as the modal calving interval in this population is 3 years (Best et al. 2001a), this would suggest that all of these escort females were in a potential calving year. The absence of a calf could therefore imply that it was lost, undetected, or still unborn: the 9th female "escort" was in fact seen with a calf of its own later the same year. It is also possible that there was a misclassification of the cow and its escort: aerial contact with each group usually lasted only a few minutes and if the calf moved between adults during this period, the identification of the true mother became somewhat subjective (3 of the 9 "cows" have never been seen with a calf on any other occasion). The evidence is therefore somewhat inconclusive: a few single females in their calving year associate with another female and calf but the motivation for this association is unclear and might include attempts to abduct the calf.

Cases of non-offspring nursing have been recorded in captive cetaceans, mainly bottlenose dolphins *Tursiops truncatus* (Kasuya and Marsh 1984; Smolders 1988; Kastelein et al. 1990; Ridgway et al. 1995; Messinger et al. 1996; Gaspar et al. 2000). In wild cetaceans, allomaternal care of offspring has been proposed for schooling odontocetes such as sperm whales *Physeter macrocephalus* (Best et al. 1984; Whitehead and Weilgart 2000), and possible observations of a sperm whale calf suckling from different females on different occasions, and of 2 calves suckling from the same female, have been made (Gordon 1987). In 1,679 h of observations, 3 instances were recorded of bottlenose dolphin calves attempting to nurse from nonmothers, 2 of which were immature females while the 3rd was a female that had lost its calf 6 weeks earlier: these calves never attempted to adopt an infant position with females with dependent offspring (Mann and Smuts 1998). Although cases of genuine adoption by a female that has lost its own calf are difficult to detect, Frasier et al. (2010) describe an exchange of calves between 2 adult female North Atlantic right whales on the nursing ground within about 2 months of birth, with both adopted calves surviving to reach maturity themselves. The current observations of females permitting contemporaneous suckling attempts by their own and non-offspring calves therefore seem to be the first for any mysticete.

As reviewed by Roulin (2002), several hypotheses (not necessarily mutually exclusive) have been advanced to explain the nursing of non-offspring in mammals in general. These include (1) misdirected parental behavior, (2) reciprocity (with other females), (3) kin selection (inclusive fitness), (4) milk evacuation (surplus to needs), and (5) improving maternal skills. As the current observations do not include any indication of reciprocal suckling, hypothesis (2) appears untenable. Estimates of the minimum ages of 8 of the adult females involved ranged from 6 to 25 (average 12) years, 4 of which were with their first recorded calf. This makes hypothesis (5), of improving maternal skills, unlikely, as it usually applies to virgin females that spontaneously lactate, and is unlikely to apply in the instance where the cow nurses non-offspring along with her own (Roulin 2002). Unfortunately, we do not know the extent of relatedness of any of the females to the non-offspring calves: attempts to match R91/55A to 3 of the 4 calves produced by R79/02A (the mother of non-offspring F) from 1979 to 1990 were unsuccessful and the 4th was unmatchable, so although we cannot disprove that R91/55A and F were related the likelihood of hypothesis (3) is reduced in this case. The current observations do not allow us to discriminate between the remaining hypotheses (1) and (4). Thus, a female that seems to tolerate a non-offspring suckling is consistent with both misdirected parental care and milk evacuation (if she has an abundant milk supply), while we are uncertain whether the degree of toleration is influenced by the relatedness of the non-offspring calf.

The case of R91/55A is especially interesting in that it appears to be the only 1 of the 6 incidents where the recorded association with a non-offspring extended beyond a day. Less comprehensive photographic coverage of some of the earlier incidents, where an extended association with a particular cow may have been missed, may have contributed to this apparent difference, although the maximum possible periods of association in 2 instances where a switch between mothers was recorded could only have been 4 and 8 days compared to at least 21 days in the case of R91/55A. The fact that R91/55A had not been seen with a calf since its first sighting (as an apparent adult) 22 years earlier might suggest that she was in better physical condition than other adult females that had calved at much shorter intervals, and thus more capable of simultaneously suckling 2 calves. However, her possible failure to be spotted with a calf earlier might reflect a different reproductive strategy (calving later than the aerial surveys or calving outside the survey area) or success (early loss or abandonment of calves): it is interesting that this female was seen in 2 previous years as an "escort" to another mother–calf pair. It should also be borne in mind that these observations occurred late in the season for right whales on the South African south coast (Best and Scott 1993), and dwindling numbers of cow–calf pairs in the area may have reduced options for the non-offspring to switch to another mother.

As Packer et al. (1992) point out, non-offspring nursing in monotocous species is generally rare, and the costs to the female potentially high (from either simultaneous or sequential suckling of 2 calves, for instance). This is certainly the case in seasonally feeding mysticetes such as the right whale, where the costs of lactation cannot be recovered until the cow resumes feeding about 4 months after parturition: comparison of blubber thickness between pre-pregnant and late lactating females indicates a loss of 25% of the blubber layer over this period (Miller et al. 2011). Hence, it will be especially interesting to monitor the future calving histories of those females identified in non-offspring associations in this paper.

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11 Appendix 5

11.1 Poster presentations

2014, July South African Marine Science Symposium. Stellenbosch. Poster presentation.

Cetacean data collection from commercial whale watching vessels: Consistency, validity, and value in local habitat monitoring

Katja Vinding[1,2], Michael Christiansen[2], Meredith Thornton[1], Marthán Bester[1], Wilfred Chivel[3] and Simon Elwen[1]

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INTRODUCTION

Whale watching vessels (WWVs) constitute a valuable and cost-effective platform of opportunity for collection of information on the species, distribution, number, and behaviour of cetaceans encountered

In South Africa, licensed WWVs are required since 1998 to submit trip summary data to the South African Department of Environmental Affairs (DEA). Currently a total of approximately 25 licences are issued, with no more than 3 licences in one area

This study analyses the consistency and validity of 13 years of data collected from a South African WWV. Guiding principles for future data collection is provided

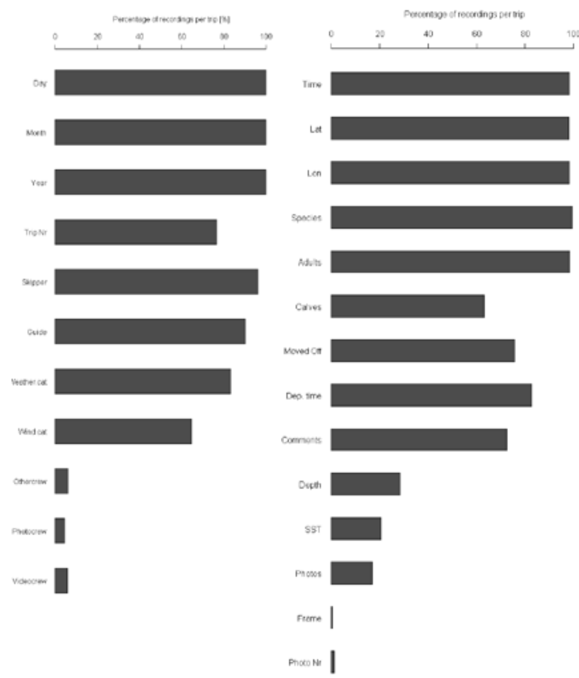

Figure 2.
Consistency in recordings per trip Consistency recordings per sighting

RESULTS

1. Consistent records: date, skipper and guide ID (100% of cases)
2. Less consistent records: weather and oceanographic information (from 12% for water depth to 88% for sea state)
3. Less than 5% recorded: trip duration, route (spatial effort), other crew, and photographic information
4. Validity of species identification: 100% agreement between observer records and photographic documentation
5. Location data were erroneous in 1.5% of cases
6. Behavioural data were described in overly subjective terms making a post-hoc analysis impossible

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MATERIALS AND METHODS

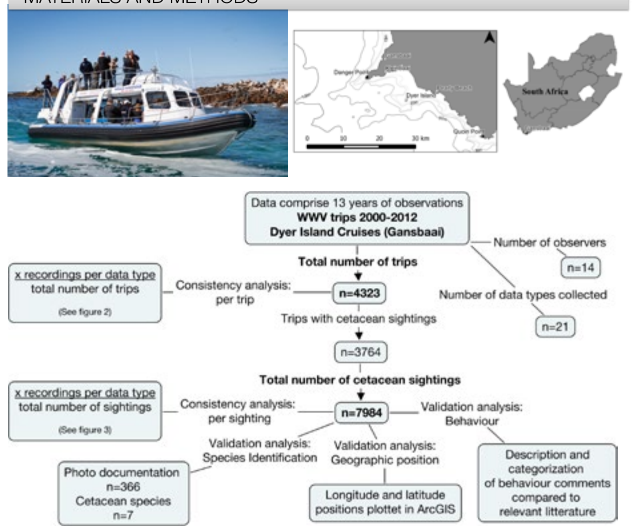

Figure 1. WWV permit area (Danger Point to Quion Point) and over view of data

CONCLUSIONS

1. Simplify the data sheet
2. Collect effort data (Lack of spatial and temporal effort makes spatial distributional analyses impossible)
3. Simplify and minimise behaviour categories
4. Register online through mammalMAP, Coastal Walkabout (Free App), Blue Flag accredited WWV, or a SA-server at DEA

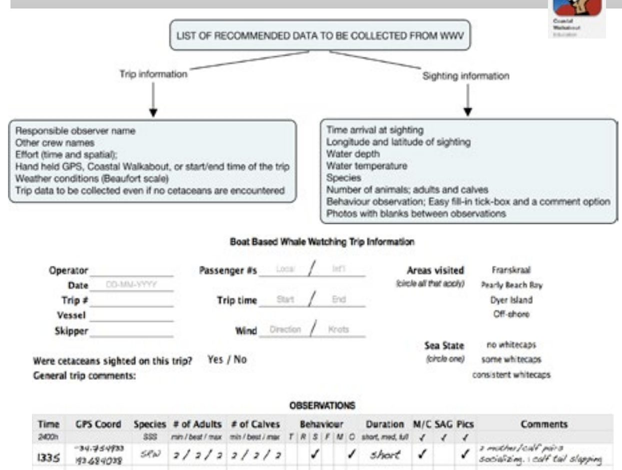

Figure 4. List of recommended data to be collected from WWV and an example of a simplified data sheet, based on the list of recommended data

In the absence of dedicated scientific surveys, the collected data provide valuable information on the long-term presence and distribution of cetaceans in the investigated area

This work has been recognised by the International Whaling Commission (IWC) and contribute to the development of worldwide standards guiding principles for data collection hosted on IWC website (IWC 2014)

2015, December Marine Mammal Society MARMAM, San Fransisco. Poster presentation.

VOCALIZATION PATTERNS
of Southern Right Whales, South Africa

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ABSTRACT

The southern right whale (*Eubalaena australis*) (Ea) population in South Africa is increasing at approximately 7% per year. The inshore waters of the south coast is the primary calving, nursing, socializing, and mating area during the austral winter and spring.

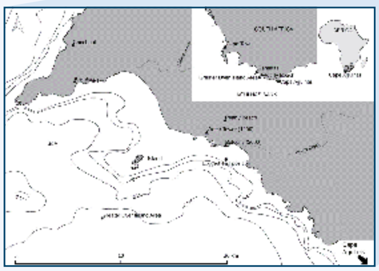
The aim of this study was to quantify the vocalizations of Ea, to associate call types with behaviour and group composition, and to develop a call specific classifier for use in automated analysis of passive acoustic monitoring (PAM) data. A total of 44 days of sound recordings were collected with a Loggerhead DSG-Ocean during three periods in January/February, September, and October 2014.

The Loggerhead was deployed in 12m of water in the Greater Dyer Island area, Western Cape. Weather permitting, shore based visual observations of whales around the Loggerhead were conducted with a theodolite in September 2014 (30h25m). Ea group compositions, behaviors, and locations were recorded during hourly visual scans.

Classification of right whale vocalization was based on the objective scheme of Urazghildiiev and Parks (2014) using six main classes: Narrowband fm upsweep (NU), Narrowband fm downsweep (ND), Narrowband complex fm (NC), Narrowband high calls (NH), Complex wideband signals (WC), and Gunshot sounds (WG). Only calls with a high signal to noise ratio were included in the analysis.

All six classes of Ea vocalization were identified in the analysis. Vocalizations were mainly below 400 Hz, except the gunshots extending above 5 kHz. No calls from Ea were recorded during the period of January/February, which corresponded with the well known migration pattern of this species. The most frequent call type was NU.

RESEARCH AREA



Situated inshore of the Agulhas Bank (Hutchings et al. 2009) in a shallow gently sloping sandy bay, protected from open ocean swell and seasonal winds (Elwen and Best 2004a & 2004b).

FIGURE 1
Research area. Triangles marks the theodolite stations and the position of the DSG-Ocean loggerhead is marked with a diamond.

METHODS

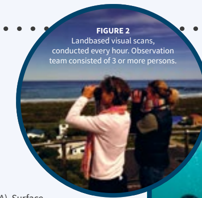


FIGURE 2
Landbased visual scans, conducted every hour. Observation team consisted of 3 or more persons.

THEODOLITE & VISUAL

- Land-based focal follows from two vantage points at 38.8 m and 14.7 m ASL using a Leica TC307 and VADAR.
- Visual scans were performed once hourly. Only observations in < Beaufort 4 included.
- Location, group composition (unaccompanied adult (UA), Surface active group (SAG) and cow-calf pairs (Cc-pair)) (Figure 3), behaviour, and number of individuals from each hourly visual scans was calculated and compared to PAM results.

PASSIVE ACOUSTIC MONITORING

- One DSG-Ocean Loggerhead deployed in 12 m of water. A custom designed mooring was used (Figure 3).
- Right whale vocalization was identified and classified following Urazghildiiev and Parks (2014) but only focused on Up-calls and gunshots (Figure 4) as they represent the best characterized right whale sounds.
- Calls were logged manually in Raven Pro 1.5 and assigned call type, Signal-to-noise Ratio (SNR) (Figure 5), and selection category (fundamental or entire call). Parameters measure: Table 1.

HYDROPHONE SETTINGS Sensitivity = -180 dBV/µpa, system gain = 20 dB. Two duty cycles: 1) Low frequency (LF) recordings, decimation factor of 8, sampling rate 10 kHz for 54.5 minutes; 2) High frequency (HF) recording, decimation factor of 1, sampling rate of 80 kHz, for 4.5 min.

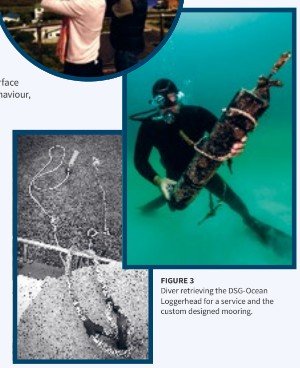


FIGURE 3
Diver retrieving the DSG-Ocean Loggerhead for a service and the custom designed mooring.

CONCLUSIONS

It was possible to identify and monitor the presence of SRW acoustically from their up-calls and gunshots.

There was no correlation between the call types and presence of different southern right whale groups.

The up-calls of southern right whales could be distinguished from the up-call units that were recorded as part of a theme of a humpback song.

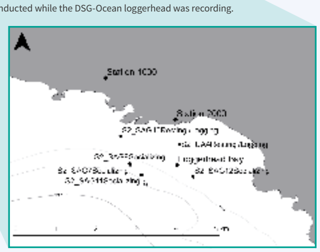
RESULTS

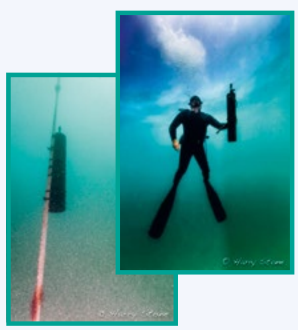
FIGURE 3
Ea group compositions; Cow-calf pairs (CC-pair), Surface active group (SAG), and unaccompanied adult (UA).

VISUAL

During September 2014 a total of 26 hours and 28 minutes of land-based visual observations were conducted while the DSG-Ocean loggerhead was recording.

FIGURE 8
Example of positions of different Ea groups on the 12th of September 2014, 9:38.





PAM

A total of 255 southern right whale up-calls and 83 gunshots were recorded during the visual observation periods.

Up-calls of Ea were tonal, frequency modulated up-sweep sounds with a mean centre frequency of 107 ± 16 Hz SD, mean start frequency of 56 ± 13 Hz SD, and mean duration of 0.92 ± 0.28 s SD.

Gunshots were broadband and had a higher centre frequency than the up-calls (centre frequency 1 426 ± 976 Hz SD; Table 1). The upper frequency of some gunshots recorded at the higher sampling rate exceeded 30 kHz.

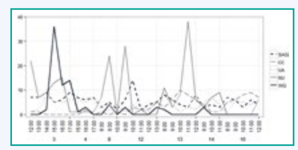


FIGURE 7
Y-axis: Total number of each group type (Cc-pair, SAG, and UA) and calls (NU or WG).
Y-axis: Time of the day (visual scan hour) and dates in September 2014. The total number of calls and of each Ea group type per visual scan hour per day was calculated.

	Southern right whale Gunshots (n=83) Mean value ± SD	Southern right whale Gunshots (n=6) Sampling rate = 80kHz Mean value ± SD	Southern right whale Up-call (n=255) Mean value ± SD	Humpback Up calls (n=20) Mean value ± SD
Low Frequency (Hz)	80 ± 46	81 ± 16	56 ± 13	94 ± 12
High Frequency (Hz)	5 714 ± 5 603	19 941 ± 14 295	184 ± 54.5	198 ± 8
Duration 90% (s)	0.11 ± 0.09	0.07 ± 0.07	0.55 ± 0.18	0.39 ± 0.03
Centre frequency (Hz)	833 ± 713	1 426 ± 976	107 ± 16	149 ± 6
Peak frequency (Hz)	564 ± 534	1 003 ± 1 075	107 ± 18	150 ± 9
Frequency 5% (Hz)	248 ± 88	293 ± 30	80 ± 14	122 ± 10
Frequency 95% (Hz)	4 035 ± 1 600	7 116 ± 2 445	146 ± 30	173 ± 8

TABLE 1 Call characteristics of Ea up-calls and gunshots and humpback whale up-calls (mean ± standard deviation).

Unexpectedly, humpback whale (*Megaptera novaeangliae*) vocalisations were present in some of the recordings and this complicated the sound analysis.

This discovery was a first for the area. Songs of humpback whales containing themes, phrases and units were registered. One of the themes contained up-call like sound units which was analysed to obtain the characteristics and to enable a definition of species-specific up-calls (Figure 6).

UP-CALL GUNSHOT

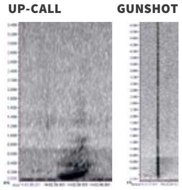


FIGURE 4
Example of an up-call (NU) and a gunshot (WG) from southern right whales.

SPECTROGRAM SETTINGS
512-point Hann window (3 dB bandwidth, LF = 14 Hz, HF = 28.4Hz) with 50% overlap.
1024-point DFT, LF; time resolution = 51.2 ms, frequency resolution = 9.8 Hz.
4096-point DFT, HF; time resolution = 25.4 ms, frequency resolution = 19.5 Hz.

SIGNAL TO NOISE RATIO

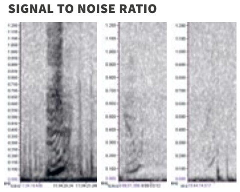


FIGURE 5
Three SNR categories: **Excellent**, **Potential** and **Poor**. Only calls with excellent or potential SNR was included in the analysis.

HUMPBACK WHALE THEME WITH UP-CALLS

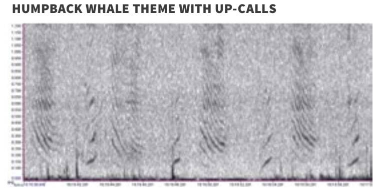


FIGURE 6
Humpback whale themes containing up-call like sound units which was analysed to obtain the characteristics.

- Out of 29 hours with animals present, sounds attributable to southern right whales were recorded in 23 hours (78%).
- Total number of each group type and call type was calculated and compared (Figure 7).
- There was no significant correlation between up-calls or gunshots and the number of UAs, SAGs, and Cc-pairs present in the bay.

THANK YOU

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