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Annual Report of the Southern Ocean Research Partnership (IWC-SORP) 2017/18

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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

The Southern Ocean Research Partnership (IWC-SORP) was established in 2009 with the aim of developing a multi-lateral, non-lethal scientific research programme that would improve the coordinated and cooperative delivery of science to the IWC. There are now 13 member countries in the Partnership: Argentina, Australia, Belgium, Brazil, Chile, France, Germany, Italy, Luxembourg, New Zealand, Norway, South Africa, and the United States. This paper reports on the continued progress of IWC-SORP and its five ongoing research themes[1] since the Scientific Committee meeting in 2017. This progress includes the production of at least 33 peer-reviewed scientific papers in 2017/18, bringing the total number of peer-reviewed publications related to IWC-SORP produced since the start of the initiative to ca. 126. Moreover, 124 IWC-SORP related papers have been submitted to the Scientific Committee, 21 of them this year. Fieldtrips to the western Antarctic Peninsula, Marion Island, the Ross Sea, the Chesterfield-Bellona Reef complex west of mainland New Caledonia, and the Great Barrier Reef, Australia have taken place in the past year. Thousands of images for photo-identification have been collected, satellite tags have been deployed on killer whales, Antarctic minke whales and humpback whales. As well as video suction cup tags on Antarctic minke and humpback whales. Biopsy samples have been collected from killer whales, humpback and Antarctic minke whales; and hundreds of hours of cetacean acoustic recordings have been made and analysed.

KEYWORDS: SOUTHERN OCEAN RESEARCH PARTNERSHIP, IWC-SORP, ANTARCTICA, ABUNDANCE ESTIMATE, ACOUSTICS, BIOPSY SAMPLING, PHOTO-IDENTIFICATION, SATELLITE TAGGING, MOVEMENT, CONNECTIVITY, RESEARCH VOYAGE

INTRODUCTION

In 2008, the development of regional non-lethal cetacean research partnerships was proposed to the International Whaling Commission (IWC). These research partnerships would use modern, non-lethal, scientific methods to provide the information necessary to best conserve and manage cetacean species. The proposal was received very positively by IWC member nations. Subsequently, the Southern Ocean Research Partnership (IWC-SORP), a multi-lateral, non-lethal, scientific whale research program was established in March 2009 and has been supported by financial contributions from the Governments of Australia, the United States of America, Chile, the Netherlands, and the NGOs WWF-Australia and International Fund for Animal Welfare. The aim of IWC-SORP is to improve the coordinated and cooperative delivery of science to the IWC. Partnership members include

Argentina, Australia, Belgium, Brazil, Chile, France, Germany, Italy, New Zealand, Norway, South Africa, the United States of America and Luxembourg was warmly welcomed to the Partnership in May 2017.

The objectives, research plan, and procedural framework for the Partnership were developed through a workshop held in Sydney, Australia in March, 2009. Subsequently, a framework and set of objectives for IWC-SORP were endorsed by the IWC at its Annual Meeting in June 2009. Project plans (SC/63/O13) were presented to the IWC in 2011 and 2012 and reports summarising the activities of six IWC-SORP research projects have been presented annually to the Scientific Committee (SC/63/O12; SC/64/O13; SC/65a/O11; SC/65b/SH12; SC/66a/SH8Rev2; SC/66b/SH10Rev2; SC/67a/SH04Rev1; this paper). One of the endorsed IWC-SORP projects, the Living Whales Symposium, held in Chile, was completed in March 2012 and reported to the Scientific Committee in 2012 (SC/64/O14). Five endorsed research themes[1] are ongoing and this paper reports on the progress and results of these since the last meeting of the Scientific Committee in 2017. Further details of this work can be found at https://iwc.int/sorp.

BRIEF SUMMARY OF PROGRESS

Overall, IWC-SORP projects have produced ca. 126 peer-reviewed publications to date and 124 IWC-SORP related papers have been submitted to the Scientific Committee, 21 of which will be considered by the IWC Scientific Committee this year.

IWC-SORP Research Fund

In 2016, 144,058 GBP were allocated to 10 projects during an open, competitive grants round. Details of these allocations can be found in SC/67a/02 and project progress reports are presented in Bell (2018) SC/67b/SH18.

A new, open, competitive grants round was opened in September 2017 and closed in January 2018. Nineteen research applications were received. An independent assessment process, endorsed by the Scientific Committee and detailed in Annex V, was undertaken. The proposed allocation of funds to successful projects will be presented to the SC for endorsement during this meeting.

A financial report of the IWC-SORP Research Fund as of January 2018 is detailed in the Secretariat financial report, SC/67b/01. **£641,828 GBP** remain unallocated and unspent.

Funding and vessel time

The following vessel time has been awarded to IWC-SORP researchers:

- Argentinean Coast Guard vessel - 2018 (Iniguez et al.)
- *RV Polar Stern* and helicopters – 2018 (Herr et al.)
- NSF-funded voyages to the Antarctic Peninsula – 2018 (Friedlaender et al.)
- New Zealand MBIE funded voyage to study the Ross Sea Region MPA – 2018 (Constantine et al.)
- Argentinean Coast Guard vessel - 2019 (Iniguez et al.)
- *RV Maria S. Merian* - 2019 (Herr et al.)
- *RV Investigator* - 2019 (Nicol, Double, Bell et al.)
- New Zealand MBIE funded voyage to study the Ross Sea Region MPA – 2019 (Constantine et al.)
- Berths on One Ocean Expedition voyages to the Antarctic Peninsula – annually (Friedlaender, Double, Bell)

Progress within IWC-SORP research themes

Brief summaries of progress on each of the five ongoing IWC-SORP research projects in 2017/18 are given below. Full project reports are included in Annexes 1 to 5.

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[1]There are currently five IWC-SORP Themes (formerly referred to as Projects) covering 1) blue whales, 2) killer whales, 3) baleen whale foraging, 4) humpback connectivity and 5) blue and fin whale acoustics.

IWC-SORP Project 1: Antarctic Blue Whale Project (ABWP)

The objectives of the Antarctic Blue Whale Project are to improve our understanding of the status of Antarctic blue whales after 50 years of protection from exploitation, investigate the role of these whales in the Antarctic ecosystem, and ultimately to deliver a new circumpolar Antarctic blue whale abundance estimate and determine rate of recovery.

In 2017/18 work on the Antarctic Blue Whale Project has focused on the analysis of data collected during recent voyages, analysis of movements of Antarctic blue whales from recent and historic data, photo-identification of Antarctic blue whales, analysis of historic blue whale populations from bone samples, and the planning of upcoming research voyages.

Prefecto García voyage 2018

Visual and acoustic surveys of cetaceans were conducted on board the Argentinean Coast Guard (Prefectura Naval Argentina) cutter GC-189 *Prefecto García*, 22 January and 11 February, 2018, departing from the port of Ushuaia (54° 48.52'S 68° 18.17'W), and navigating along the Western Antarctic Peninsula to the Argentinean Antarctic base "Brown" (64° 53.72'S, 62° 52.25'W). Visual surveys were conducted over a total of 60.5 h and 472.5 nm. On-effort cetacean sightings included three odontocete and three mysticete species, encompassing a total of 210 encounters. A total of 147.6 h of acoustic recordings were collected with the towed hydrophone array. Detections included NBHF clicks recorded during an encounter with hourglass dolphins, NBHF clicks possibly also from this species, and other clicks. Further analysis of the recorded signals will be conducted to confirm species. These acoustic data also make an important contribution to the IWC-SORP Acoustic Trends Project.

New Zealand-Australia Antarctic Ecosystems Voyage (2015) – data analysis

Antarctic blue whale foraging grounds were surveyed during the 2015 New Zealand-Australian Antarctic Ecosystems Voyage by collaborators from the IWC-SORP Antarctic Blue Whale Project. This rich dataset has now been analysed to describe the distribution of these rare whales in relation to their main prey species, Antarctic krill, thanks to the IWC-SORP Grant: 'Antarctic blue whale-krill interactions: an analysis'. During the voyage, a combination of passive acoustic technology and visual observations were used to locate Antarctic blue whales, and active acoustics were used to simultaneously survey krill swarms in the vicinity and demonstrably far blue whales. Using Boosted Regression Trees, the characteristics of krill swarms in areas near and far from blue whales were compared. Results suggest that Antarctic blue whales are more likely to be present within the vicinity of krill swarms detected at night, those of higher internal density, greater vertical height, and those found shallower in the water column. This analysis is described in detail in SC/67b/EM06. The nature of krill aggregations preferred by Antarctic blue whales is an important consideration, not only for the management of this endangered species in a challenging environment, but also for the management of Antarctic krill fisheries. The findings will be used to refine and inform survey design for an Australian Antarctic Division-led *RV Investigator* voyage in 2019 (SC 67b/SH07) as well as other future multidisciplinary field campaigns for both the IWC-SORP Antarctic Blue Whale Project and other non-lethal baleen whale-focussed surveys in the Southern Ocean. Funding was received from the IWC-SORP Research Fund in 2017 to carry out these analyses (SC/67b/SH18).

Antarctic blue whale photo-identification

17 new ID's have added to the Antarctic Blue Whale Catalogue, enhancing the database of individual blue whales and their sighting histories. To date, a relatively small number of whales have been re-sighted inter-annually: 3% (14/458). There is evidence that the Antarctic blue whale population has indeed been increasing (Branch, 2007) which would explain the low re-sighting rate. The photographs from 1998 are a valuable contribution to the Catalogue; a future recapture of any of the identified whales from this year would improve the estimate of survival in an abundance model. To date the longest recapture interval is 12 years, 1995-2007 (Olson et al., 2016).

All 17 of the new identifications came from Areas underrepresented in the catalogue, Areas I and II. In recent summer seasons, there are anecdotal reports that blue whales are occurring more frequently now at South

Georgia/ Islas Georgias del Sur and in the Drake Passage. It is hoped this will provide the opportunity for more identification photographs to be collected opportunistically in the future from these areas. The Catalogue has benefited from the contribution of opportunistic photos. More details from this project are presented in detail in Olson et al. SC/67b/PH02 and SC/67b/SH08. Funding was received from the IWC-SORP Research Fund in 2017 to assist with these analyses (SC/67b/SH18).

Platforms of opportunity

Partnerships with tourist ships, fishing vessels and naval vessels are yielding data for the circumpolar estimation of Antarctic blue whale abundance and other IWC-SORP projects. One Ocean Expeditions, in particular, is thanked for their support of IWC-SORP field research and the contribution of images. Blue whale sightings information have been submitted by vessels operating in the Ross Sea and around the South Atlantic island located between 54.4296°S and 36.5879°W, via the local Heritage Trust. Further cetacean sightings information images continue to be shared with IWC-SORP by French fisheries observers. We acknowledge the contributions of Nicolas Gasco from the Museum of Natural History, Paris, and Sarah Lurcock, Marie Shafi and Alison Neil of the South Georgia/Islas Georgias del Sur Heritage Trust.

Presentations continue to be delivered to encourage Antarctic expeditioners, tourists on cruise ships, and others who may encounter whales to report their sightings of all Southern Ocean whale species to the IWC-SORP Secretariat for dissemination to IWC-SORP investigators and collaborators. Posters and fliers in six languages (English, French, German, Japanese, Portuguese and Spanish) continue to be distributed to promote the on-line reporting system, with detailed instructions for photography and data upload:
www.marinemammals.gov.au/sorp/sightings

Beached bones: assessing genomic diversity and population differentiation of historical Antarctic blue whales

During the 20th century, the Antarctic blue whale was heavily exploited by the commercial whaling industry with over 340,000 whales killed, reducing the population to less than 0.1% of its pre-exploitation abundance. This exploitation began on the South Atlantic island of South Georgia/ Islas Georgias del Sur and in various whaling stations around the Antarctic Peninsula. Over one hundred years later, bones of whales killed by the early commercial whaling industry in the Southern Hemisphere lay scattered along the shorelines and abandoned whaling stations. These bones have preserved the genomic diversity of the pre-exploitation Antarctic blue whale and offer the opportunity to explore the impact of exploitation on genomic diversity through comparison to contemporary populations. The historical sample size of 18 blue whale bones from Sremba et al. (2015) was increased with the addition of 12 bones identified as blue whale from South Georgia/ Islas Georgias del Sur and the Antarctic Peninsula presented at SC67a (SC/67a/SH11). Using next-generation sequencing (Illumina HiSeq), we reconstructed mitochondrial genomes from 20 blue whale bones collected from South Georgia/ Islas Georgias del Sur and the Antarctic Peninsula. These were compared to 53 mitogenomes from 73 contemporary samples considered to be Antarctic blue whale. A total of 69 unique mitogenome haplotypes were resolved, of which only two were shared between the historical and contemporary samples. The sharing of only two of the mitogenome haplotypes between the historical and contemporary samples suggests a loss of maternal lineages due to 20th century whaling. This work is further detailed in SC/67b/SH02. It was partially funded by a grant from the IWC-SORP Research Fund (2017); further information can be found in SC/67b/SH18.

13 peer-reviewed publications have been generated by the Antarctic Blue Whale project to date. A full IWC-SORP Antarctic Blue Whale Project report is included in Annex 1, pp. 15-28.

IWC-SORP Project 2: Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean

The IWC-SORP killer whale project has had a productive year since SC/66a. Fieldwork has been undertaken in the western Antarctic Peninsula and around sub-Antarctic, Marion Island.

Pitman and Durban

The main objectives of this component are to describe killer whale diversity, ecology, and abundance in Antarctica and to quantify their overall impact through trophic interactions within the Antarctic ecosystem.

McMurdo Sound – We did not conduct research in McMurdo Sound this season although we did complete an analysis of our extensive collection of killer whale photographs from the Sound and published a paper on the status of type C killer whales there (Pitman et al. 2018). We are currently collaborating with Italian scientists (Giancarlo Lauriano and Simone Panigada, working from Terra Nova Base) on an analysis of satellite tracking data for type C killer whales in the southern Ross Sea as part of a nearly-completed paper on why killer whales, and all whales, migrate.

Western Antarctic Peninsula – Fieldwork was conducted from the M/V *National Geographic Explorer* in November 2017 and January and February, 2018. An unmanned hexacopter was used to collect high-resolution vertical images of killer whales to enable photogrammetry measurements to assess body size and condition (Figure 1); 18 flights were made and 2749 images collected of two ecotypes of killer whales (types B1 and B2; Figure 2). Natural markings documented from aerial photographs were used to identify 5 different individual type B1s and 25 different individual type B2s in these aerial images. Similar to the previous two years, some individuals were documented to be in extremely poor body condition, displaying a "peanut head" appearance due to loss of adipose tissue behind the cranium. Photogrammetric analysis of all images is currently underway to estimate the size and assess the condition of all individual whales. The long-term monitoring of all three killer whale ecotypes was continued through the collection of photo-identification data to estimate abundance, monitor population trends and assess predatory impact through inclusion of abundance data in ecosystem models. Ten groups of killer whales (3 type A, 2 type B1 and 5 type B2) were located and 7416 boat-based identification photographs were collected (Figure 2).

The unmanned hexacopter was also used to collect vertical images of humpback whales and Antarctic minke whales to estimate body condition and further evaluate health by collecting samples of blow exhalate to measure the respiratory microbiome - the assemblage of microorganisms residing in the respiratory tract, which are a common source of cetacean diseases (Figures 3-4). Twenty-five flights were made and 4336 aerial images collected of 25 different individual humpback whales. Blow samples were collected from 11 of these individuals, bringing the project total to 21 blow samples from humpback whales in 2017 and 2018 combined. Twenty-one flights were flown over Antarctic minke whales, resulting in 4015 images of 35 different individuals, increasing the sample size by tenfold over previous years combined. Seven blow samples were collected from Antarctic minke whales, the first blow samples ever collected from minke whales worldwide. Photogrammetric analysis of all images is currently underway to estimate the size and assess the condition of all individual whales. Laboratory analysis of the whale blow is also underway to relate body condition to respiratory health.

Small skin and blubber biopsy samples were also collected from nine type B2 killer whales, one type B1 killer whale, 11 humpback whales and two Antarctic minke whales. Blubber from these samples will be analyzed to relate hormone levels to body condition and the skin will be analyzed to describe microbiome communities that reside on the skin. Killer whale microbiome will be related to diatom levels and body condition, while humpback and minke skin microbiome will be compared to respiratory microbiome and related to body condition. Laboratory analysis of the biopsy samples is underway.

Dalla Rosa

During February-March 2018, the waters of the Bellingshausen Sea and Bransfield and Gerlache Straits, western/northern Antarctic Peninsula, were surveyed aboard the Brazilian Navy's Polar ship, *Almirante Maximiano*. Approximately 315 nautical miles of cetacean search effort was conducted, resulting in 337 on-effort sightings (685 individuals) of four cetacean species. One sighting corresponded to a group of 12 individuals of type B killer whales. Another three killer whale sightings were made opportunistically, two of type Bs and one type A. A total of 1,903 photographs were taken for individual identification. These photographs are currently under analysis, and will join our killer whale catalogues which include at least 56 type A individuals and over 140 individuals of both type B1 and B2. A paper was published online which included some preliminary data on killer whale stable isotopes (see Seyboth et al. in press).

De Bruyn and Reisinger

At the time of writing, fieldwork is being carried out on Marion Island for the 2018 field season, partially funded by a grant awarded from the IWC-SORP Research Fund (SC/67b/SH18). Building on, and set within, the long-term killer whale research at Marion Island, the project seeks to address three objectives related to movement and foraging ecology. Satellite tagging, biopsy sampling and photo-identification have been employed to address the social organisation, population structure, movement, diving and diet of a population of killer whales. The project's image database contains ~90,000 images and 63 individuals have been identified. Over 5 years, 32 satellite tags have been successfully deployed and these have revealed seasonal site fidelity as well as rapid, long-distance movements and deep diving over seamounts. 66 biopsy samples have been collected, and stable isotope analyses indicate that killer whales are indeed apex predators in the Marion Island marine ecosystem, with mean δ15N values higher than any seals, penguins or Patagonian toothfish. However δ15N values in killer whales were not high enough to suggest that they prey exclusively on such high trophic level prey. Genetic analysis of these samples, in conjunction with photo-identification association data, has shown that Marion Island killer whales form small, fairly stable social units.

Lauriano and Panigada

The aim of this research is to assess the dynamics and role of killer whales in the highly local productive marine ecosystem of Terra Nova Bay, Ross Sea, Antarctica, through the understanding of their fine and large scale movements (satellite tagging), prey-related distribution (photo-ID and behavioural sampling), dietary preferences (fatty acids and stable isotopes), toxicological status, and to estimate their abundance (mark recapture). No fieldwork was conducted during the 2017/18 austral summer. Funding is being sought to continue this fieldwork in 2018/19.

Overall, 34 peer-reviewed publications have been generated by the IWC-SORP killer whale project to date. A full project report is included in Annex 2, pp. 29-49.

IWC-SORP Project 3: Foraging ecology and predator-prey interactions between baleen whales and krill: a multi-scale comparative study across Antarctic regions

Recent technological advances in the miniaturization of sensors have allowed for the development of tags that can measure, in fine detail, the underwater movement patterns and behaviours of marine mammals. Likewise, satellite-linked telemetry and analytical tools have advanced to allow for greater understanding of how the broad scale movement patterns and behaviours of marine mammals links to changes in the physical and biological seascape. Understanding both fine and broad scale behaviour of baleen whales in Antarctic waters is critical to understanding the ecological role of cetaceans and how these are being affected by climate-driven changes to their environment. The objectives of this research program are to use technological advances in animal biotelemetry to elucidate the behaviour and ecological role of cetaceans in the nearshore waters around the Antarctic Peninsula and to relate these to climate-driven changes that are currently occurring.

In 2017-2018 we continued our work through the NSF LTER program with personnel deploying on the *LM Gould* and at Palmer Station. We continued our collaboration with One Ocean Expeditions and conducted research on 3 expedition trips. We also deployed a field team as part of a new NSF award to Dr Friedlaender to study the ecological role of Antarctic minke whales.

Effort focused on deploying video suction cup tags on both humpback and minke whales, measuring prey and sea ice, and using UAS to generate estimates of body condition and animal size. This incredibly successfully effort resulted in 10 deployments on minke whales and 10 deployments on humpback whales. Additionally, 13 LIMPET tags were deployed on humpback whales and 1 on a minke whale through funding and support provided from the Antarctic and Southern Ocean Coalition (ASOC), the Hogwarts Running Club and WWF-Australia. These data are part of a current NSF award to Dr Friedlaender. Lastly, we have published several articles that specifically show the dynamic nature of humpback whale foraging behaviour throughout the feeding season, and the spatio-temporal overlap between humpback whale foraging areas and the krill fishery around the Antarctic Peninsula.

40 peer-reviewed publications have been generated by the IWC-SORP baleen whale foraging ecology project to date. A full project report is included in Annex 3, pp. 50-68.

IWC-SORP sincerely thanks One Ocean Expeditions for their ongoing and invaluable support of this IWC-SORP Theme, as well as WWF-Australia, the Antarctic and Southern Ocean Coalition (ASOC) and the Hogwarts Running Club for their contributions to fieldwork and financial support of tagging and analyses during the 2017/18 season.

Friedlaender and Weinstein also received funding from the IWC-SORP Research Fund in 2017 to assist with analyses of long-term baleen whale dive data to quantify feeding rates. The results of these are detailed in SC/67b/SH18.

IWC-SORP Project 4: What is the distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica? Phase 1: East Australia and Oceania

The focus of the 2017/18 research was:

1) Opportunistic genetic and photo-identification of whales migrating past the Kermadec Islands on their southern migration, led by Rochelle Constantine;
2) A 27th – 31st October 2017 pilot trip to Fiordland, southwest New Zealand to identify the breeding ground origins of whales on their southern migration, led by Rochelle Constantine;
3) A 9th February – 21st March 2018 multi-disciplinary voyage to the Ross Sea region feeding grounds with the whale research, led by Rochelle Constantine;
4) A 7th – 27th August 2017 voyage to the Chesterfield-Bellona archipelago to genetically identify individuals, determine genetic linkages to assess the origin of the whales, led by Claire Garrigue;
5) Surveys from 16th July – 4th August and 3rd September – 22nd September 2017 to the Great Barrier Reef breeding ground complex to genetically profile this breeding stock and determine genetic linkages to Oceania, led by Dave Paton.

The Kermadec Islands are a significant migratory corridor for humpback whales throughout Oceania and for at least some individuals from east Australia. The 2017 data revealed a similar diversity of breeding ground origins for whales migrating past the Kermadecs. There are now resights of whales at the Kermadecs across multiple years, suggesting fidelity to this migratory corridor by some individuals. It remains a logistical challenge to survey the Antarctic waters south of the South Pacific, but it is critical that we ascertain the stock structure, pregnancy rates and environmental variables that affect the distribution of whales. Further tag deployments from Raoul Island may be the best way to understand Antarctic habitat use. The 2018 New Zealand MBIE funded voyage to study the Ross Sea Region MPA enabled basic data collection on all whales encountered, but there was also prey-field mapping that will be used to examine the distribution of all four species of baleen whale we encountered, including humpback whales.

The Fiordland region will now include capacity for New Zealand Department of Conservation rangers to collect tissue biopsy samples from whales as they are encountered during other on-water research. Photo-identification images are incorporated in the New Zealand catalogue (curated by Nadine Bott) and the genetic samples will be included in the South Pacific Whale Research Consortium genetic catalogues. Whilst analysis is not complete, we suspect that theses whales are part of some east Australian whale's southern migration path (Gales et al. 2009). One whale was observed over four days in Dusky Sound and foraging has been observed in this area; so whales may remain for short periods of time either resting or foraging before completing their migration to the Southern Ocean.

The number of whales in the Chesterfield-Bellona archipelago remains low but 2017/18 surveys of this region and of the Great Barrier Reef breeding grounds have provided important information about stock structure and connectivity to neighbouring breeding grounds. The high female to male ratio is of interest and further work will reveal the significance of this area to females. The humpback connectivity project will now expand to include other Antarctic regions and build on the advanced use of tissue biopsy samples to answer questions about age, reproductive status and diet.

The outcomes of the research will allow for an improved understanding of the structure and status and migratory paths and feeding grounds of the Oceania humpback whales, will result in an improved assessment of status, and lead to better conservation and management. Specifically, it would allow the more appropriate allocation of historical catches made in Areas I-VI. This would improve the accuracy of recovery assessments and estimates of pre-whaling abundance.

18 peer-reviewed publications have been generated by the IWC-SORP Oceania humpback whale project to date. A full project report is included in Annex 4, pp. 69-76.

IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project. IWC-SORP gratefully acknowledges contributions from Pew Charitable Trusts, the New Zealand Ministry for Business, Innovation and Employment, the New Zealand Department of Conservation, the Australian Antarctic Division, the University of Auckland and the International Fund for Animal Welfare (IFAW). Constantine et al. and Paton et al. were both awarded grants from the IWC-SORP Research Fund in 2017 to support this Theme; see SC/67b/SH18 for more details. Expedition MARACAS 3 is a component of the WHERE Project funded by the New Caledonian Government, the Ministère de la Transition Ecologique et Solidaire, the World Wildlife Fund for Nature, and Opération Cétacés; further details can be found in Annex 6, pp. 86-107 and SC/67b/SH17.

IWC-SORP Project 5: Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean

In 2017/18 the Acoustic Trends Working Group conducted high-level review of the project work completed to date and synthesized an ambitious work plan for the next 3 years of the project. The work plan focuses on continuation and expansion of long-term data collection, and development of novel, efficient, and standardized analysis of acoustic data collected in the Antarctic. Standardized analysis methods will build upon the Library of Annotated recordings that was started in 2016/17. Work on this Annotated Library continued in 2017/18 with the initial Library estimated to be completed by the end of the 2018 calendar year.

In 2017/18, members of the Acoustic Trends Project deployed 3 autonomous recording devices in the Southern Ocean at 3 different recording sites, and the group recovered 2 previously deployed autonomous recorders as planned (data volume from of approximately 18,000 hours of underwater sound). Group members have also deployed a number of autonomous recorders at low and mid-latitudes in the Indian, Atlantic, and Pacific oceans, and the data from these instruments are expected to value-add and supplement those from the Southern Ocean Hydrophone Network.

In 2017/18, the group produced four peer reviewed papers, four conference presentations, three manuscripts submitted to the scientific committee of the IWC, and presently has numerous manuscripts that have been submitted to journals and are under peer review.

The steering group of the Acoustic Trends Project has continued to forge strong links with other IWC-SORP and international programs. In December 2017 the IWC-SORP Acoustic Trends Working Group became a Capability Working Group of the Southern Ocean Observing System (SOOS), and presented our work to members of the International Quiet Ocean Experiment (IQOE). This marks the first official joint IWC-SORP/SOOS working group. Additionally, in 2017/18 the group provided advice to colleagues from Norway and New Zealand regarding upcoming deployments of moored acoustic recorders around Antarctica.

In late 2016 The SORP Acoustic Trends Steering Group was awarded a grant of £22,000 from the IWC-SORP Research Fund for the creation of an annotated library of acoustic detections. Several intercessional meetings of the steering group were held to discuss the implementation of this library, and annotation of acoustic data from four circumpolar sites is presently underway. Annotations of data is expected to continue until mid-2018. Details of planned and completed work can be found in the Annotated Library Progress Report (SC/67b/SH18).

The project has generated 25 peer-reviewed publications to date (two are also listed under the Antarctic Blue Whale Project). A full project report is included in Annex 5, pp. 77-85.

LIST OF IWC-SORP RELATED PAPERS SUBMITTED FOR CONSIDERATION TO SC/67b

SC/67b/Info09 Attard CRM, Beheregaray LB, Sandoval-Castillo J, Jenner KCS, Gill PC, Jenner M-NM, Morrice MG, Moller LM (2018) From conservation genetics to conservation genomics: a genome-wide assessment of blue whales (*Balaenoptera musculus*) in Australian feeding aggregations. Royal Society Open Science 5: 170925.

SC/67b/SH05 Barlow DR, Torres LG, Hodge KB, Steel D, Baker SC, Chandler TE, Bott N, Constantine R, Double MC, Gill P, Glasgow D, Hamner RM, Lilley C, Ogle M, Olson PA, Peters C, Stockin KA, Tessaglia-Hymes CT, Klinck H (2018) Documentation of a New Zealand blue whale

	population based on multiple lines of evidence. Endangered Species Research. doi: https://doi.org/10.3354/esr00891
SC/67b/SH18	Bell E (2018) IWC-SORP Research Fund: progress reports (2016-2018).
SC/67b/SH21	Bell E (2018) Annual Report of the Southern Ocean Research Partnership 2017/18.
SC/67b/Info28	de la Mare W (2018) Developing functional responses using an individual-based energetics model for rorqual foraging dives.
SC/67b/EM04	de la Mare W (2018) The contribution of prey spatial distribution to baleen whale functional responses.
SC/67b/EM07	de la Mare (2018) Further development of individual base energetic models including the effects of feeding during migration.
SC/67b/SH07	Double M, Westwood K, Bell EM, Kelly N, Miller BS, de la Mare W, Andrews-Goff VA, Cox MJ, Kawaguchi S, King R, Melbourne-Thomas J, Davidson A, Nicol S, Williams G, Laverock B, Ratnarajah L, Seymour J, Friedlaender A, Herr H, Findlay K, Iñiguez Bessega M, Miller EJ (2018) Cruise plan for the 2019 IWC-SORP research voyage 'The availability of Antarctic krill to large predators and their role in biogeochemical recycling in the Southern Ocean'
SC/67b/SH16	Galletti Vernazzani B, Attard C, Barlow DR, Burton C, de Vos A, Double M, Gill P, Jenner C, Jenner M-N, Moller L, Olson P, Salgado-Kent C, Torres LG (2018) Preliminary Results of 2017 IWC Comparisons among Southern Hemisphere Blue Whale Catalogues off Australia, New Zealand and Sri Lanka regions.
SC/67b/SH22	Galletti Vernazzani B, Olson P, Salgado-Kent C (2018) Progress report on Southern Hemisphere Blue Whale Catalogue: Period May 2017-April 2018.
SC/67b/SH17	Garrigue C, Derville S, Bonneville C (2018) Searching for humpback whales two centuries post-whaling: what is left in the Chesterfield-Bellona archipelago?
SC/67b/SH15	Jackson J et al. (2018) Southern Hemisphere fin whale stock structure: a summary of published information to date.
SC/67b/SH19	Herr H (2018) Southern Hemisphere Fin Whales: Update on available data sets.
SC/67b/Info11	Miller B, Miller E (2018) Silent nights: The seasonal occupancy and diel cycles of Antarctic sperm whales revealed by acoustic monitoring.
SC/67b/EM06	Miller EJ, Miller BS, Cox MJ, Potts J, O'Driscoll R, Kelly N, Double MC (2018) The characteristics of krill swarms in relation to aggregating Antarctic blue whales.
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ANNEX 1 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2017/18

IWC-SORP Project 1. Antarctic Blue Whale Project (ABWP)

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Introduction

About a third of a million Antarctic blue whales (*Balaenoptera musculus intermedia*) were taken during commercial whaling in the Southern Hemisphere. In 1964 the International Whaling Commission banned the hunting of blue whales, although some were still caught illegally until 1973. The Antarctic blue whale is currently classified as critically endangered by the International Union for Conservation of Nature and is of global interest as one of the most at-risk species of baleen whale in the Southern Ocean.

Currently our understanding of Antarctic blue whale ecology, behaviour and post-exploitation recovery is very poor. Only two abundance estimates for Antarctic blue whales (ABW) have been derived since 1964, each with low precision. The Antarctic Blue Whale Project is a coordinated, international research programme, focused on applying a multi-disciplinary approach to understand both the recovery of Antarctic blue whales and their important role in the Southern Ocean ecosystem through an investigation of their foraging ecology, distribution, movements and habitat preferences. These data will ultimately contribute toward a precise estimation of Antarctic blue whale circumpolar abundance and their rate of recovery.

Overall objectives

The objectives of the Antarctic Blue Whale Project are:

- to identify the most appropriate and efficient method to deliver a new circumpolar abundance estimate of Antarctic blue whales;
- to develop and refine methods to improve survey efficiency;
- to deliver a new circumpolar Antarctic blue whale abundance estimate;
- to improve understanding of Antarctic blue whale population structure;
- to improve understanding of linkages between Antarctic blue whale breeding and feeding grounds;
- to characterise the behaviour of Antarctic blue whale on the feeding grounds.

Project activities in 2017/18

Work on the Antarctic Blue Whale Project has focused on the analysis of acoustic data collected during recent voyages, analysis of movements of Antarctic blue whales from recent and historic data, photo-identification of whales from research datasets and platforms of opportunity, and planning of IWC-SORP research voyages following several successful applications for vessel time.

2018 "Tango" voyage to the Western Antarctic Peninsula - Vanesa Reyes Reyes, Simone Baumann-Pickering, Marta Hevia, John Hildebrand, John Hurwitz, Alexander Marino, Mariana Melcón, Ally Rice, Ana Širović, Jennifer Trickey, Juan Pablo Torres Flores, Miguel Iñíguez Bessega

This voyage contributes to three IWC-SORP themes: 1. Antarctic Blue Whale Project (ABWP), 2. Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean, 3. Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean.

Introduction

Since 2014, five summer season cruises to the Western Antarctic Peninsula area have been conducted on board an Argentinean Coastguard cutter, as part of an IWC-SORP project led by Argentina. This ongoing research focuses on line-transect visual observations of cetaceans and acoustic monitoring of odontocetes by dedicated researchers from a platform of opportunity. In addition, passive acoustic monitoring of cetaceans using an autonomous broad-band recorder package is conducted throughout the year.

Objectives

1. Determine year-round relative abundance, distribution, and seasonality of cetaceans in the NW Antarctic Peninsula area.
2. Characterize acoustic signals of cetaceans to enable use of passive acoustics to monitor their occurrence.
3. Study distribution and relative abundance of cetaceans in the Western Antarctic Peninsula during the austral summer.
4. Study possible migratory routes of cetaceans through photo-identification.

Results

Visual and acoustic surveys of cetaceans were conducted onboard the Argentinean Coast Guard (Prefectura Naval Argentina) cutter SB-15 "Tango" between 22 January and 11 February, 2018, departing from the port of Ushuaia (54° 48.52'S 68° 18.17'W), and navigating along the Western Antarctic Peninsula to the Argentinean Antarctic base "Brown" (64° 53.72'S, 62° 52.25'W) (Figure 1).

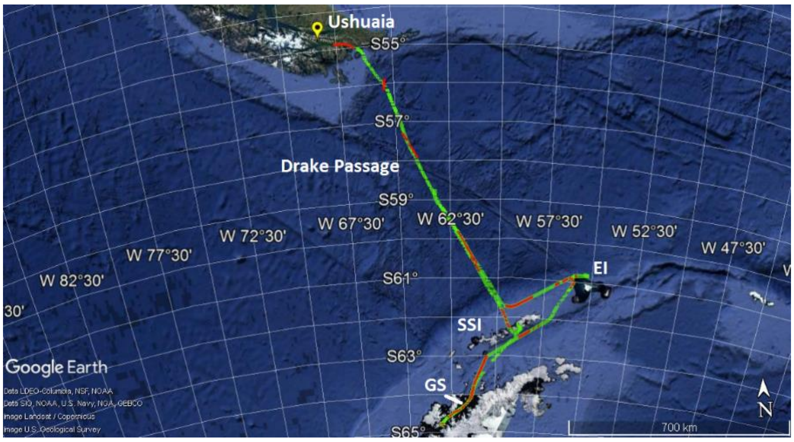

Figure 1 On-effort visual (red lines) and acoustic tracks using a towed hydrophone array (green lines). SSI: South Shetland Islands/Islas Shetland del Sur; EI: Elephant Island/Isla Elefante; GS: Gerlache Strait/Estrecho de Gerlache.

Visual surveys were conducted over a total of 60.5 h and 472.5 nm (Figure 1). On-effort cetacean sightings included three odontocete and three mysticete species, encompassing a total of 210 encounters (Table 1; Figure 2).

A total of 147.6 h of acoustic recordings were collected with the towed hydrophone array. Detections included NBHF clicks recorded during an encounter with hourglass dolphins, NBHF clicks possibly also from this species, and other clicks. Further analysis of the recorded signals will be conducted to confirm species.

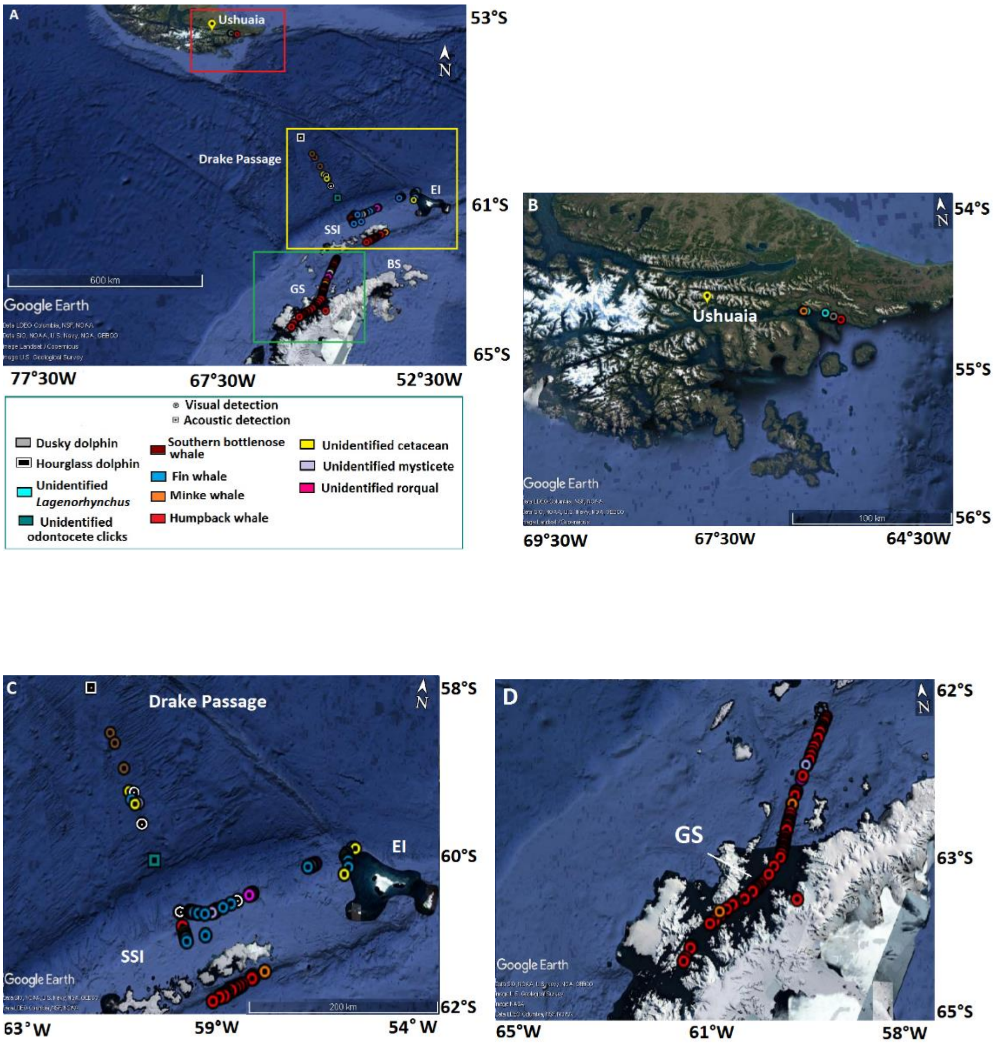

Figure 2 (A) Cetacean sightings (circles) and acoustic detections (squares) using a towed hydrophone array from the deck of the Argentinean Coast Guard (Prefectura Naval Argentina) cutter "Tango" SB-15 between 22 January and 11 February, 2018. Close-up of red (B), yellow (C) and green squares (D) in panel A. SSI: South Shetland Islands/Islas Shetland del Sur; EI: Elephant Island/Isla Elefante; GS: Gerlache Strait/Estrecho de Gerlache.

Table 1 Total number of individuals sighted per species, total number of sightings, and group size during on-effort visual survey.

Scientific name	Common name	Number of sightings	Number of individuals	Group size	
				Range	Mean ± SD
Balaenoptera physalus	Fin whale	29	39	1-3	1.3 ± 0.6
*Balaenoptera acutorostrata**	Minke whale	4	4	1	1 ± 0
Megaptera novaeangliae	Humpback whale	104	199	1-5	1.9 ± 1.0
Unidentified *Balaenopteridae*	Unidentified *Balaenopteridae*	3	5	---	---
Unidentified mysticete	Unidentified mysticete	7	9	---	---
Hyperoodon planifrons	Southern bottlenose whale	3	3	1	1 ± 0
Lagenorhynchus cruciger	Hourglass dolphin	4	33	2-20	8.3 ± 8.0
Lagenorhynchus obscurus	Dusky dolphin	2	19	7-12	9.5 ± 3.5
Unidentified Lagenorhynchus	Unidentified Lagenorhynchus	3	7	---	---
Unidentified cetacean	Unidentified cetacean	11	15	---	---

* includes *B. acutorostrata* and *B.bonaerensis*

Acoustic data obtained with a HARP were collected between 2014-2016 at three recording sites in the South Shetland Islands/ Islas Shetland del Sur (SSI) (see 2014, 2015 and 2016 annual reports of IWC-SORP for detail on HARP position). Efforts were made to recover the HARP deployed in January 2017 nearby Elephant Island/Isla Elefante (EI) (60° 52.136'S, 56° 00.628'W) during this voyage but after numerous attempts to release it the operation had to be abandoned without success. We hope that if the equipment gets released eventually, it will make its way to a shore and Scripps Institution of Oceanography will be contacted to recover the HARP. (This has happened on numerous previous occasions).

Analysis of the previous HARP data collected between 2014 and 2016 showed that three different beaked whale echolocation signal types were detected (Figure 3), and the relative abundance and distribution of these signal types varied across the three recording sites (Figure 4). Seasonality was evident, with fewer beaked whale detections occurring during the austral winter, and these seasonal shifts were likely driven by sea ice concentration around the recording sites. A peer-reviewed paper on beaked whale acoustic presence and relationship to sea ice dynamics is being prepared.

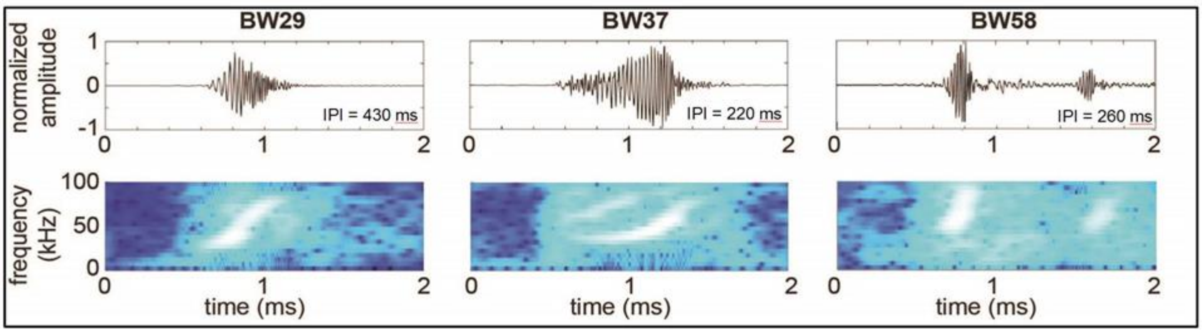

Figure 3 Frequency-modulated pulses of the three Antarctic beaked whale signal types recorded between 2014 and 2016 are shown as time series (top) and spectrograms (bottom). Signals were named after their peak frequencies. Median inter-pulse interval (IPI) values are also displayed.

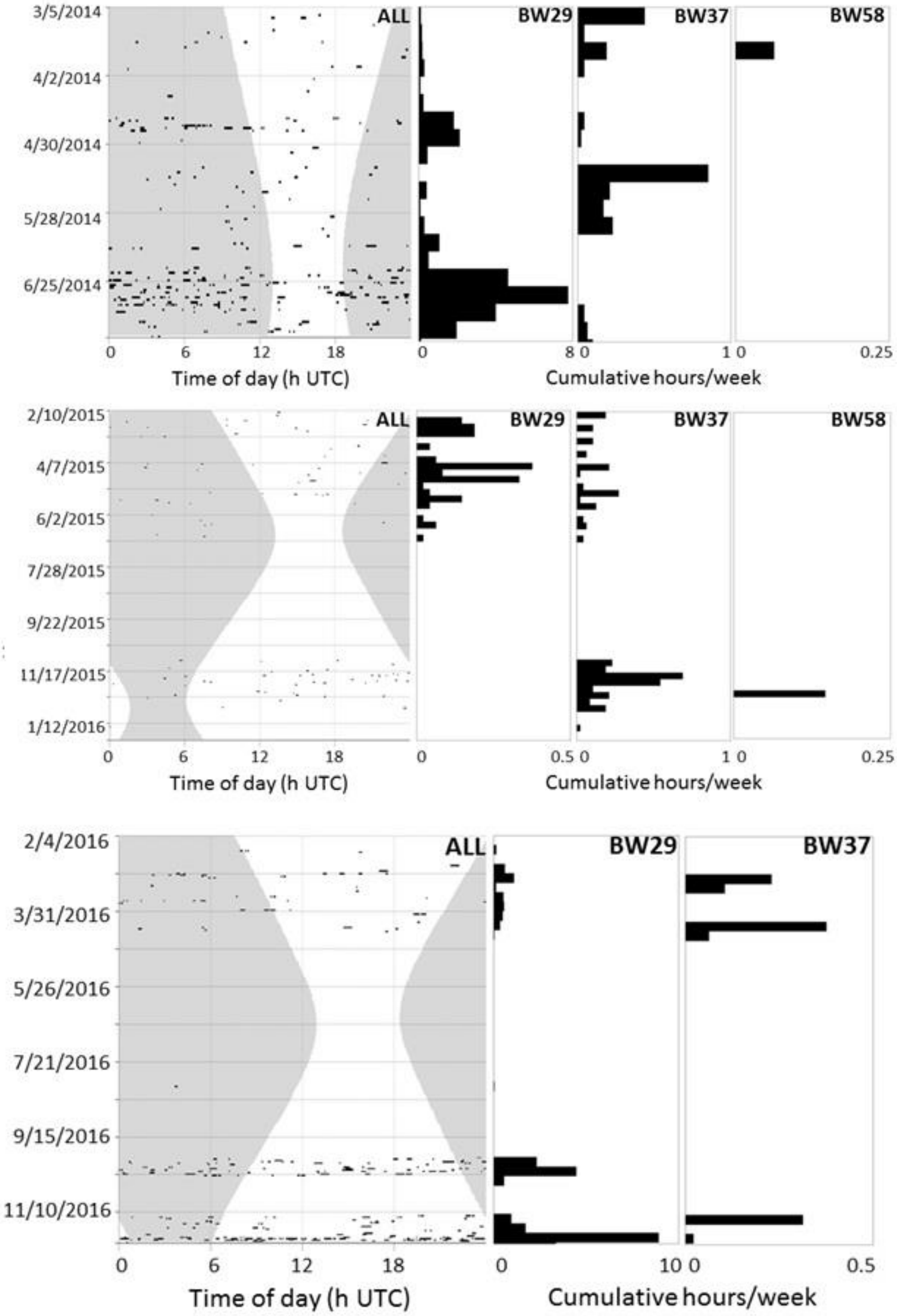

Figure 4 On the left, daily and hourly occurrence of all beaked whale signal types in the HARP data is shown as black marks, with grey shading representing night time. On the right, the weekly breakdown of occurrence of the three signal types is show (note the differing y-axis maximum values).

Blue whales D calls were detected using automatic detection methods (Helble et al. 2012) in recordings spanning the period since 2014. The three sites at which the HARP was deployed during this period showed different levels of blue whale D call occurrence, with fewest calls detected at site EI in 2014, and most calls detected at the east of EI (site EIE) in 2016 (Figure 5). Generally, peak detections occurred during late austral summer and into the fall (February to May) and again in the spring and early summer (November and December). This bimodal distribution reflects the migratory pattern of blue whales through this area.

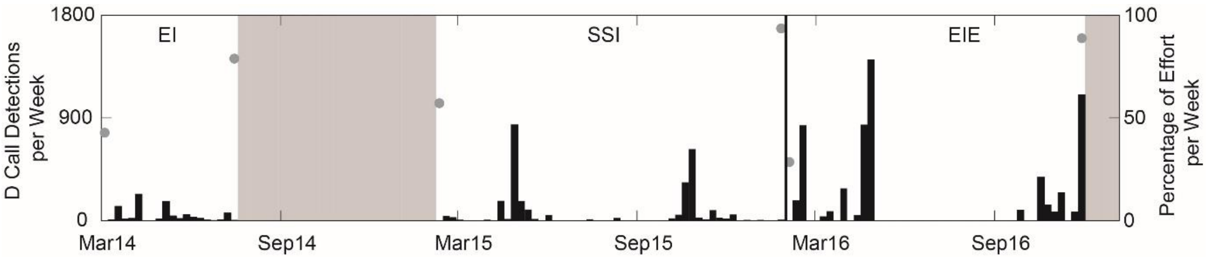

Figure 5 Total weekly count of blue whale D call detections from March 2014 to January 2017. Black bars represent D call detections, grey dots denote weeks with less than 100% recording effort, and shaded areas are times without acoustic recordings. Note that data from three different sites are combined into one plot: 2014 data are from site EI, 2015 and early 2016 are from SSI, and the remainder of 2016 data are from EIE. The vertical line in February 2016 indicates change of location.

High-frequency modulated signals (HFM) with a stereotyped down-swept contour were recorded with the HARP and the towed hydrophone array. Signals have a mean start frequency at 21.6 kHz, end frequency at 15.7 kHz, −10 dB bandwidth of 5.9 kHz, and duration of 65.2 ms. Bouts of signals were generally recorded with a median inter-signal interval of 2.1 s. HFM signals partially modulated in the non-ultrasonic range similar to the ones described in this paper have already been reported for killer whales in the North Pacific, Western South Atlantic and Western Australian coast. The HFM signals were recorded in the presence of other odontocete sounds such as whistles, echolocation clicks and burst-pulsed sounds. The similarities of these sounds with vocalizations described for killer whales in the Western Australian coast lead us to strongly believe that the described HFM signals were produced by Antarctic killer whales. A peer-reviewed paper describing for the first time HFM signals in Antarctica has been published (Reyes Reyes et al. 2017) where we discussed evidence suggesting that Antarctic type A killer whales are the most probable candidates to produce such signals. However, a visual confirmation is still needed and the function of the HFM signals remains unknown.

Data on the seasonal distribution of fin, sei, killer and sperm whales will be analysed during this year and presented at the SC68a meeting.

Photographs were taken of humpback, minke and fin whales which are currently being reviewed. Those suitable for photo-identification will be classified and shared with other catalogues.

Challenges

The main challenge has been securing vessel time and funds for ongoing research, and the purchase, development, and/or refurbishment of equipment. Try to recover the lost HARP.

Outlook for the future

A sixth voyage aboard an Argentinean vessel to the western Antarctic Peninsula is planned for the austral summer season 2019 and we expect to include skin biopsy sampling on cetacean species in the NW Antarctic Peninsula area.

Complete analysis of acoustic data collected with the HARP during 2014-2016 in order to assess the seasonal distribution of blue whales, fin whales, killer whales, sperm whales, beaked whales, and possibly other cetaceans. Deploy a new HARP to replace the lost one in order to continue monitoring the seasonal distribution of blue whales, fin whales, killer whales, sperm whales, beaked whales, and possibly other cetaceans.

Complete the analysis of visual data to assess the distribution of fin whales along north and northeast SSI during the austral summer.

Build a catalogue with photo-ID data on fin whales in the Western Antarctic Peninsula and continue work on photo-ID of other species as mentioned above.

New Zealand-Australia Antarctic Ecosystems Voyage (2015) – data analysis –Brian Miller, Elanor Miller, Joanne Potts, Martin Cox, Robert Harcourt, Michael Double

Antarctic blue whale foraging grounds were surveyed during the 2015 New Zealand-Australian Antarctic Ecosystems Voyage by collaborators from the IWC-SORP Antarctic Blue Whale Project. We have now analysed this rich dataset to describe the distribution of these rare whales in relation to their main prey species, Antarctic krill, thanks to the IWC-SORP Grant: 'Antarctic blue whale-krill interactions: an analysis'. During the voyage, a combination of passive acoustic technology and visual observations were used to locate Antarctic blue whales, and active acoustics were used to simultaneously survey krill swarms in the vicinity and demonstrably far blue whales. Using Boosted Regression Trees, we have compared the characteristics of krill swarms in areas near and far from blue whales. Results suggest that Antarctic blue whales are more likely to be present within the vicinity of krill swarms detected at night, those of higher internal density, greater vertical height, and those found shallower in the water column. Our analysis has been submitted as SC/67b/EM06 as summarised below. The nature of krill aggregations preferred by Antarctic blue whales is an important consideration, not only for the management of this endangered species in a challenging environment, but also for the management of Antarctic krill fisheries. Our findings will be used to refine and inform survey design for an Australian Antarctic Division-led RV Investigator voyage in 2019 (SC 67b/SH07) as well as other future multidisciplinary field campaigns for both the IWC-SORP Antarctic Blue Whale Project and other non-lethal baleen whale-focussed surveys in the Southern Ocean. Funding was received from the IWC-SORP Research Fund in 2017 to carry out these analyses (SC/67b/SH18).

Additionally, funding was received from the IWC-SORP Research Fund assist with the development of an annotated library of underwater acoustic recordings for testing and training automated algorithms for detecting Southern Ocean baleen whales (SC/67b/SH18). The technical task of annotating every low-frequency sound throughout 800 hours of acoustic recording has been undertaken in 2017/18. For the remainder of 2018, work will focus on continued annotation, the aim being to create an Annotated Library containing a sample of approximately 2000 hours annotated sounds. The Annotated library will be the most representative collection of ground-truth sounds to date, and it will contain regularly sampled data throughout the year across different areas (Western Antarctic Peninsula, Atlantic, Pacific, and Indian sectors of the Southern Ocean), instruments (Scripps ARP, Aural, AAD Moored Acoustic Recorder, SonoVault), and years (2005, 2014, 2015). Once completed, the Annotated Library will be made publicly available.

Photo-identification of Antarctic blue whales – Paula Olson

<u>Introduction</u>

The population status of the endangered Antarctic blue whale (*Balaenoptera musculus intermedia*) is of interest to the IWC Scientific Committee and is the focus of the IWC-SORP Antarctic Blue Whale Project. The Project aims to broaden the knowledge of the conservation status of Antarctic blue whales, by conducting research toward providing an updated circumpolar abundance estimate, by improving understanding of population structure, and by discovering linkages between feeding and breeding grounds (Bell, 2017). The use of photo-identification data in a capture-recapture analysis for the production of a contemporary (new) estimate of abundance of Antarctic blue whales is a component of the Antarctic Blue Whale Project (Bell, 2017).

The Antarctic Blue Whale Catalogue was established in 2007, in support of an in-depth assessment of Southern Hemisphere Blue Whales initiated by the IWC Scientific Committee in 2006. The Antarctic Blue Whale Catalogue contains the sighting histories, based on photo-ID, of 441 individual blue whales in the circumpolar Antarctic (Olson et al., 2017). These provide potential data for a capture-recapture estimate of abundance as well as information on the movement of individual blue whales within the Antarctic region. Previously, the photo-identification data from this catalogue have provided information on inter-annual whale movement (Olson et al., 2016), within season sighting rates (Olson et al., 2016), and produced the data for a pilot capture-recapture study (Olson and Kinzey, in press).

Recently, photographs of Antarctic blue whales became available (recovered from storage) from the IWC IDCR and SOWER cruises conducted in 1989/1990, 1993/1994, and 1997/1998, as well as opportunistic photographs collected by collegial scientists, naturalists, and tourists in 2015-2018. This project identified and compared individual identification photographs of Antarctic blue whales from the new photo collections with the Antarctic Blue Whale Catalogue. The addition of newly identified individuals will increase the sample size needed to conduct a capture-recapture analysis and to reveal movement patterns.

Objectives

1. Identify individual Antarctic blue whales from photographs collected during the IWC IDCR cruises in 1989/1990 and 1993/1994, and during the IWC SOWER cruise 1997/1998. Compare the identified individuals from these photographs with the Antarctic Blue Whale Catalogue, adding newly identified whales to the Catalogue and updating sighting histories of re-sighted whales.

2. Identify individual Antarctic blue whales from photographs collected opportunistically by collegial scientists, naturalists, and tourists in the Antarctic during 2015-2018. Compare the identified individuals from these photographs with the Antarctic Blue Whale Catalogue, adding newly identified whales to the Catalogue and updating sighting histories of re-sighted whales.

3. Complete unfinished quality coding of identification photographs in the Catalogue. Conduct miscellaneous organizing, archiving, and quality control tasks to keep the Catalogue up-to-date and in preparation for future analyses.

Results

The photographs from the IWC cruises yielded four new ID's, all from 1998 and IWC Management Area IIE (Table 2). Thirteen individual blue whales were identified from the photographs collected by scientists, naturalists, and tourists on vessels in Area IE and Area II during the seasons 2015/2016 – 2017/2018. There were no matches between any of these newly identified individuals or to the Antarctic Blue Whale Catalogue. The 17 new ID's from these photo collections brings the total number of photo-identified Antarctic blue whales up to 458 whales, represented by 342 left sides and 332 right sides. The minimum (332) and maximum (458) number of unique individuals represents 15% and 20%, respectively, of the most recent accepted estimate of abundance of Antarctic blue whales, 2,280 in 1997/1998 (Branch, 2007).

Table 2 Number individual Antarctic blue whales identified from photographs analysed in 2017/2018.

Year	IWC Area	No. of photos	No. left side ID's	No. right side ID's	Total no. identified blue whales	Source
1989/1990	I	5	0	0	0	IWC/IDCR
1993/1994	I	13	0	0	0	IWC/IDCR
1997/1998	IIE	72	2	2	4	IWC/SOWER
2015/2016	II	3	0	2	2	N. Hartley
2016/2017	II	199	2	3	6	M. de Boer; B. Haggar[2]
2017/2018	IE, II	62	2	4	5	Kennedy/Jackson[3]; Happywhale[4]
TOTAL		354	6	11	17	

[2] Ocean One Expeditions

[3] South Georgia/ Islas Georgias del Sur Right Whale Project

[4] Citizen science contributors via Happywhale include C. Croxson, J. Daltry, J Reynolds, D. Tatooles

Conclusions

With the addition of 17 new ID's, the Antarctic Blue Whale Catalogue is continuing to build a database of individual blue whales and their sighting histories. To date, a relatively small number of whales have been re-sighted inter-annually: 3% (14/458). There is evidence that the Antarctic blue whale population has indeed been increasing (Branch, 2007) which would explain the low re-sighting rate.

The photographs from 1998 are a valuable contribution to the Catalogue; a future recapture of any of the identified whales from this year would improve the estimate of survival in an abundance model. To date the longest recapture interval is 12 years, 1995-2007 (Olson et al., 2016).

All 17 of the identifications came from Areas underrepresented in the catalogue, Areas I and II. In recent summer seasons, there are anecdotal reports that blue whales are occurring more frequently now at South Georgia/ Islas Georgias del Sur and in the Drake Passage. It is hoped this will provide the opportunity for more identification photographs to be collected opportunistically in the future from these areas. The Catalogue has benefited from the contribution of opportunistic photos. More details from this project are presented in detail in Olson et al. SC/67b/PH02 and SC/67b/SH08. Funding was received from the IWC-SORP Research Fund in 2016/17 to assist with these analyses (SC/67b/SH18).

Challenges

The primary issue is that without ship time (dedicated or piggy-backed), it is challenging to continue to collect identification photos. Opportunistic platforms are one source of photos, but contribution levels are uneven and unpredictable.

Outlook for the future

1) Continue to build a dataset by adding more Antarctic blue whale photo-ID sighting history data to the Catalogue. It is hoped that a dedicated Antarctic Blue Whale voyage planned for next year by SORP will provide a sizable number of ID's (~50 ID's; at a level similar to past SORP Antarctic Blue Whale voyages in 2013 and 2015).

2) Continue to explore capture-recapture analyses for estimates of abundance using the photo-ID sighting history data. An updated pilot study using these data will be presented in an IWC/SC 67b paper.

3) Finalize a data set to be combined with Discovery tag data from Antarctic blue whales for analysis on movement patterns within the Antarctic region and for clues into possible low latitude migration routes. (This future spatial analysis to be conducted in collaboration with Dr Virginia Andrews-Goff with results in a paper intended for submission to the Journal of Cetacean Research and Management).

Platforms of opportunity

Partnerships with tourist ships, fishing vessels and naval vessels are yielding data for the circumpolar estimation of Antarctic blue whale abundance and other IWC-SORP projects. One Ocean Expeditions, in particular, is thanked for their support of IWC-SORP field research and the contribution of images. Blue whale sightings information have been submitted by vessels operating in the Ross Sea and around the South Atlantic island located between 54.4296°S and 36.5879°W, via the local Heritage Trust. Further cetacean sightings information images continue to be shared with IWC-SORP by French fisheries observers. We acknowledge the contributions of Nicolas Gasco from the Museum of Natural History, Paris, and Sarah Lurcock, Marie Shafi and Alison Neil of the South Georgia/Islas Georgias del Sur Heritage Trust.

Presentations continue to be delivered to encourage Antarctic expeditioners, tourists on cruise ships, and others who may encounter whales to report their sightings of all Southern Ocean whale species to the IWC-SORP Secretariat for dissemination to IWC-SORP investigators and collaborators. Posters and fliers in six languages (English, French, German, Japanese, Portuguese and Spanish) continue to be distributed to promote the on-line reporting system, with detailed instructions for photography and data upload:
www.marinemammals.gov.au/sorp/sightings

Beached bones: assessing genomic diversity and population differentiation of historical Antarctic blue whales
Angie Sremba, C. Scott Baker, Jennifer Jackson

During the 20th century, the Antarctic blue whale was heavily exploited by the commercial whaling industry with over 340,000 whales killed, reducing the population to less than 0.1% of its pre-exploitation abundance. This exploitation began on the South Atlantic island of South Georgia/ Islas Georgias del Sur and in various whaling stations around the Antarctic Peninsula. Over one hundred years later, bones of whales killed by the early commercial whaling industry in the Southern Hemisphere lay scattered along the shorelines and abandoned whaling stations. These bones have preserved the genomic diversity of the pre-exploitation Antarctic blue whale and offer the opportunity to explore the impact of exploitation on genomic diversity through comparison to contemporary populations. We increased the historical sample size of 18 blue whale bones from Sremba et al. (2015) with 12 bones identified as blue whale from South Georgia/ Islas Georgias del Sur and the Antarctic Peninsula presented at SC67a (SC/67a/SH11). Using next-generation sequencing (Illumina HiSeq), we reconstructed mitochondrial genomes from 20 blue whale bones collected from South Georgia/ Islas Georgias del Sur and the Antarctic Peninsula. We compared these to 53 mitogenomes from 73 contemporary samples considered to be Antarctic blue whale. We resolved a total of 69 unique mitogenome haplotypes of which only two were shared between the historical and contemporary samples. The sharing of only two of the mitogenome haplotypes between the historical and contemporary samples suggests a loss of maternal lineages due to 20th century whaling. This work is further detailed in SC/67b/SH02. It was partially funded by a grant from the IWC-SORP Research Fund (2017); further information can be found in SC/67b/SH18.

This project is a component of the PhD thesis of A. Sremba and the comparison of the historical and contemporary Antarctic blue whale mitogenome diversity will be completed within the next year.

Project outputs

Peer-reviewed papers

Barlow DR, Torres LG, Hodge KB, Steel D, Baker SC, Chandler TE, Bott N, Constantine R, Double MC, Gill P, Glasgow D, Hamner RM, Lilley C, Ogle M, Olson PA, Peters C, Stockin KA, Tessaglia-Hymes CT, Klinck H (2018) Documentation of a New Zealand blue whale population based on multiple lines of evidence. Endangered Species Research. doi: https://doi.org/10.3354/esr00891

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Miller BS, Barlow J, Calderan S, Collins K, Leaper R, Olson P, Ensor P, Peel D, Donnelly D, Andrews-Goff V, Olavarria C, Owen K, Rekdahl M, Schmitt N, Wadley V, Gedamke J, Gales N, Double M C (2015) Validating the reliability of passive acoustic localisation: a novel method for encountering rare and remote Antarctic blue whales. Endangered Species Research 26:257–269.

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Olson P A, Ensor P, Olavarria C, Bott N, Constantine R, Weir J, Childerhouse S, van der Linde M, Schmitt N, Miller B S, Double M C (2015) New Zealand blue whales: residency, morphology, and feeding behaviour of a little-known population. Pacific Science 69(4): 477-485.

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Peel D, Miller B S, Kelly N, Dawson S, Slooten E, Double M (2014) A simulation study of acoustic-assisted tracking of whales for mark-recapture surveys. PLoS ONE 9(5):e95602. doi:10.1371/journal.pone.009560

Reyes Reyes MV, Baumann-Pickering S, Simonis A, Melcón ML, Trickey J, Hildebrand J, Iñíguez M (2017) High-Frequency Modulated Signals Recorded Off the Antarctic Peninsula Area: Are Killer Whales Emitting Them? Acoustics Australia: Australian Acoustical Society 45: 253-260, issn 0814-6039.

Trickey JS, Baumann-Pickering S, Hildebrand JA, Reyes Reyes MV, Melcón ML, Iñíguez MA (2015) Antarctic beaked whale echolocation signals near South Scotia Ridge. Marine Mammal Science 31: 1265–1274.

Book chapters

Melcón M, Reyes Reyes V, Iñíguez M (2017) Bioacoustic techniques applied to odontocete conservation and management in Argentina. In: M. Rossi-Santos and C. Finkl (eds.) Advances in Marine Research in Latin America: Technological Innovation in Ecology and Conservation, pp.149-167. doi:10.1007/978-3-319-56985-7_6

Reports

Hevia M, Marino A, Reyes Reyes,V. Informe preliminar de actividades realizadas durante la navegación en el guardacostas GC-189 “Prefecto García. Report presented to the Argentinean Coastguard.

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Collins K, Miller B, Ensor P, Olson P, Calderan S, Leaper R, Barlow J, McDonald M, Olavarria C, Childerhouse S, Constantine R, Van de Linde M, Double M (2013) New Zealand blue whales: Distribution, confirmation of acoustic identity, and a nascent photographic identification catalogue. Oral presentation at the Biennial Conference on Marine Mammals, Dunedin, New Zealand, 9-13 December 2013.

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Posters

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Reyes Reyes MV, Hevia M, Zuazquita E, Trickey J, Iñíguez Bessega M (2014) Encounter rates of mysticetes in Antarctic waters of the Scotia Sea and western Antarctic Peninsula: preliminary results. Poster presentation to the XVI Conference on Specialists on Aquatic Mammals from South America and 10th SOLAMAC Congress, December 2014, Cartagena de Indias, Colombia.

Trickey JS, Baumann-Pickering S, Hildebrand JA, Reyes Reyes MV, Melcón M, Iñíguez MA (2015) Echolocation signals of an Antarctic beaked whale. Poster presentation to the Southern California Marine Mammal Conference, January, Newport Beach, United States.

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Cahalan S (2013) Out of the Blue. Island, Issue 133.
Pyper W (2012) Listening to the blues. Australian Antarctic Magazine, Issue 23.
Pyper W (2013) Songs reveal elusive giants. Australian Antarctic Magazine, Issue 24.

Fundación Cethus´ blogs:
https://cethusnews.wordpress.com/2013/05/03/fundacion-cethus-in-antarctica/

https://cethusnews.wordpress.com/2013/04/24/new-sorp-meeting/

Media

The successful 2015 Joint New Zealand-Australia Antarctic Ecosystems Voyage attracted considerable media attention. The voyage webpage including voyage sitreps and news items can be found here:
http://www.antarctica.gov.au/science/southern-ocean-ecosystems-environmental-change-and-conservation/wildlife-conservation/new-zealand-australia-antarctic-ecosystems-voyage-2015
and
http://www.niwa.co.nz/antarctic-ecosystems-voyage

ABWP scientists conducted a feature interview on the ABC Radio programme Off Track AMMC's Antarctic blue whale research and Antarctic blue whale song:
http://www.abc.net.au/radionational/programs/offtrack/the-biggest-underwater-choir-in-the-world/6914940
and
http://www.abc.net.au/radionational/programs/offtrack/antarctic-blue-whale-song-worlds-biggest-choir/6919222

The ABWP was represented at the sold-out panel discussion, Discovering the Deep, at the World Science Festival in Brisbane, Australia:
http://www.worldsciencefestival.com.au/program/events/discovering-the-deep/

Antarctic Circumnavigation Expedition (ACE):
http://www.antarctica.gov.au/news/2016/australian-scientists-to-join-international-colleagues-for-antarctic-circumnavigation-voyage
and
http://www.businessinsider.com.au/the-first-circumnavigation-of-antarctica-to-study-whales-and-ocean-plastics-2016-4

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ANNEX 2 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2017/18

IWC-SORP Project 2. Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean

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Introduction

There are three ecotypes of killer whales described from Antarctic waters comprising at least three separate species. Little is known about these ecotypes and it is important to understand these populations as killer whales play a key role in the Antarctic marine ecosystem. This is especially true with respect to the impacts that they have on prey populations including marine mammals, fish and penguins.

This project is investigating the factors relative to the ecosystem impact of the species of killer whales that occur in Antarctic and adjacent waters, by focusing on their systematic relationships, abundance, distribution, movement patterns and prey preferences.

Progress and results for 2017/18

Robert Pitman, John Durban and Holly Fearnbach, McMurdo Sound and Western Antarctic Peninsula

Introduction

Since 2009, R. Pitman, J. Durban, and H. Fearnbach have annually conducted research on killer whales in Antarctic waters, mainly in the Western Antarctic Peninsula area but also in the southern Ross Sea (McMurdo Sound). To date we have conducted research on four of the five morphologically distinct types of killer whales that occur Antarctic waters (Pitman and Ensor, 2003; Pitman et al. 2007; Pitman et al. 2011, Durban et al. 2016), including three sympatric types that occur in the coastal waters of the Antarctic Peninsula (type A, B1 and B2), and two that occur in the southern Ross Sea (types B and C). For our current research we are using satellite tagging, photo-identification, biopsy sampling, acoustic recordings, biochemical analyses, focal-follow behavioural studies, and aerial photogrammetry (the latter using a hexacopter). Below is a summary of our field work during the 2017-18 season.

Objectives

Our main objectives are to describe killer whale diversity, ecology, and abundance in Antarctica, to quantify their overall impact through trophic interactions within the Antarctic ecosystem, and to assess their vulnerabilities to anthropogenic drivers such as commercial fishing and climate change. Our research methods include collecting observational data on school sizes, habitat associations, foraging behaviour and prey preferences (Pitman and Durban 2010, 2012); collecting skin and blubber biopsy samples for ongoing phylogenetic analyses of taxonomic status (LeDuc et al. 2008.; Morin et al. 2010, 2015; Foote et al. 2011; Durban et al. 2016) and chemical analyses to infer diet (Krahn et al. 2008); deploying satellite tags to learn about movements and diving behaviour (Andrews et al. 2008; Durban and Pitman 2012); photographing individuals to estimate abundance and demographic parameters (Durban et al. 2010; Fearnbach et al. 2012; Pitman et al. 2018). More recently, we have begun using a hexacopter and aerial photogrammetry to obtain morphometric data to assess health and taxonomic status and to collect blow samples to broaden health assessment by studying the individual microbiomes. We have expanded our use of these techniques to include humpback whales and Antarctic minke whales when the opportunity arises.

Preliminary results from 2017-18 season

McMurdo Sound – We did not conduct research in McMurdo Sound this season although we did complete an analysis of our extensive collection of killer whale photographs from the Sound and published a paper on the status of type C killer whales there (Pitman et al. 2018). We are currently collaborating with Italian scientists (Giancarlo Lauriano and Simone Panigada, working from Terra Nova Base) on an analysis of satellite tracking data for type C killer whales in the southern Ross Sea as part of a nearly-completed paper on why killer whales, and all whales, migrate.

Western Antarctic Peninsula - We had a very successful season onboard the M/V *National Geographic Explorer* in November 2017 and January and February, 2018. We used an unmanned hexacopter to collect high-resolution vertical images of killer whales to enable photogrammetry measurements to assess body size and condition (Figure 1); we flew 18 flights and collected 2749 images of two ecotypes of killer whales (types B1 and B2; Figure 2).

Figure 1 Photograph of unmanned hexacopter flight operations conducted from a zodiac inflatable launched from the M/V National Geographic Explorer in the Antarctic Peninsula in February 2018. Research was conducted under NMFS Permit No. 19091 and Antarctic Conservation Act Permit ACA 2017-029.

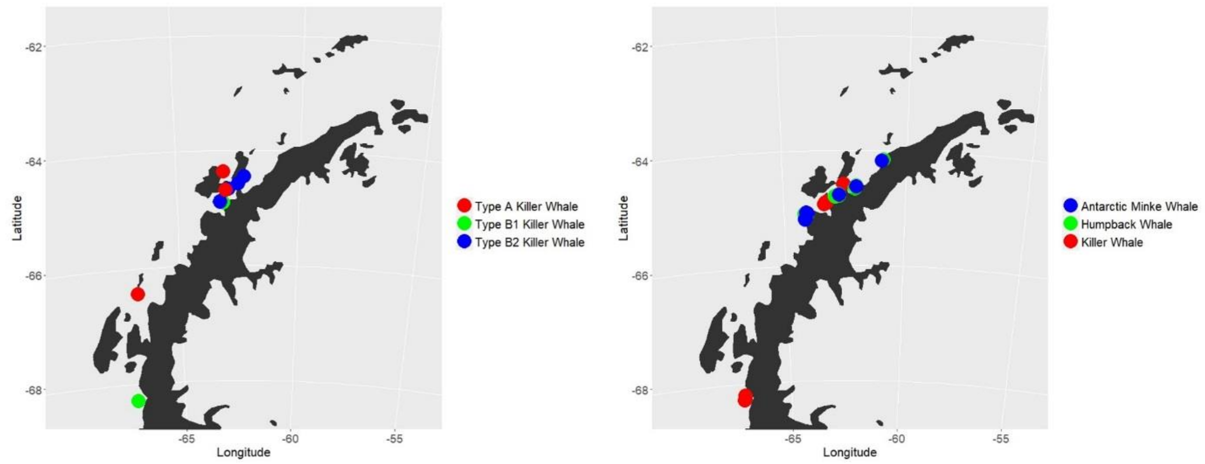


Figure 2 Maps showing locations of killer whale sightings (left) and hexacopter flights over killer, humpback and Antarctic minke whales (right) in the Antarctic Peninsula in November 2017 and January-February 2018. Killer whales were assigned to Types (A, B1, B2) based on previously described differences in pigmentation patterns and morphology (see Pitman and Ensor 2003; Durban et al. 2016).

We used natural markings documented from aerial photographs to identify 5 different individual type B1s and 25 different individual type B2s in these aerial images. Similar to the previous two years, we documented some individuals that were in extremely poor body condition, displaying a “peanut head” appearance due to loss of adipose tissue behind the cranium. Photogrammetric analysis of all images is currently underway to estimate the size and assess the condition of all individual whales. We also continued our long-term monitoring of all three killer whale ecotypes through the collection of photo-identification data to estimate abundance, monitor population trends and assess predatory impact through inclusion of abundance data in ecosystem models. We located 10 groups of killer whales (3 type A, 2 type B1 and 5 type B2) and collected 7416 boat-based identification photographs (Figure 2).

We also used the unmanned hexacopter to collect vertical images of humpback whales and Antarctic minke whales to estimate body condition and further evaluate health by collecting samples of blow exhalate to measure the respiratory microbiome - the assemblage of microorganisms residing in the respiratory tract, which are a common source of cetacean diseases (Figures 3-4).

We flew 25 flights and collected 4336 aerial images of 25 different individual humpback whales and collected blow samples from 11 of these individuals, bringing our project total to 21 samples from humpback whales in 2017 and 2018 combined. Twenty-one flights were flown over Antarctic minke whales, resulting in 4015 images of 35 different individuals, increasing our sample size by tenfold over previous years combined.

Figure 3 Photographs of a small unmanned hexacopter hovering over Antarctic minke whales during a blow sample collection. Blow will be analyzed to assess respiratory health. Research was conducted under NMFS Permit No. 19091 and Antarctic Conservation Act Permit ACA 2017-029.

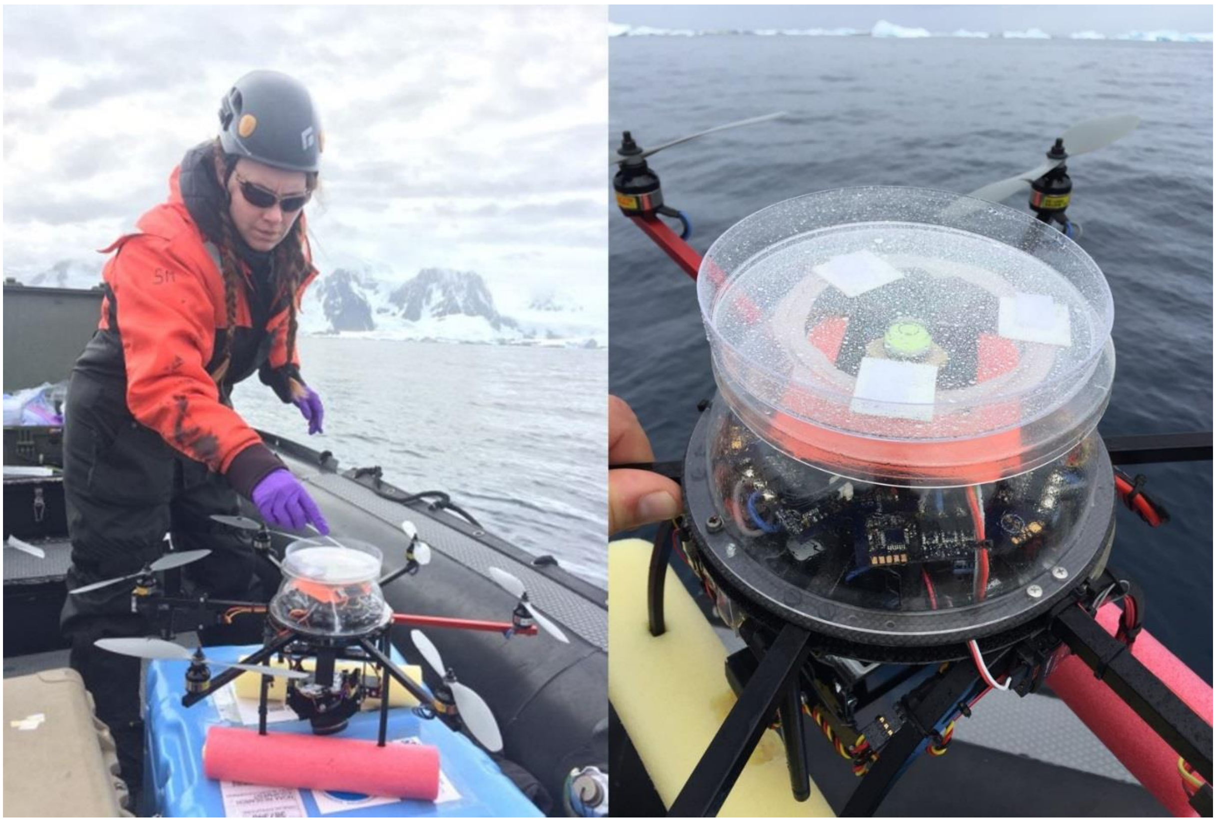


Figure 4 Photographs of Dr. Holly Fearnbach processing a blow sample from an Antarctic minke whale that was collected in a sterile plate mounted on an unmanned hexacopter. Blow will be analyzed to assess respiratory health. Research was conducted under NMFS Permit No. 19091 and Antarctic Conservation Act Permit ACA 2017-029.

We also collected seven blow samples from Antarctic minke whales, the first blow samples ever collected from minke whales worldwide. Photogrammetric analysis of all images is currently underway to estimate the size and assess the condition of all individual whales. Laboratory analysis of the whale blow is also underway to relate body condition to respiratory health. In addition to collecting aerial and boat-based photographs, we also collected small skin and blubber biopsy samples from nine type B2 killer whales, one type B1 killer whale, 11 humpback whales and 2 Antarctic minke whales. Blubber from these samples will be analyzed to relate hormone levels to body condition and the skin will be analyzed to describe microbiome communities that reside on the skin. Killer whale microbiome will be related to diatom levels and body condition, while humpback and minke skin microbiome will be compared to respiratory microbiome and related to body condition. Laboratory analysis of the biopsy samples is underway.

Conclusions

From our 9720 photographs of killer whales in McMurdo Sound taken between 2002 and 2015, we identified a total of 442 individual type C killer whales. From these, we have written a paper describing the current abundance and population trend of this distinctive ecotype of killer whale (Pitman et al. 2018).

From the Antarctic Peninsula and adjacent waters, we currently have over 73,000 killer whale images, representing over 519 killer whale encounters, and we rarely see groups of killer whales now that we have not previously encountered, either personally or from other peoples' photos. This means we have high capture probabilities and resighting rates, which will provide robust and precise population estimates for each of the three killer whale types that regularly occur in the Antarctic Peninsula area. In addition, we have received several thousand photos from people on other tour vessels that operated in the Peninsula area this past season, and we have not yet processed those images.

We received a Pew grant to compile a photo-identification catalogue of killer whales in the Antarctic Peninsula area. We have recently completed a catalog of type A killer whales there and submitted a paper to CCAMLR on the status of type A killer whales in the Antarctic Peninsula area (Fearnbach et al. 2017); we expect to submit the paper to a journal in the near future. We are currently cataloging the types B1 and B2 killer whales from the Antarctic Peninsula. We hope to have all of our images catalogued by the end of the current year. Although these three types are broadly sympatric, our satellite-tracking data quite clearly show the different habitat preferences, and our feeding observations confirm prey specializations hypothesized for each of the different types. We have now documented long-distance, round-trip migrations for all 4 killer whale types that known to regularly occur in Antarctic waters, and despite their long migrations (up to 11,000 km, roundtrip) all are also known to be strongly philopatric on their Antarctic feeding grounds.

Challenges

Our main challenge is to source funds to gain access to a dedicated research vessel so that we can work full time on the whales that we find, and also to support the purchasing of equipment for tagging, acoustic, and photogrammetry studies.

Outlook for the future

We will continue to apply for support for a dedicated research vessel time to conduct focused research on Antarctic killer whales to better document prey types and feeding rates. In the meantime, our on-going support on the *National Geographic Explorer* guarantees us access to killer whales in Antarctica for tagging, photographing, biopsy sampling and UAV work. Currently, we do not have support for further work on type C killer whales in the Ross Sea (McMurdo Sound), but it is a site with excellent access to both Antarctic minke whales and Type C killer whales, and we will be pursuing options to continue on there. We expect, one way or another, to continue our work on Antarctic killer whales at both locations, in the long term.

Luciano Dalla Rosa, West Antarctic Peninsula and Powell Basin.

Introduction

Luciano Dalla Rosa and colleagues (Projeto Baleias, Brazilian Antarctic Program) have been conducting cetacean research around the Antarctic Peninsula since 1997. Research on killer whales has included line transect surveys to investigate distribution and relative abundance, photo-identification, acoustics, and biopsy sampling for genetics, contaminant and stable isotope analyses.

Objectives

Our specific objectives include investigating killer whale distribution and relative abundance around the Antarctic Peninsula, investigating the species-habitat relationships, and their acoustics. We have also conducted biopsy sampling for genetics, contaminant and stable isotope analyses, and have continued our photo-identification efforts, all of which contribute to the IWC-SORP killer whale project. In addition, our ongoing cetacean satellite tagging efforts, which have focused on fin whales, may opportunistically include killer whales depending on ecotype and area.

Results

During February-March 2018, we surveyed the waters of the Bellingshausen Sea and Bransfield and Gerlache Straits, western/northern Antarctic Peninsula, aboard the Brazilian Navy's Polar ship, Almirante Maximiano. Approximately 315 nautical miles of cetacean search effort was conducted, resulting in 337 on-effort sightings (685 individuals) of four cetacean species. One sighting corresponded to a group of 12 individuals of type B killer whales. Another three killer whale sightings were made opportunistically, two of type Bs and one type A. A total of 1,903 photographs were taken for individual identification. These photographs are currently under analysis, and will join our killer whale catalogues which include at least 56 type A individuals and over 140 individuals of both type B1 and B2.

A paper was published online which included some preliminary data on killer whale stable isotopes (see Seyboth et al., in press).

Challenges

Funding for new equipment, including satellite tags, is very limited. Also, ship time is divided among other projects, so depending on weather conditions, all projects may have their activities restricted to some level. Weather conditions are particularly limiting for small boat activities in open areas such as Bransfield Strait and the Weddell Sea.

Outlook for the future

We expect to continue our long term cetacean research in the northern Antarctic Peninsula, and we will be applying for additional funding and ship time for future seasons.

P.J.N. (Nico) de Bruyn and Ryan R. Reisinger, Marion Island, sub-Antarctic

Introduction

As large and versatile apex predators, killer whales (*Orcinus orca*) play an important role in marine ecosystems. They are globally distributed, however populations show marked variation in diet, movement and social organization, which mediates the ecological role of a given population. The divergence and genetic isolation of sympatric populations in various locations seems to be driven by dietary specialisation. However, most long-term, detailed studies of these aspects have been confined to the Northern Hemisphere, and killer whale studies in the sub-Antarctic present an opportunity to investigate the ecological role of killer whales in these systems, to assess the generality of observations from the Northern Hemisphere, and to identify drivers of ecological specialisation. At Marion Island, killer whales may impact the populations of seals and penguins which are concentrated at the island (Reisinger et al. 2011), but the seasonality of these prey resources likely creates special constraints for diet specialisation, movement and social organization.

Objectives

- Continued photographic identification of individuals in order to investigate social organization and eventually demographic parameters.
- Satellite tagging to investigate movement and environmental drivers of distribution and temporal changes therein.
- Population genetic structure to investigate population connectivity, evolutionary history and kinship.
- Stable isotope and fatty acid analyses, coupled with behavioural observations, to describe diet and temporal variation thereof, as well as foraging specialisations in social units.

Results

Photo-identification

- ~90,000 images to date
- 1 unique individual identified (new calf).

	2008-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018*	All (2008-2018)
Observation sessions									
Number	481	210	273	231	216	170	196	165	1942
Hours	2,511 h	1,145 h	1,846 h	1,380 h	1,247 h	916h	951h	921 h	10917h
Sightings									
Dedicated	406	413	466	399	402	217	149	216	2668
Opportunistic	670	270	265	153	273	123	108	215	2077
Images									
Dedicated	9,160	5,354	7,833	6,288	8,313	6453	6224	9413	59038
Opportunistic	6,420	5,803	2,346	876	4,639	1918	1177	7575	30754
Tagging									
Attempts	-	25	7	10	6	0	2	6	56
Successful	-	10	6	6	2	0	2	6	32
Tags lost (without transmitting)	-	6	1	4	0	0	0	0	11
Duration (average)	-	7.5 d	26.6 d	8.2 d	5.9 d	0	30 d	12.7 d	90.9d
Biopsy									
Attempts	-	63	9	18	15	9	14	14	142
Samples	-	24	5	6	6	7	8	10	66

*To 2018/03/15

Satellite tagging and biopsy sampling – effectiveness, immediate reactions and mid- to long-term effects

Based on a subset of biopsy sampling attempts (n = 72) and satellite tagging attempts (n = 37), we found that individuals most often showed no reaction when attempts missed (66%) and a slight reaction – defined as a slight flinch, slight shake, short acceleration, or immediate dive – when hit (54%). Severe immediate reactions were never observed. Hit or miss and age-sex class were important predictors of the reaction, but the method (tag or biopsy) was unimportant. Multievent trap-dependence modelling revealed considerable variation in individual sighting patterns; however, there were no significant mid- or long-term changes following biopsy sampling or tagging (Reisinger et al. 2014). Also based on this subset, biopsy sampling success rates were low (44%) but, tagging rates were high with the improved (LIMPET; Andrews et al. 2008) tag designs (86%). The improved tags remained attached for 26 ± 14 days (mean ± SD) (Reisinger et al. 2014).

Social organisation

We calculated the half-weight association index among 39 individuals, creating a weighted association network (Reisinger et al. 2017). There was strong social differentiation among individuals, with clearly preferred long-term associations between individuals. Using a community detection algorithm, we defined 8 social units – typically containing 3 individuals of mixed age-sex class composition. Association rates among all individuals always exceeded random expectations, but declined over years. Association rates within social units, however, were stable over the study period. Association index values within and between social units were heterogeneous. This indicates fluid social associations within a framework of stable social units. We calculated pairwise genetic relatedness among 20 individuals and found that relatedness was not correlated with association index. Individuals were on average more related within than between social units, however some dyads had high association index values but were not related, while some highly related individuals showed low levels of association. Likely parent pairs of eight individuals indicated mating between social units. Overall, Marion Island killer whales have a similar social structure to Northeast Pacific mammal hunting killer whales and we ascribe this to their functionally similar diets (Reisinger et al. 2017).

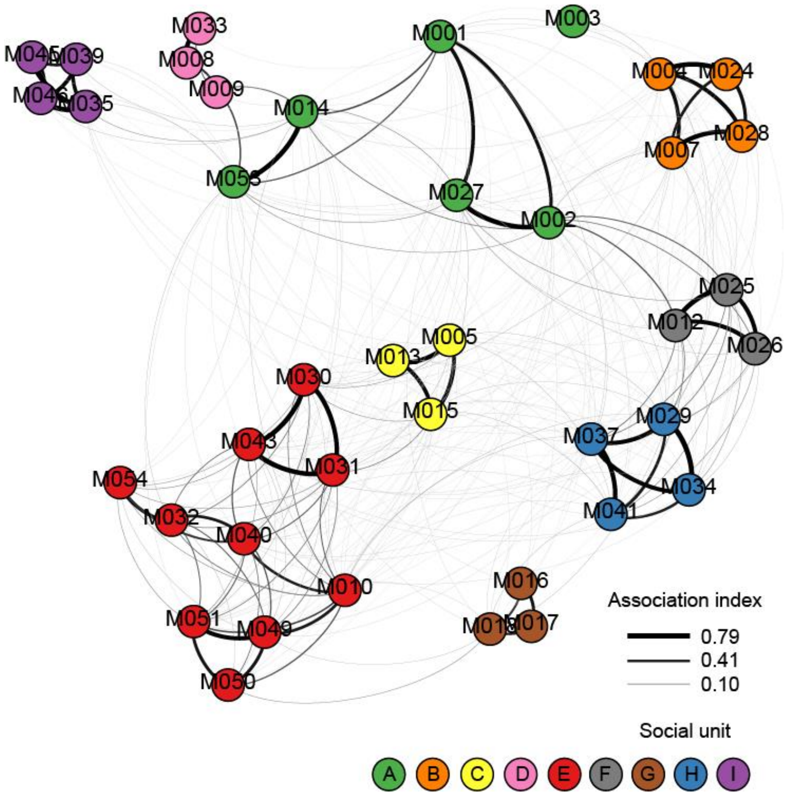


Figure 5 Network graph showing the associations between killer whales at Marion Island. Individuals are represented by nodes (coloured circles) and associations by edges (lines) between nodes. Colours represent social units and edges are weighted by the half-weight association index (Reisinger et al. 2017).

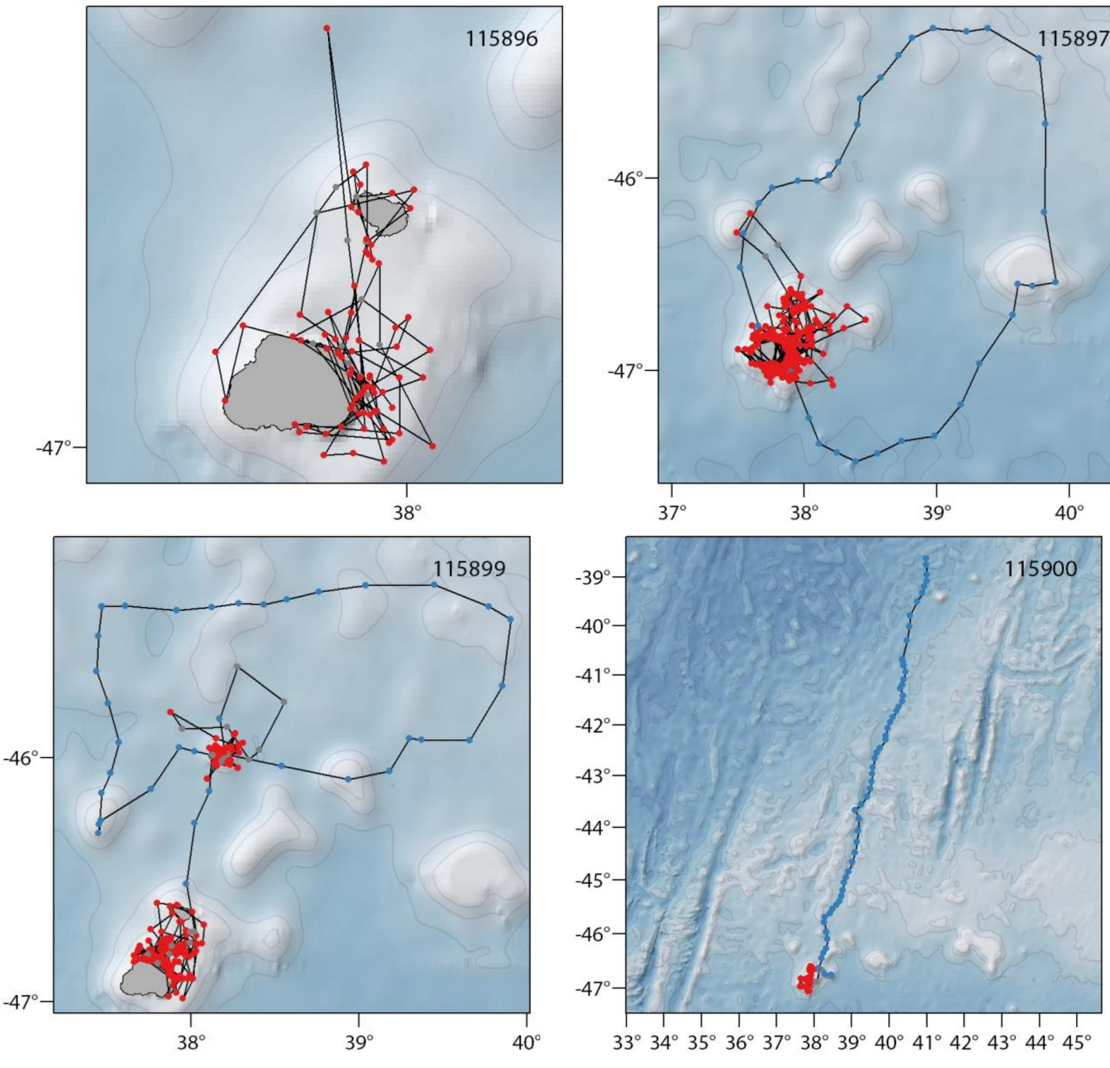
Movement and diving

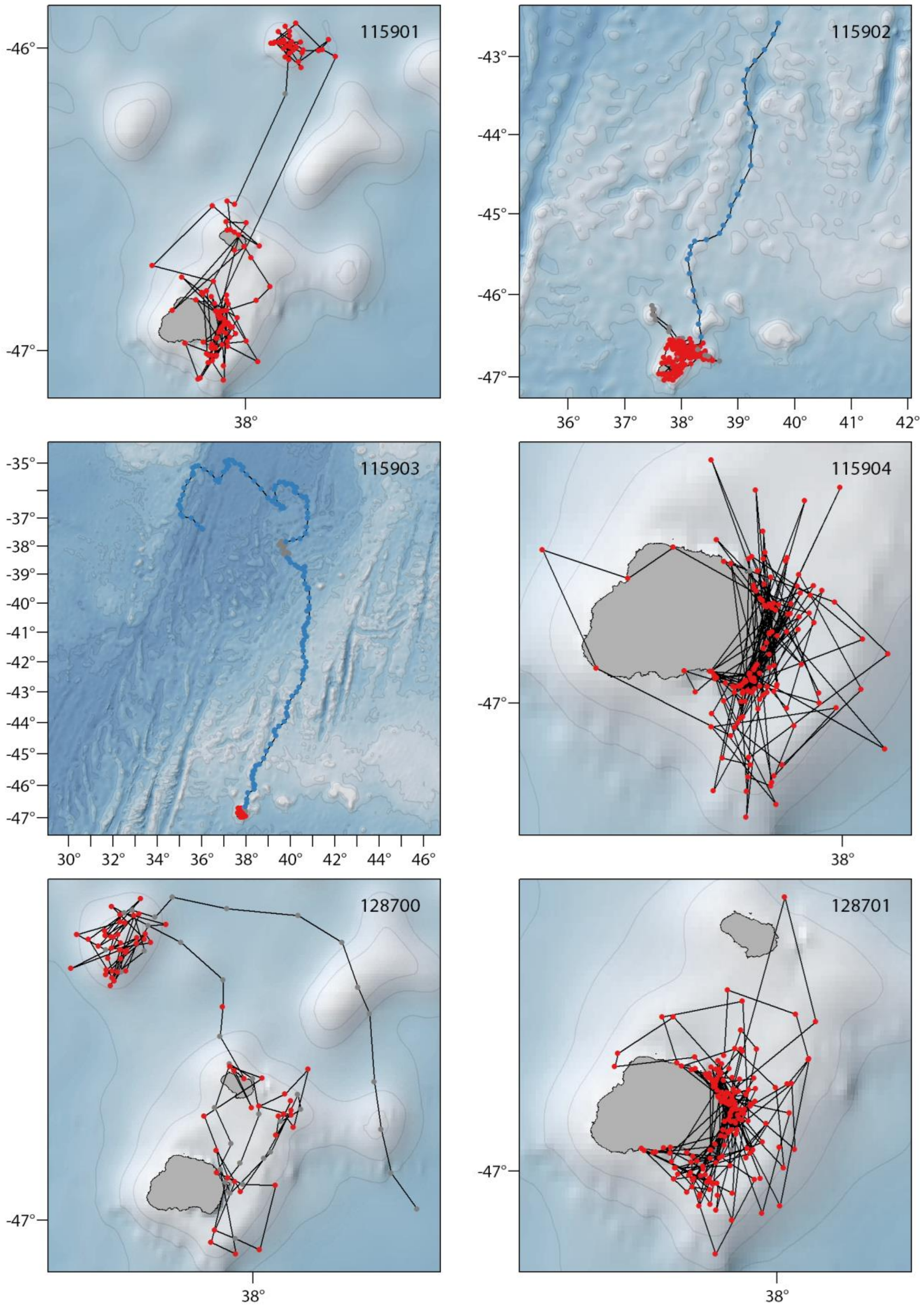
Based on 11 satellite tag deployments on 9 individuals, we used state-space switching models to generate position estimates from Argos location data (Reisinger et al. 2015). We simultaneously estimated two behavioural modes from the data: restricted behaviour and transit behaviour. We also constructed utilization distributions for each individual.

We tracked individuals for 5.6–53.2 days, during which time they moved 416–4,470 km (an average of 82.7 km day-1. Killer whales showed restricted behaviour close to the islands, particularly inshore (52% of position estimates <5 km from shore) where they can effectively hunt seals and penguins, and at seamounts to the north of the islands.

We used generalized linear mixed effect models to explore the relationship between 7 environmental variables and behavioural mode. Our best model included depth, sea surface temperature, latitude, sea surface height anomaly and bottom slope, but killer whales did not clearly target features such as fronts and apparent mesoscale eddies, in contrast to seals and seabirds in the Southern Ocean.

Dive data from two individuals largely revealed shallow dives (81% of dives 7.5–50 m deep), but deeper dive bouts to around 368 m were also recorded. Dives were significantly deeper during the day and both individuals dived deeper (767.5 and 499.5 m) than any published dive records for killer whales. We therefore suggest that killer whales might also prey on vertically migrating cephalopods and perhaps Patagonian toothfish.
Three individuals made rapid and directed long-distance movements northwards of the islands, the reasons for which are speculative, but discussed within the context of hypotheses such as 'physiological maintenance migrations' to regenerate their skin in warmer waters.

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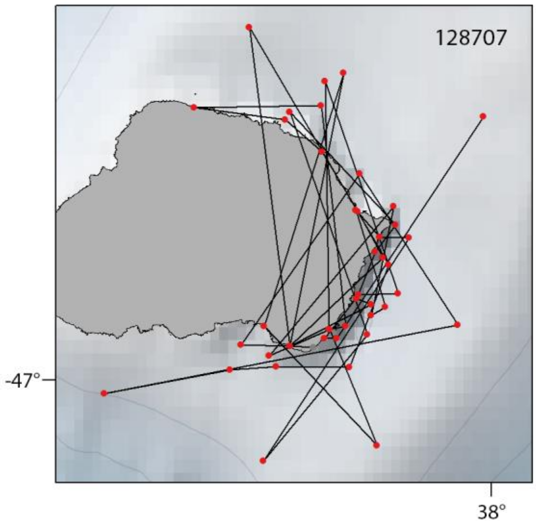

Figure 6 Individual tracks of satellite-tagged killer whales at Marion Island. Points represent state-space switching model position estimates based on ARGOS position estimates, and are coloured by behavioural mode (red – restricted; blue – transit; grey – uncertain). Solid lines represent straight lines between position estimates. Track IDs (PTTs) are indicated in the top right corner of each map. Depth contours are at 1000 m intervals. Spherical Mercator projection (Reisinger et al. 2015).

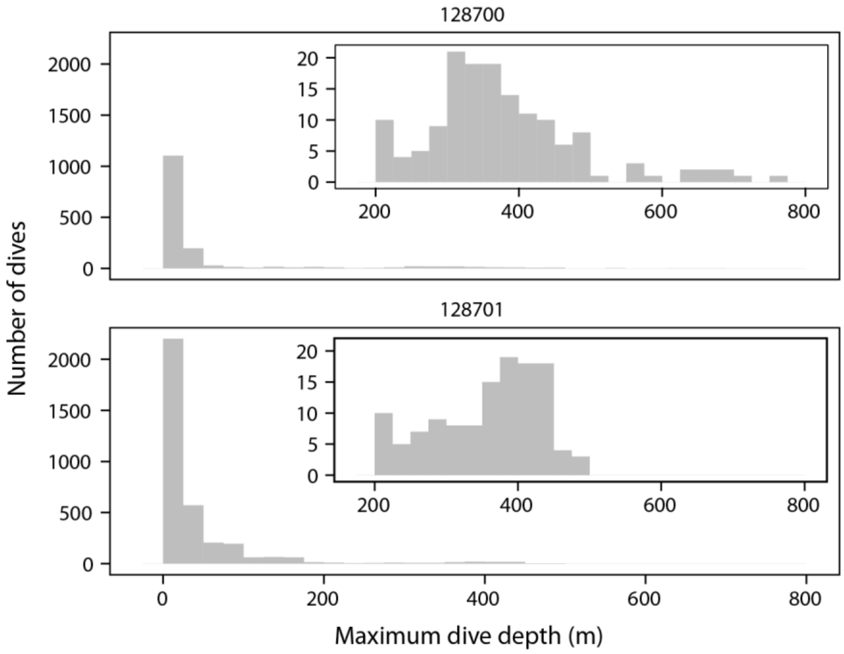

Figure 7 Histogram showing the distribution of maximum dive depths of two killer whales around Marion Island. The 200–800 m depth range is enlarged in the insets (Reisinger et al. 2015).

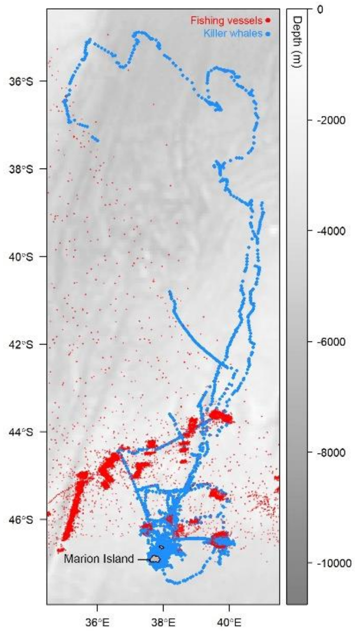

Figure 8 Map showing location estimates (blue points) from 22 satellite tag deployments on killer whales at Marion Island (2011-11-08 - 2017-05-02), with VMS locations of longline fishing vessels (red points) over the same period. For killer whales, hourly locations were estimated from Argos data using a first difference correlated random walk model (MRI unpublished data).

Diet

Killer whales at Marion Island have been observed preying on seals and penguins inshore and depredate Patagonian toothfish from longline fishing vessels in the region. However their diet is unknown when they are not observed inshore. We analysed the carbon and nitrogen stable isotope ratios in 32 skin and blubber samples remotely collected from 24 killer whales (Reisinger et al. 2016). Blubber δ13C and δ15N values were higher than in skin. Adult males had higher skin δ15N values than adult females or subadults. There were no substantial differences among social units, but two social units which have been observed depredating Patagonian toothfish at the Crozet Islands had higher skin δ15N values. Temporal variation in the difference between skin and blubber values suggests temporal dietary variation. We also analysed tissue samples from seal, penguin and Patagonian toothfish prey and used available values for Antarctic fur seals and putative cephalopod prey. Results show that killer whales around Marion Island are apex predators, but that they do not feed exclusively on other high trophic level predators such as elephant seals, fur seals, and Patagonian toothfish. Killer whales had skin δ15N values similar to those of Patagonian toothfish and adult male elephant seals. An initial set of Bayesian stable isotope mixing models indicated that adult male elephant seals and Eudyptes penguins were the most important prey, but the inclusion of cephalopods improved models and cephalopods became important prey.

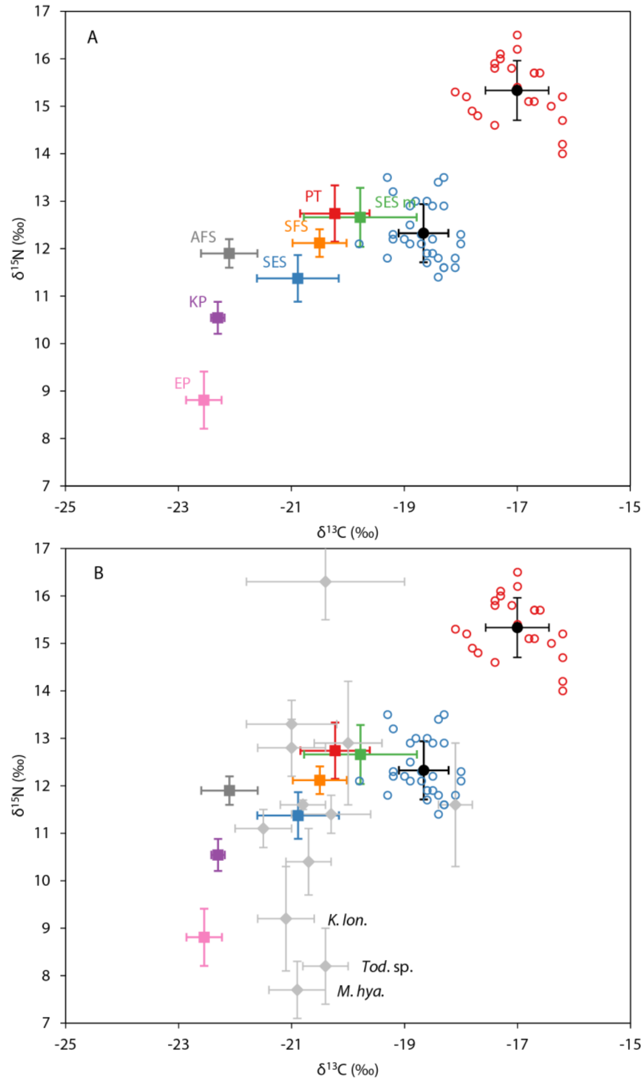

Figure 9 Biplot of δ13C against δ15N showing mean values ± SD for killer whales (filled circles) and their prey (squares). Individual values for killer whale blubber (red) and skin (blue) are shown with open circles. PT – Patagonian toothfish; AFS – Antarctic fur seal; SFS – Subantarctic fur seal; SES – southern elephant seal (adult females, subadults and juveniles); SES m – southern elephant seal adult males; KP – king penguin; MP – macaroni penguin; RP – rockhopper penguin. Part b includes mean δ values ± SD of cephalopods from around the Kerguelen Islands (diamonds) (Cherel et al. 2008). Cephalopod values included in our mixing models are labelled: K. lon – *Kondokovia longimana*; Tod. sp. – *Todarodes* sp.; M. hya – *Martialia hyadesi*. The highest mean δ15N value (16.3 ± 0.8 ‰) is for the colossal squid *Mesonychoteuthis hamiltoni* (Reisinger et al. 2016).

<u>Conclusions</u>

Photographic identification, biopsy sampling and satellite tagging have facilitated studies of the social organisation, population genetic structure, diet, movement and diving of killer whales at sub-Antarctic Marion Island. The results indicated that the spatio-temporal distribution of prey at Marion Island – particularly seasonal changes in prey – has a strong influence on the ecology of the population of killer whales which occurs there.

Tagging and biopsy sampling have been effective and no short (~1 month) to mid-term (~2years) effects on individual occurrence at Marion Island have been detectable.

Marion Island killer whales form small social units which are mostly stable over years. Genetic relatedness is higher within than between social units, but association is not correlated with genetic relatedness. Membership of social units is dynamic: some long-term associations are among non-kin, and kinship levels within pods is highly variable. While social units are stable, associations between them are flexible, which may allow for the adjustment of group sized suited to different contexts.

Killer whales make use of a dense and predictable prey aggregation in the shallow, inshore waters of the Prince Edward Islands, but seem to alternate this hunting strategy with foraging over nearby seamounts. The oceanic setting of the islands appears to make this switching profitable. This population of killer whales does not seem to utilize distant bathymetric features or fronts as penguins and seals from the Prince Edward Islands do. The restricted movements and general philopatry of individuals is interspersed with long-distance directed movements north of the islands.

We show that killer whales are indeed apex predators in the Marion Island marine ecosystem, with mean δ15N values higher than any seals, penguins or Patagonian toothfish. However δ15N values in killer whales were not high enough to suggest that they prey exclusively on such high trophic level prey.

Challenges

Timing of tag deployment to record long-distance movement of individuals remains a challenge.
Biopsy sampling individuals at a temporal interval which will allow the detection of seasonal dietary variation and movement (e.g., simultaneous to tag deployment or before and after long-distance movements).

Outlook for the future

- Photo-ID and behavioural observations will continue, and this will facilitate the calculation of demographic parameters in this population and further investigations of social structure. The process whereby social units split or fuse deserves particular attention.
- Satellite tagging should continue, to identify the reasons for rapid, long-distance movements. Continued tagging with time depth recorders will shed more light on deep diving behaviour over seamounts. Simultaneous biopsy sampling of tagged animals, although difficult to achieve logistically, may allow the detection of any dietary shifts associated with this behaviour.
- Quantitative fatty acid analyses need to be performed on blubber samples already in hand, but sampling of putative prey first needs to be improved.

The funds for the purchase of three of the SPLASH10-292B tags deployed were awarded from the IWC-SORP Research Fund (SC/67b/SH18).

Giancarlo Lauriano and Simone Panigada, Terra Nova Bay, Ross Sea, Antarctica

Knowledge on the distribution, foraging habits and the abundance of Type B (both pack ice and Gerlache) and Type C (Ross Sea) killer whale ecotypes in the Antarctic is scant. Moreover, information on the species seasonal distribution and occurrence, as well as its and residency patterns in the region, are lacking. The impact of killer whales on the ecosystem depends on their movements, abundance, diet and prey requirements. A decrease in the prevalence of Type C individuals has been inferred following the depletion of Antarctic toothfish, *Dissostichus mawsoni*, as one of the main prey; this would force the species to compete more directly with other top predators.

In 2004, an Italian research project in Terra Nova Bay (TNB) described the presence of both Type B (seals eater) and Type C (fish eater) killer whale types around Cape Washington and near the Italian base Mario Zucchelli Station (MZS). Following on from this, a new two year project was funded by the Italian National Antarctic Research Programme (PNRA) (Lauriano et al. 2007. 2011). The aim of the research was to assess the dynamics and role of killer whales in the highly local productive marine ecosystem of TNB, through the understanding of their fine and large scale movements (satellite tagging), prey-related distribution (photo-ID and behavioural sampling), dietary preferences (fatty acids and stable isotopes), toxicological status, and to estimate their abundance (mark recapture).

No fieldwork was conducted during the 2017/18 austral summer. However, analysis of data from previous seasons continues, peer-reviewed papers are in preparation and further funding is being sought to continue this work.

Outlook for the future

The main objectives for future collaborative research are to:

- Investigate fine scale habitat use of pack ice killer whale (large type B) and the Ross Sea killer whale (C) within the Terra Nova Bay and adjacent waters;
- Investigate the ecological importance of Terra Nova Bay and surrounding waters for both the pack ice killer whale (large type B) and Ross Sea killer whale (C);
- Identify migratory corridors for the type C killer whale and identification of medium- and long-distance movements of type B killer whales;
- Assess the toxicological stress for the two ecotypes of killer whales: POPs, molecular and oxidative stress biomarkers;
- Assess the health status of wild cetaceans from Antarctica, thereby investigating the expression of given biomarkers related to “neuro-immune function/dysfunction”, along with the evidence of stressful conditions and the presence, if any, of one of the most, if not even the most, threatening pathogen for marine mammals worldwide, namely Cetacean Morbillivirus.
- Investigate the taxonomical status of the ecotypes of this species and creation of genetic catalogue.

Project outputs

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ANNEX 3 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2017/18

IWC-SORP Project 3. Foraging ecology and predator-prey interactions between baleen whales and krill: a multi-scale comparative study across Antarctic regions

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Executive summary

Quantifying the linkages between predators and their prey are fundamental to understanding ecosystem function. The goals of our research program are to use tag technology and concurrent oceanographic and prey mapping methods to study the relationships between humpback and minke whales and their prey around the Antarctic Peninsula. We use short-term multi-sensor suction cup tags and long-term satellite-linked tags to study the foraging behaviours and movement patterns of baleen whales in relation to the distribution and abundance of krill and oceanographic variables. To date we have deployed each type of tag on both humpback and minke whales and are completing comprehensive ecological analyses. From fine-scale tag and prey data, we have found that humpback whales feed in a manner consistent with optimal foraging theory: humpback whales feed when krill become available in the upper reaches of the water column in larger but less dense patches. However, within these patches, the deeper the whales feed the denser the krill density that they target. We have also found that the feeding rates of minke whales are greater than those of any other baleen whale and that their foraging strategies, while similar to humpback whales in some respect, also include species-specific behaviours that indicate under sea-ice feeding. This information on the underwater behaviour of minke whales is the first of its kind for the species. From long-term satellite-linked tags, we have found that humpback whales range over broad spatial regions in the continental shelf waters of the Western Antarctic Peninsula. There is evidence that the size of their home ranges decreases throughout the feeding season in relation to the spatial distribution of krill. All of the humpback whales that have migrated while still carrying active tags, all have gone up the western side of South America. Antarctic minke whales were tagged for the first time in 2013 and we continue to build a database from satellite tag including 4 LIMPET tag deployments in March 2016 as part of an Australian Antarctic Division and Oregon State University collaboration in the Western Antarctic Peninsula. Their movement patterns are in the process of being analysed but include a variety of movement patterns. While some animals remained in close proximity to nearshore bays for over 120 days, other whales moved from the Antarctic Peninsula into both the Weddell Sea to the north and east and the Bellingshausen Sea to the south and west. There is also evidence to support migration of some whales to tropical areas. While the main analytical focus of this work is to understand ecological linkages, the practical focus has been to develop methodologies that can be transported in a manner so as to replicate this research with international collaborators in a variety of regions around Antarctica. International collaboration and regional research studies are at the core of the Southern Ocean Research Partnership and we continue to develop both our research methods and collaborative relationships towards this goal. Over the past year, we focused effort on deploying suction cup tags on both humpback and minke whales, measuring prey and sea ice, and using UAS to generate estimates of body condition and animal size. This incredibly successfully effort resulted in 10 deployments on minke whales and 10 deployments on humpback whales. Additionally, 13 LIMPET tags were deployed on humpback whales and 1 on a minke whale through funding provided from the Antarctic and Southern Ocean Coalition and the Hogwarts Running Club. These data are part of a current NSF award to Dr Friedlaender. Lastly, we have published several articles that specifically show the dynamic nature of humpback whale foraging behaviour throughout the feeding season, and the spatio-temporal overlap between humpback whale foraging areas and the krill fishery around the Antarctic Peninsula.

Introduction

Recent technological advances in the miniaturization of sensors have allowed for the development of tags that can measure, in fine detail, the underwater movement patterns and behaviours of marine mammals. Likewise, satellite-linked telemetry and analytical tools have advanced to allow for greater understanding of how the broad scale movement patterns and behaviours of marine mammals links to changes in the physical and biological seascape. Understanding both fine and broad scale behaviour of baleen whales in Antarctic waters is critical to understanding the ecological role of cetaceans and how these are being affected by climate-driven changes to their environment.

Objectives

The objectives of our research program are to use technological advances in animal biotelemetry to elucidate the behaviour and ecological role of cetaceans in the nearshore waters around the Antarctic Peninsula and to relate these to climate-driven changes that are currently occurring.

Results

In 2017-2018 we continued our work through the NSF LTER program with personnel deploying on the *LM Gould* and at Palmer Station. We continued our collaboration with One Ocean Expeditions and conducted research on 3 expedition trips. We also deployed a field team as part of a new NSF award to Dr Friedlaender to study the ecological role of Antarctic minke whales. Below is the scientific report presented to the NSF Office of Polar Programs Program Manager at the conclusion of our field work and selected abstracts and figures from published work.

Collaborative Research: Foraging behavior and ecological role of the least studied Antarctic krill predator, the Antarctic minke whale (Balaenoptera bonaerensis)

Proposal OPP-1643877
Event # B-206-L

Chris Fritsen, NSF/OPP Program Officer
Timothy McGovern, NSF/OPP Ocean Projects Manager
Weekly Science Report 43 March 2018
Prepared by: Dr. Ari Friedlaender
Additional field team members: Dave Johnston, Jeremy Goldbogen, Chris Taylor, Dave Cade, Emma Levy, KC Beirlich, and Mary Lide Parker

Award Abstract

Part 1. The Antarctic Peninsula is warming rapidly and one of the consequences of this change is a decrease in sea ice cover. Antarctic minke whales are the largest ice-obligate krill predator in the region yet little is known about their foraging behaviour and ecology. The goals of our research project are to use suite of new technological tools to measure the underwater behaviour of the whales and better understand how they exploit the sea ice habitat. Using video-recording motion-sensing tags, we can reconstruct the underwater movements of the whales and determine where and when they feed. Using UAS (unmanned aerial systems) we can generate real-time images of sea ice cover and link these with our tag data to determine how much time whales spend in sea ice versus open water, and how the behaviour of the whales changes between these two habitats. Lastly, we will use scientific echosounders to characterize the prey field that the whales are exploiting and look for differences in krill availability inside and out of the ice. All of this information is critical to understand the ecological role of Antarctic minke whales so that we can better predict and understand the impacts of climate change not only on these animals, but on the structure and function of the Antarctic marine ecosystem.

Our research will promote the progress of science by elucidating the ecological role of a poorly known Antarctic predator and using this information to better understand the impact of climate change in polar regions. The integration of our multi-disciplinary methods to study marine ecology and climate change impacts will serve as a template for similar work in other at-risk regions and species. Our educational and outreach program will increase awareness and understanding of minke whales, Antarctic marine ecosystems, sea ice, and climate change through the use of documentary filming, real-time delivery of project events via social media, and Scientific Research and Education Network curriculum development for formal STEM educators.

Part 2. To understand how climatic changes will manifest in the demography of predators that rely on sea ice habitat requires knowledge of their behaviour and ecology. The largest ice-dependent krill predator and most abundant cetacean in the Southern Ocean is the Antarctic minke whale yet virtually nothing is known of the their foraging behaviour or ecological role. Thus, we lack the knowledge to understand how climate-driven changes will affect these animals and therefore the dynamics of the ecosystem as a whole. We will use multi-sensor and video recording tags, fisheries acoustics, and unmanned aerial systems to study the foraging behaviour and ecological role of minke whales in the waters of the Antarctic Peninsula. We pose the following research questions:

1. What is the feeding performance of AMWs?
2. How important is sea ice to the foraging behavior of AMW?
3. How do AMWs feed directly under sea ice?

We will use proven tagging and analytical approaches to characterize the underwater feeding behaviour and kinematics of minke whales. Combined with quantitative measurements of the prey field, we will measure the energetic costs of feeding and determine how minke whales optimize energy gain. Using animal-borne video recording tags and UAS technology we will also determine how much feeding occurs directly under sea ice and how this mode differs from open water feeding. This knowledge will: (1) significantly enhance our knowledge of the least-studied Antarctic krill predator; and (2) be made directly available to international, long-term efforts to understand how climate-driven changes will affect the structure and function of the Antarctic marine ecosystem.

Our educational and outreach are to increase awareness and understanding of: (i) the ecological role of minke whales around the Antarctic Peninsula; (ii) the effects of global climate change on an abundant but largely unstudied marine predator; (iii) the advanced methods and technologies used by whale researchers to study these cryptic animals and their prey; and (iv) the variety of careers in ocean science by sharing the experiences of scientists and students. These will be achieved by delivering continuous near-real-time delivery of project events and data to informal audiences through pervasive social media channels, together with a traditional professional development program that will provide formal STEM educators with specific standards-compliant lesson plans. These traditional products will be delivered through the established Scientific Research and Education Network (SCiREN) program.

Weekly Science Synopsis

During the second and final week of our dedicated time to study the foraging behavior and ecological role of Antarctic minke whales we completed an extremely successful campaign highlighted by a large number of tags deployed on minke whales, high numbers of UAS flights, and significant prey mapping in the vicinity of tagged whales. We moved from Andvord Bay to Paradise Harbor where we found high numbers of minke whales in the numerous bays in this area. Below are summaries of the major scientific and educational components of our research effort including whale tagging, prey mapping, photogrammetry and sea ice habitat mapping, and outreach.

Our daily activities have consisted of working from small boats during morning hours to search for whales to tag and/or to recover tags deployed previously. During this time the LMG conducts prey mapping surveys and/or CTD/net tows for environmental sampling. Afternoons have been similar with continued tagging efforts and prey mapping. During night hours, operations have ceased and the ship has maneuvered to be in a desired position for the next morning's operations.
None of this work would have been completed without the tireless efforts and extraordinary support from the ASC MTs, ET, MLT, and MPC as well as the Captain, Officers, and crew of the ARSV Laurence M Gould. We are grateful for their efforts.

Whale Tagging

During the second half of tagging efforts, high numbers of minke whales were discovered in the head of Andvord and the numerous bays around Paradise Harbor. Aggregations of up to 5 animals within 2 body lengths of each other were observed on multiple occasions, though most often minkes were spotted in pairs and groups of three. Three separate pairs of tagged minke whales were observed feeding concurrently in the same location.

Figure 1 A pair of Antarctic minke whales with video-recording multi-sensor tags in Paradise Bay.

In total during the seven days of tagging efforts, suction cup tags were deployed on 20 animals (9 minke whales, 10 humpback whales and 1 killer whale). A total of 293 hours and 47 minutes (minke: 125h 57m, humpback: 166h 55m, killer: 1h 57m) of animal behavior and spatial orientation were logged in three dimensions at high resolution (50-400 Hz), and approximately 90 hours of on-animal video data were collected. Two tagged minkes and eight tagged humpbacks had corresponding UAV imagery that will allow body lengths to be accurately determined. The accelerometry data will be synched with the video, allowing the camera data to be interpreted in the context of the tagged animal's orientation, motion and dynamic acceleration. Lunge feeding events can be easily identified in the accelerometry data as increases in speed followed by rapid decreases in speed, in connection with high overall body acceleration (the "jerk" signal) and often in connection with body roll and pitch. In Figure 2 the tagged animal is oriented vertically and rolls to its right during the filtration stage of feeding.

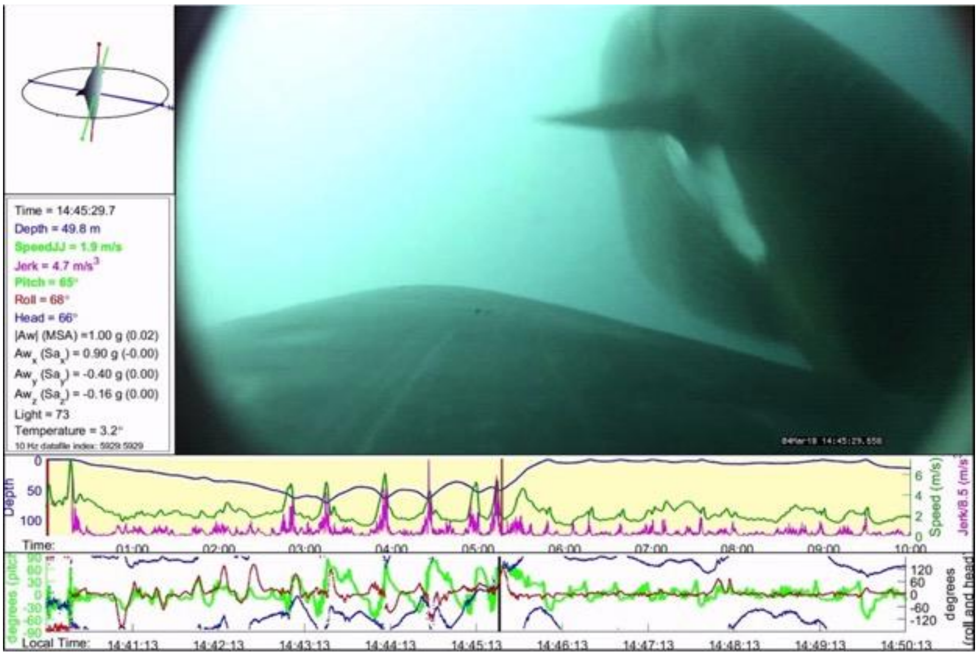

Figure 2 Data frame from a video-recording multi-sensor tag on an Antarctic minke whale. The video frame shows, from the tagged whale's perspective, another minke whale that has just lunge fed. The upper left of the panel shows the orientation of the whale, while the lower two panels show the depth, speed, and jerk signal (top panel) and the pitch, roll, and heading (bottom panel) from the tag's data.

Using occasional GPS positions from the tag, ARGOS satellite positions from an independent transmitter, known tag deployment and recovery locations, and dead reckoned tracks from the animal's derived heading, pitch and speed, a "pseudotrack" of each tagged animal's 3D location can be constructed. Figure 3 shows a track from bb180304-45 over 28 hours showing its spatial utilization of Paradise Harbor (Figure 3).

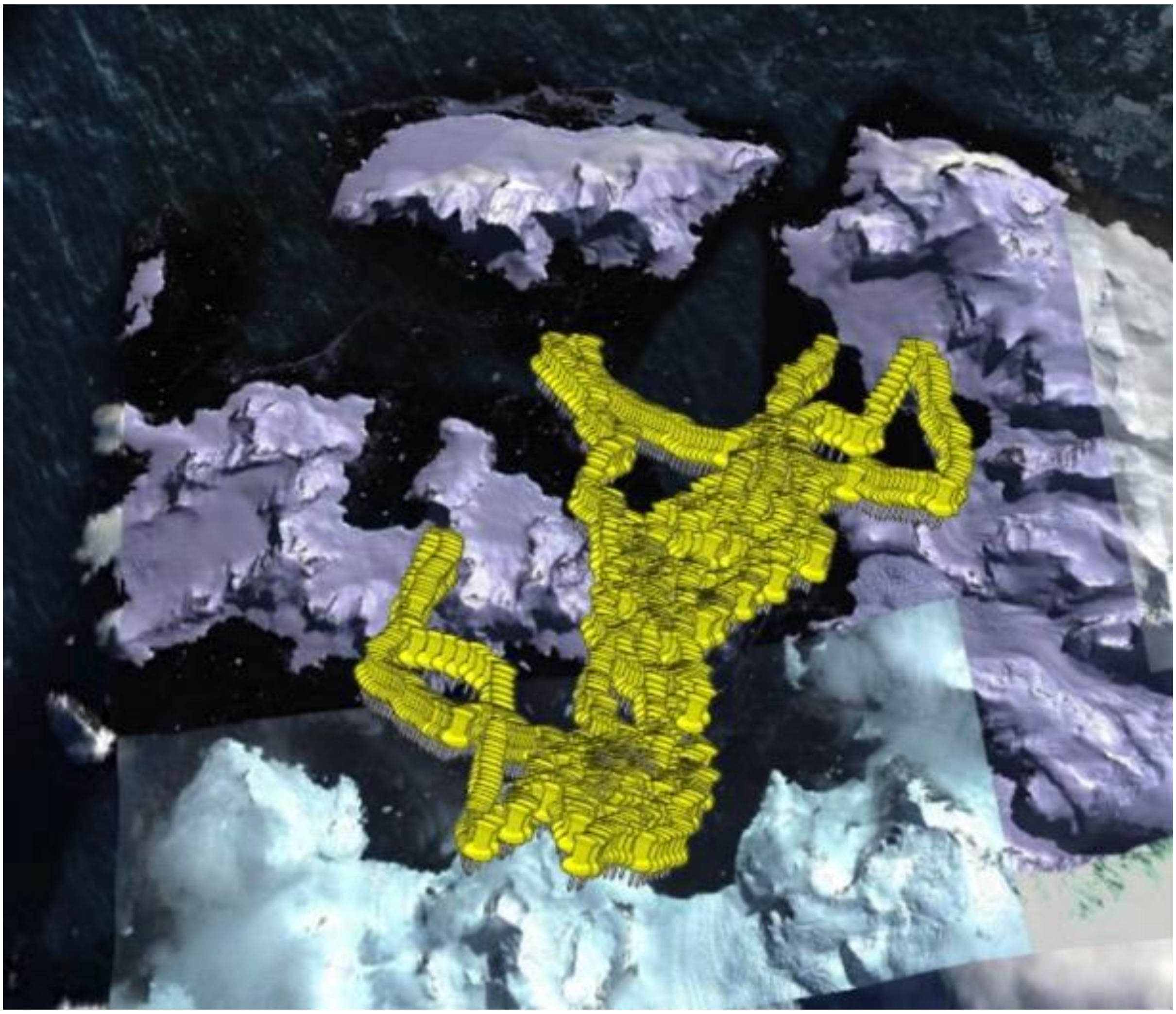

Figure 3 Corrected pseudo-track showing the movement patterns of a tagged minke whale in Paradise Harbor over a 28 hour period.

Of the 20 tags deployed, 18 were recovered without issue using a combination of ARGOS and VHF telemetry. The ARGOS system was particularly useful for 3 tags that were carried to Charlotte Bay, Fournier Bay and the Gerlache Strait by humpback whales which we observed to have higher spatial ranges than the Antarctic minke whales under study. One tag was lost due to a non-transmitting VHF antenna, and one tag was found but not recoverable due to its drift into an area not safe for recovery (e.g. close to the face of an active glacier).

UAS Photogrametry and Habitat Mapping

During the reporting period, we flew a LEMHex-44 hexacopter UAS fitted with a 20mp RGB camera to collect remote imagery of whales and their habitat. Flights were conducted from both the Zodiac and Solas small boat platforms, launched and recovered by hand. A total of 16 flights were conducted, resulting in the acquisition of 1797 images of whales and foraging habitat (~40gb of data). During image acquisition the UAS was flown at 40-50m and no flight anomalies occurred. All launches and recoveries occurred without incident. The duration of flights ranged from 9 to 13 minutes with a total flight time: 2 hr 44 min 17 sec.

In total, 15 humpback whales were photographed for morphometric purposes, including 3 mother/juvenile pairs and two animals fitted with Limpet Satellite-linked time depth recorders. Examples of UAS photogrammetry imagery are included in Figure 4.

Figure 4 UAS image of an adult and juvenile humpback whale in Charlotte Bay. The Zodiac Mark V is shown for scale.

In addition, 14 minke whales were photographed for morphometric purposes, including 2 animals that were fitted with CATS motion and video tags. Examples of UAS photogrammetry imagery are included in Figure 5.

Figure 5 UAS image of a group of four Antarctic minke whales. Two tagged whales are present in the group; one underwater in the lower left of the image and one at the surface at the bottom centre of the image.

Prey Mapping

Prey mapping, primarily targeting krill, is conducted on two platforms: a towfish towed from the ARSV Laurence M Gould and a pole mount on a 12ft Zodiac. Both systems use similar Simrad splitbeam echosounders (SBES) operating simultaneously at 38 kHz and 120 kHz. The two frequencies allow for discrimination between krill and fish schools; krill swarms have stronger backscatter at higher frequencies. The LM Gould conducts larger scale systematic surveys in relatively low ice cover to map the broad distribution of krill swarms. The Zodiac surveys while following tagged animals to assess krill patches in closer proximity to the animals and/or higher ice cover.

We focused surveys in Andvord Bay and Paradise Harbor. Between the two platforms we have surveyed over 180 km of the bay (Table, Figure 6). The vast majority of the backscatter in the water column have come from krill patches, which are easily differentiated between the two echosounder frequencies. Ice cover in the bay has hampered survey coverage by the LM Gould, far less so on the Zodiac. Krill patches have been highly variable in size and shape, but most have been within 100m of the surface in Andvord Bay (Figure 7). In Paradise Harbor, krill patches varied from small sparsely distributed in the upper 100m to very large and nearly continuous swarms between 100 and 200m depths (Figure 8). Densities were mapped along the survey lines in 250 distance bins separated by depth layer (less than 100 meters and greater than 100 meters) (Figures 9&10). One krill net two were conducted on 2 March in Andvord Bay and two were conducted on 6 March in Paradise Harbor to ground truth sizes and acoustic target strengths and calibrate the estimates of krill biomass. About 100 krill were measured for length from each tow and 11 were subsampled and frozen for gut fluorescence (Image, Figures 11&12).

Table 1 Line kilometres surveyed for prey mapping on the ASRV LM Gould (LMG) and Zodiac.

Location	Platform	Date	Survey km
Andvord	Zodiac	27 February	26
Andvord	Zodiac	28 February	15
Paradise	Zodiac	4 March	14
Paradise	Zodiac	5 March	11
Andvord	LMG	27 February	54
Andvord	LMG	28 February	29
Andvord	LMG	2 March	9 (abbreviated due to ice)
Paradise	LMG	5 March	24

<u>Assessing performance of LM Gould Simrad EK80 on Towfish</u>

Prior to the surveys, we spent significant time (two days) diagnosing noise and interference issues on the echosounder system on the LM Gould. The LM Gould EK80 38 kHz transducer had two dead channels. These channels were not functioning during the entirety of the previous LMG-1801 LTER mission. Further examination of the 38kHz EK80 discovered complete failure of the 38kHz transceiver (showing an "Overcurrent Event"). The culprit was most surely flooding and shorting in the Amphenol cannon plugs that are used to join patch cables between the transducers and deck units. Fortunately, we were able to acquire spare Simrad echosounders from Palmer Station. The LM Gould towfish was modified quickly by the marine technicians (awesome work!) to receive the new 38 kHz transducer. We formulated operating procedures that require all sonars on the ship other than the Simrad EK80s be secured. This includes the legacy docking sonars that were discovered at the beginning of this cruise. The ADCP and Knudsen Chirp echosounders present significant impulse noise that pollutes the estimates of krill biomass. Additional sources of electrical noise are still present, and most closely aligned with the change in propeller pitch and speed changes by the ship. This noise is present when using the ship's power, ship's UPS power and even an isolated battery, suggesting to us that the noise is transmitted through the transducer cables on deck and strumming in the water while leading to the towfish. The noise precludes us from interpreting acoustic signals from krill patches deeper than about 200m in most case. When compared to the pole mount on the Zodiac, noise profiles are significantly less and allow for detection of krill greater than 400m depths (Figure 13). Performance of the EK80 system would be significantly improved on the LM Gould with a hull mounted system to reduce system noise and allow for more surveys in ice.

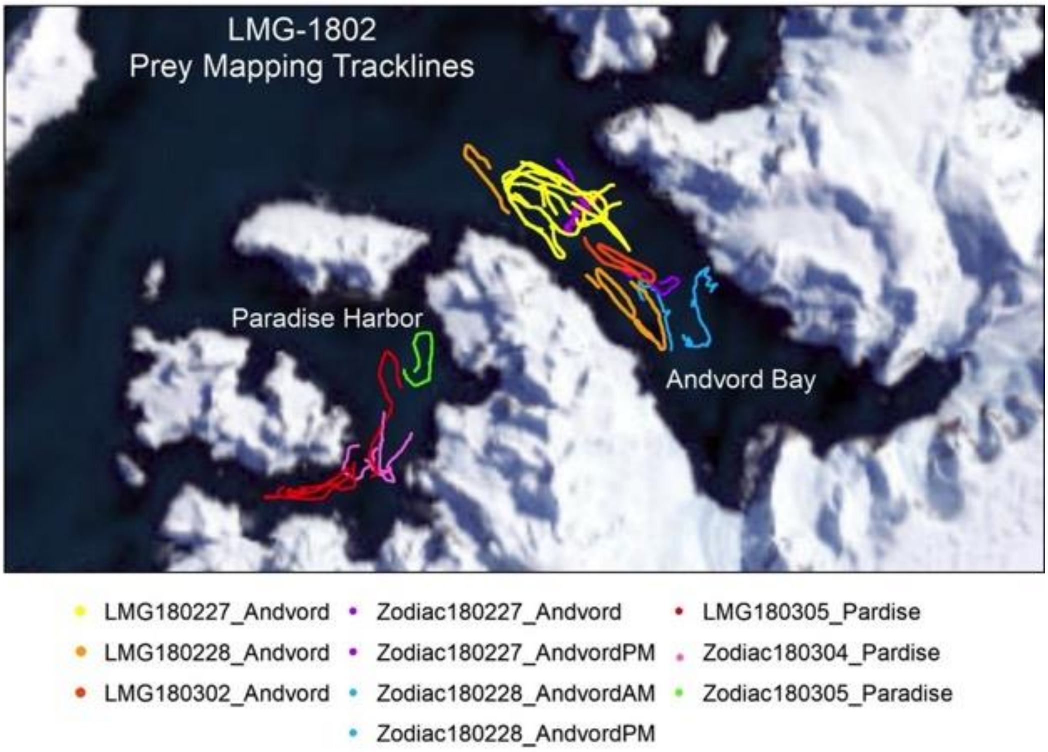

Figure 6 Map of all prey mapping acoustic survey tracklines in Andvord Bay and Paradise Harbor.

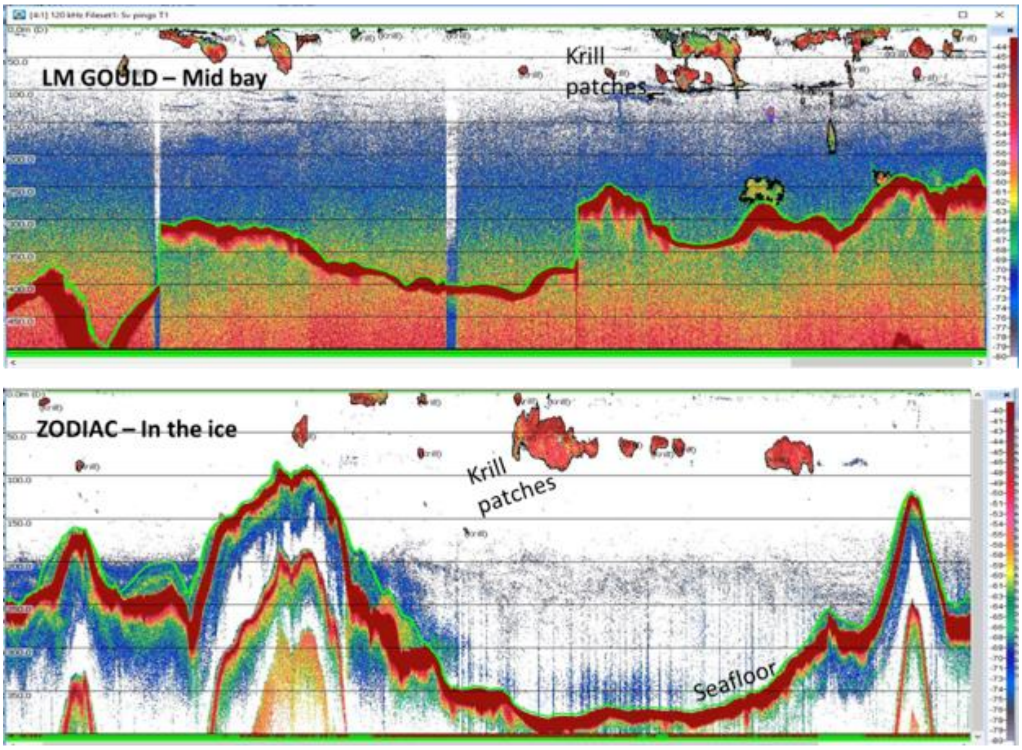

Figure 7 Example echograms from Andvord Bay on 27 February 2018. Note krill patches generally shallower than 100 metres.

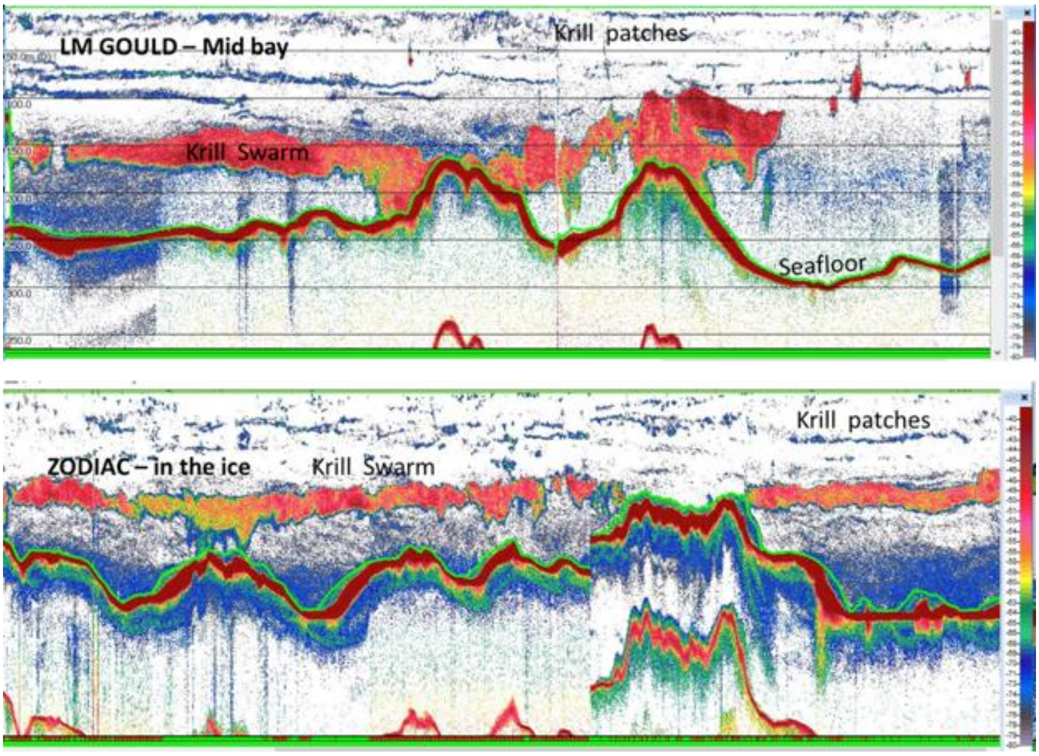

Figure 8 Example echograms from Paradise Harbor surveyed on 5 March 2018. Note large continuous krill swarms of high backscatter (orange-red) between 100-200 metres.

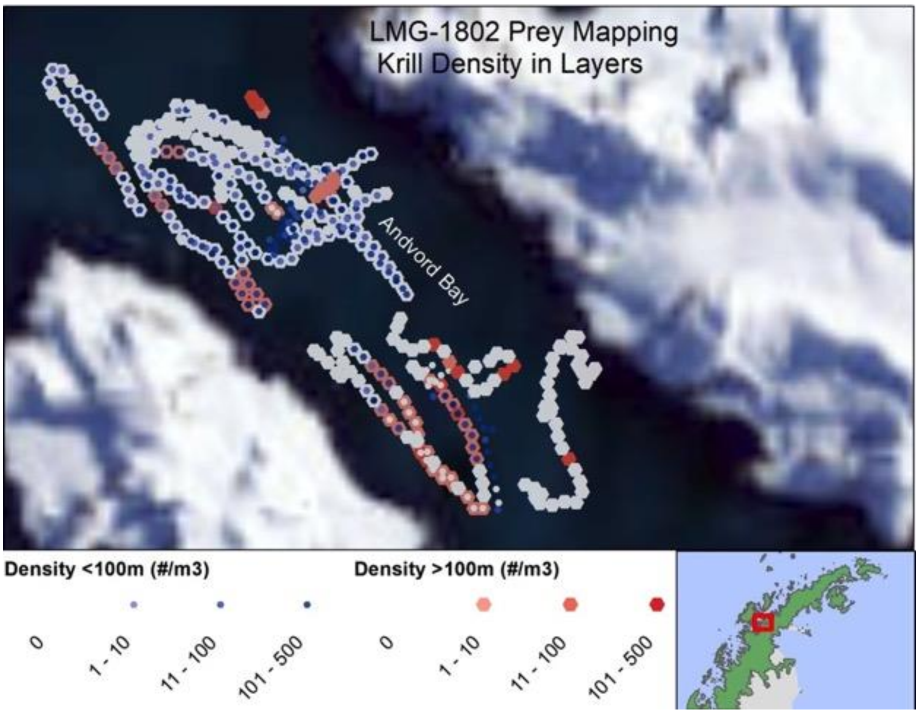

Figure 9 Map of krill patch densities in Andvord Bay (all platforms). Densities are separated by depth layers shallower than 100 m (blue) and deeper than 100m (red). Shallow symbols are smaller to allow view of deeper symbols at same location.

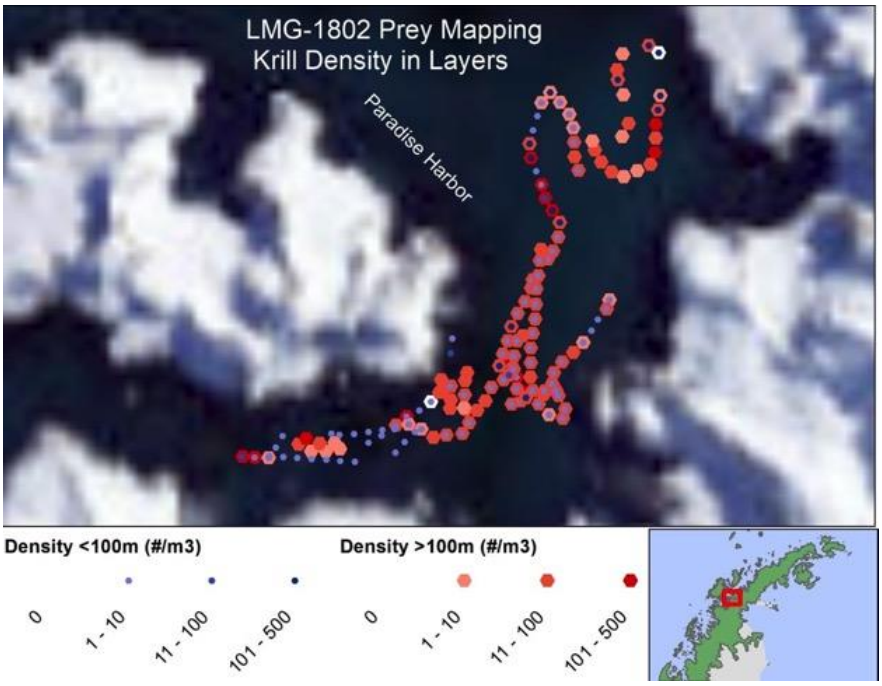

Figure 10 Map of krill patch densities in Paradise Harbor (all platforms). Densities are separated by depth layers shallower than 100 m (blue) and deeper than 100m (red). Shallow symbols are smaller to allow view of deeper symbols at same location. Continuous red marks indicate the large and continuous krill swarms at about 150 metres as shown in Figure 3.

Figure 11 Sample of krill taken on 3 March 2018 in Andvord Bay.

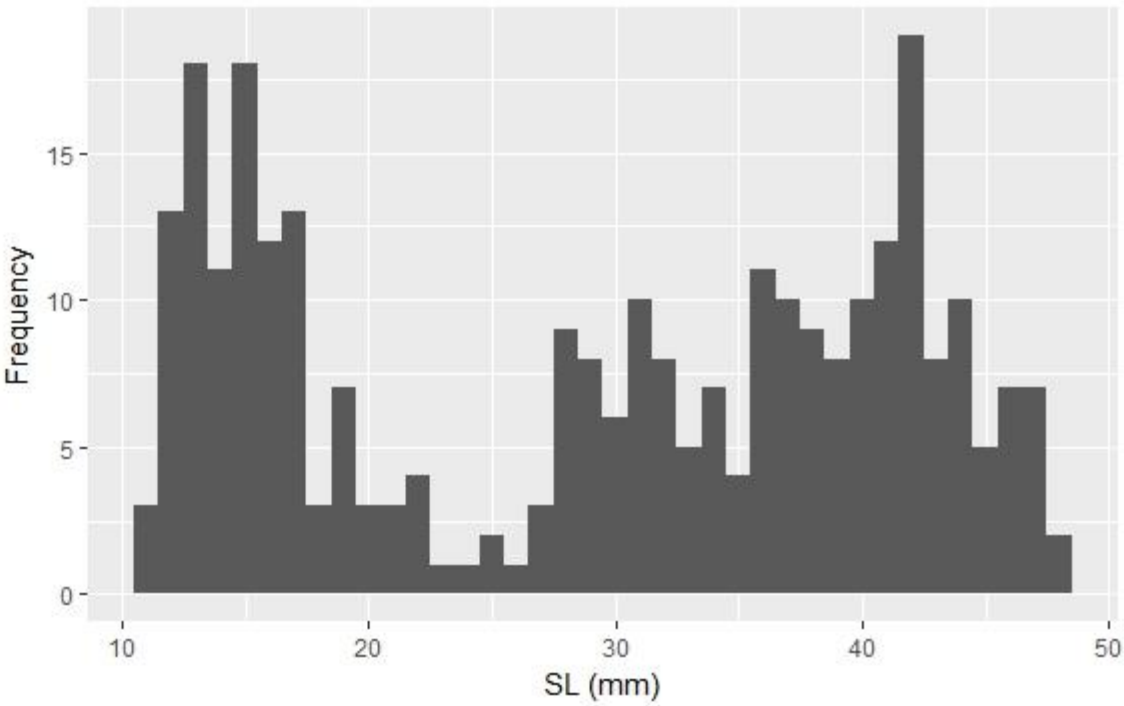

Figure 12 Length frequency of krill sampled from three net tows in Andvord Bay and Paradise Harbor.

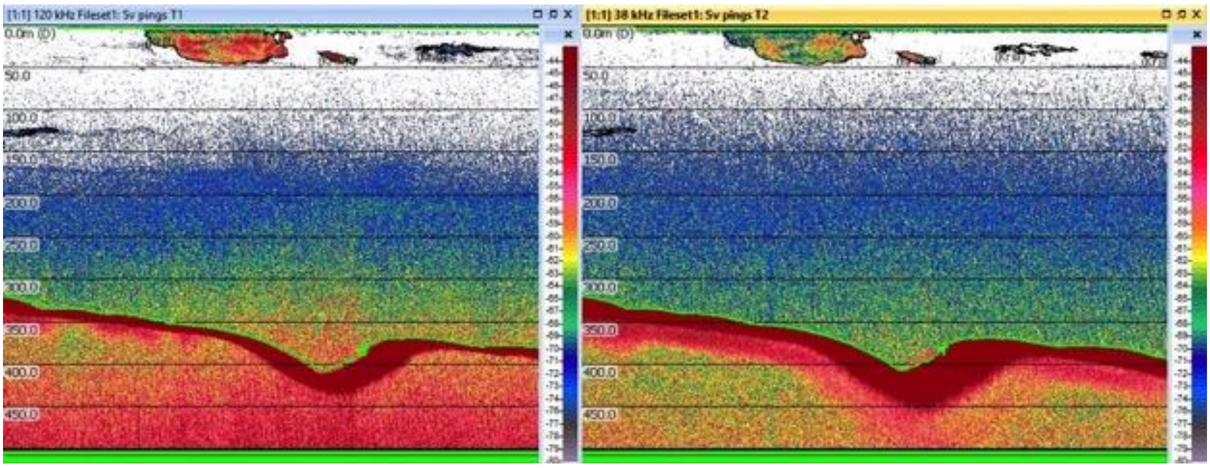

Figure 13 Example noise assessment echograms using Simrad EK80 echosounders on the LM Gould (top) and Zodiac (bottom). The 120 kHz frequency is on the left and 38 kHz frequency is on the right. Backscatter is proportional to color scale with high (red) and low (blue). Krill swarms are shown close to the top of each panel, with stronger red signal in the 120 kHz compared to the 38 kHz. Note the speckles of noise on the LMG echosounder starting around 150 m depth. This level noise is absent in the 38 kHz on the Zodiac and only appears at 250m on the 120 kHz.

Conclusions

We continue to collect and publish new information and push forward our understanding of the ecological role of cetaceans in the Antarctic marine ecosystem and ways to manage the krill fishery in relation to this knowledge. As long-lived animals that range over broad areas and have extraordinary energetic demands, long-term studies are absolutely critical and must be maintained. We are fortunate to have developed a productive and successful research program that has now been given the opportunity to continue for an additional 3 years under our current NSF LTER award, have dedicated NSF ship time to tag and study Antarctic minke whales, and perpetually through our collaboration with OneOcean Expeditions and the Australian Antarctic Division and recent support from the World Wildlife Fund. These partners are critical for providing support through funding for tags and personnel, logistic support, outreach and media coverage, and intellectual capacity. We were able to increase our field time and achieve a greater sample size in terms of tags and biopsy samples in large part because of our collaborative relationship with the AAD and using platforms of opportunity via tour vessels and an award from the ASOC and Hogwarts Running Club this season. By providing personnel, tag, and analytical support, it allowed our project to employ more students and researchers and collect far more data than in years past. The coming year will be extremely fruitful in terms of publishing new information but we will require additional funding from IWC-SORP in order to support all of the personnel required for this. We will also solicit for more international collaboration with partners from South and Central America to build connections to their national Antarctic research programs.

Challenges

The challenges to our research have always been access to animals (e.g. ship-time), resources for tagging whales, and support for personnel to conduct analysis and produce results. These will continue to be challenges. However, we have secured logistic support to gain access to the Antarctic and whales and this limitation is no longer. We have secured funding for suction cup tags and some satellite tags, although the latter are required each year. Lastly, while a number of graduate students and post-docs are now supported by our existing grants, support for the project PI is still required and sought after.

Outlook for the future

We have recently joined the National Science Foundation's Long-Term Ecological Research program as a Principal Investigator. This is a significant award that will provide us with berths on the annual research cruise in January and space at Palmer Station throughout the year (January-March) to conduct dedicated research on cetaceans. Currently we will be supporting two graduate students through this program and will be deploying both satellite-linked tags and short-term suction-cup tags on humpback whales to study their feeding ecology and behaviour in summer months. We have also begun a dedicated molecular genetics program to study the population structure and dynamics of humpback whales that feed in the region. We recently received another NSF award to study the ecological role of Antarctic minke whales and completed an extremely successful field season, and will deploy again next year. This is a significant and substantial program that will yield several important publications on minke whales in the coming years. One more recent advance is our ability to use tour vessels to deploy tags, conduct UAS photogrammetry, and collect biopsy samples. Over the past season we collected a total of ~200 biopsy samples and ~150 individual humpback whale UAS measurements that are currently being analysed by colleagues at Duke University, Murdoch University, and Stanford University. The success of this collaborative effort is clear and evident and we all strongly believe in continuing this partnership for increased field time and tag deployments. Moving forward, we have solidified our relationship with OneOcean Expeditions who have generously offered berths on a number of trips perpetually during Antarctic seasons. As well, we will continue to build our relationship with WWF to help support cetacean research and conservation efforts in the region and turn science into meaningful policy. Lastly, this research program has grown substantially in its international collaboration capacity and ability to support graduate students. Our current collaborators hail from over 10 countries and there are at least 12 graduate students and 4 post-docs utilizing data from this research program.

IWC-SORP sincerely thanks One Ocean Expeditions for their ongoing and invaluable support of this IWC-SORP Theme, as well as WWF-Australia, the Antarctic and Southern Ocean Coalition (ASOC) and the Hogwarts Running Club for their contributions to fieldwork and financial support of tagging and analyses during the 2017/18 season.

Friedlaender and Weinstein also received funding from the IWC-SORP Research Fund in 2017 to assist with analyses of long-term baleen whale dive data to quantify feeding rates. The results of these are detailed in SC/67b/SH18.

Project outputs

Papers

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Goldbogen J, Cade D, Boersma A, Calambokidis J, Kahane-Rapport S, Segre P, Stimpert A, Friedlaender AS (2017) Using digital tags with integrated video and inertial sensors to study moving morphology and associated behavior in large aquatic vertebrates. Anatomical Record. https://doi.org/10.1002/ar.23650

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Social Media

Blog Stats

Direct links to our most popular blog posts:
Steady Hands
Welcome to Minke City
Tagging Days
The full blog can be accessed here: medium.com/in-search-of-minkes
It currently features eight published posts, and will continue to be updated with new content for the remainder of the trip, and periodically over the next year.
Since the beginning of the trip, the blog has received over 1,500 views.

Twitter

The main accounts generating original tweets from our content are:
@MarineUAS
@Goldbogenlab
@mlparkermedia
So far, over 100 tweets have been posted about the trip. Here are a few examples of our most impactful tweets/content:
On Feb 28, @MarineUAS posted this tweet including an aerial photo of humpback whales, which generated 38 retweets and 137 likes.
On March 1, @Goldbogenlab posted this tweet showing video of tagging a minke whale which generated 98 retweets, over 220 likes, and over 5,000 views of the video.
On March 7, @mlparkermedia posted this tweet highlighting a blog post about our field work, which generated 20 retweets, 61 likes, and 275 views of the blog.

@AntarcticReport (which has over 17,5000 followers) has also tweeted some of our content.
On March 8, they tweeted our photo which generated 35 retweets and 87 likes.
On March 6, they tweeted our photo which generated 30 retweets and 88 likes.

It should also be noted that @MarineUAS won the #Tech4Wildlife challenge hosted by @WILDLABSNET by posting about our work in Antarctica.

Instagram

The main accounts generating original Instagram posts using our content are:

@insearchofminkes
@emmahattonlevy
@mlparkermedia
@marine_uas
The official Instagram account for the research group helps drive traffic to our blog site. The account currently has 150 followers and gains new followers each day. One of our most recent photos (of a tagged minke whale) received 50 likes. So far, the #insearchofminkes hashtag has 85 posts. The most popular post received 186 likes and 17 comments.

Media

Documentary films

National Geographic Channel Documentary Series: *Continent 7*

Antarctic Edge: 70° South

- Best in Festival, Princeton Environmental Film Festival 2015
- https://beyondtheice.rutgers.edu/
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BBC: Ocean Giants

World's Biggest Beasts, National Geographic Channel/Smithsonian Networks.

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https://au.news.yahoo.com/a/34998763/watch-incredible-footage-of-what-life-is-like-as-a-whale/#page1
https://www.rte.ie/news/2017/0411/866858-whales/
https://www.facebook.com/wwfaustralia/videos/10156028685408712/
http://news.sky.com/story/tiny-cameras-monitor-humpback-whale-feeding-habits-in-antarctic-10833509
https://phys.org/news/2017-04-whale-cams-reveal-secret-antarctic.html
http://a.msn.com/01/en-au/BBzDwSD?ocid=st
http://news.nationalgeographic.com/2017/04/humpback-whale-pov-video-antarctica-ice-critter-cam/
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https://www.youtube.com/watch?v=us9RGKaOQVI
http://www.themercury.com.au/news/tasmania/underwater-cameras-capture-whale-of-a-time-off-antarctic-peninsula/news-story/37f376677bca4ee01b24f732358ac17a
https://au.news.yahoo.com/a/34998763/watch-incredible-footage-of-what-life-is-like-as-a-whale/#page1
https://www.rte.ie/news/2017/0411/866858-whales/
https://www.facebook.com/wwfaustralia/videos/10156028685408712/
http://news.sky.com/story/tiny-cameras-monitor-humpback-whale-feeding-habits-in-antarctic-10833509
https://phys.org/news/2017-04-whale-cams-reveal-secret-antarctic.html
http://a.msn.com/01/en-au/BBzDwSD?ocid=st
http://www.eglobaltravelmedia.com.au/antarctic-scientific-whale-research-reaches-new-heights-during-popular-expedition-cruise/

Antarctic minke whale diving behaviour

http://news.nationalgeographic.com/news/2014/08/140813-minke-whale-feeding-antarctica-animals-ocean-science/
http://news.sciencemag.org/biology/2014/08/minke-whales-extreme-feeding-habits-observed-first-time
http://www.abc.net.au/news/2014-08-15/scientists-spy-on-antarctic-minke-whales-eating-habits/5673620
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http://phenomena.nationalgeographic.com/2014/08/13/little-giant-whales-take-100-gulps-an-hour/
http://www.delhidailynews.com/news/Tags-reveal-feeding-habits-of-Minkes-1408163342/
http://phys.org/news/2014-08-minke-whales-lunge-hour-sea.html

http://thenewage.co.za/135002-1021-53-Study_reveals_Antarctic_minke_whales_feeding_frenzy
http://technology.iafrica.com/news/954852.html
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http://nicholas.duke.edu/news/minke-whales-lunge-100-times-hour-feed-under-sea-ice
http://www.antarctica.gov.au/news/2014/krill-on-the-menu-for-antarctic-minke-whales-lunge-diet
http://news.stanford.edu/news/2014/august/minke-whales-feeding-081414.html?view=print
http://www.themercury.com.au/news/tasmania/minkes-tracked-going-for-the-krill/story-fnj4f7k1-1227026146584
http://www.dailynewsen.com/science/minke-whales-lunge-100-times-per-hour-to-feed-under-sea-ice-h2548665.html

Antarctic minke whale acoustics

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https://www.sciencenews.org/article/submariners-bio-duck-probably-whale
http://www.bbc.com/news/science-environment-27117669
http://news.sciencemag.org/biology/2014/04/scienceshot-mystery-quacking-caller-antarctic-solved?rss=1
http://www.independent.co.uk/news/science/50year-mystery-of-the-ocean-quack-finally-solved-by-scientists-9277824.html
http://www.zeit.de/wissen/umwelt/2014-04/antarktis-zwergwal-geraeusch-walfang
http://www.fisheries.noaa.gov/podcasts/2014/04/minke_whales.html#.U1e9kqYUC-4
http://news.discovery.com/earth/oceans/mysterious-underwater-sounds-that-have-stumped-scientists-140423.htm
http://phys.org/news/2014-04-mysterious-bio-duck-southern-ocean-minke.html
http://www.huffingtonpost.com/2014/04/23/bio-duck-sound-antarctic-minke-whales_n_5198053.html
http://www.csmonitor.com/Science/2014/0423/Scientists-unravel-mystery-of-bizarre-bio-duck-sound
http://newswatch.nationalgeographic.com/2014/04/23/whales-animals-sounds-bioduck-science-antarctica/
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ANNEX 4 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2017/18

IWC-SORP Theme 4. What is the distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica? Phase 1: East Australia and Oceania

Rochelle Constantine[1], Claire Garrigue[2,3], Dave Paton[4], C. Scott Baker[5], Megan Anderson[6], Claire Bonneville[3], Simon Childerhouse[7], Solène Derville[23], Remi Dodemont[3], Lesley Dougla7[8], Marc Oremus[8], Véronique Pérard[3], Natalie Schmitt[9], Debbie Steel[5], Mike Williamson[3]*

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4. Blue Planet Marine, P.O. Box 919, Jamison Centre, ACT, 2614, Australia
5. Marine Mammal Institution, Oregon State University, 2030 SE Marine Science Drive, Newport, OR 97365, United States
6. Southern Cross University, Lismore, NSW, 2480, Australia
7. Blue Planet Marine, PO Box 3639, Richmond, Tasman 7050, New Zealand
8 WWF BP692, 98845 Nouméa, Nouvelle-Calédonie
9. Australian Marine Mammal Centre, Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7050, Australia

Introduction

There were five research components focused on humpback whale distribution and connectivity throughout the Oceania – east Australia region during the 2017/18 period. This advances our understanding of the linkages between the breeding grounds and feeding grounds of the whales in the western South Pacific. With the east Australian Ei breeding stock close to pre-whaling abundance (IWC 2015), the linkages of these whales to migratory corridors and breeding grounds is being revealed (Gales et al. 2009 SC/61/SH17, Garrigue et al. 2011, Steel et al. 2014 SC/65b/SH07, Steel et al. 2018). The northern migratory corridor past Cook Strait, mainland New Zealand is dominated by whales from New Caledonia and east Australia (Steel et al. 2014 SC/65b/SH07) and increases in these populations is mirrored in the rapid increase in the number of whales reported over a 12 year period in Cook Strait (Gibbs et al. 2017). The completion of the Great Barrier Reef breeding ground biopsy surveys will provide the final missing breeding ground dataset for this region and enable us to answer questions about the connectivity of whales from the Chesterfield-Bellona archipelago, New Caledonia and New Zealand.

We continue to take advantage of opportunistic surveys at the Kermadec Islands to build on the genetic and photo-identification datasets started during our 2015 tagging voyage (Riekkola et al. 2018). The Kermadec Islands are the most diverse region for mixing of whales from Oceania breeding grounds and are an area where song transfer occurs (Owen 2016, Riekkola et al. 2018). Establishing the reproductive status of females once they reach their breeding grounds is an important extension of the 2015 research and will form part of a circum-polar study (led by Logan Pallin and Ari Friedlaender).

Objectives

The focus of the 2017/18 research was:

1) Opportunistic genetic and photo-identification of whales migrating past the Kermadec Islands on their southern migration, led by Rochelle Constantine;
2) A 27th – 31st October 2017 pilot trip to Fiordland, southwest New Zealand to identify the breeding ground origins of whales on their southern migration, led by Rochelle Constantine;
3) A 9th February – 21st March 2018 multi-disciplinary voyage to the Ross Sea region feeding grounds with the whale research, led by Rochelle Constantine;
4) A 7th – 27th August 2017 voyage to the Chesterfield-Bellona archipelago to genetically identify individuals, determine genetic linkages to assess the origin of the whales, led by Claire Garrigue;
5) Surveys from 16th July – 4th August and 3rd September – 22nd September 2017 to the Great Barrier Reef breeding ground complex to genetically profile this breeding stock and determine genetic linkages to Oceania, led by Dave Paton.

Results

Kermadec Islands - migratory corridor

We observed a cumulative total of 29 groups of whales over four days of surveys at Raoul Island. The research was conducted from the NZ Navy rigid hulled inflatable boats during a resupply voyage to the island. A total of 43 whales were photo-identified and sloughed skin samples were collected from 16 individuals. Four whales previously photo-identified at Raoul Island were re-sighted in 2017.

Alongside further matches to known breeding grounds, there was a genotype match to a new location; Hervey Bay, east Australia. A preliminary pairwise comparison for mtDNA haplotype diversity (FST) analysis of the 122 individuals sampled at the Kermadec Islands revealed a similar breeding ground assignment as in 2015 (FST = 0.000 p = 0.746) (Riekkola et al. 2018).

Southern migration – Fiordland, New Zealand

In response to reports of increased sightings of humpback whales during October – November, we undertook a pilot study to collect demographic and genetic data on these whales. We observed a cumulative total of 11 groups of whales over five days of boat-based surveys in Fiordland (Doubtful Sound to Preservation Inlet), southwest New Zealand. We photo-identified six individuals and biopsy sampled six individuals; of these four whales were both biopsy sampled and photo-identified. Preliminary analysis of the photo-identification has revealed no matches to catalogues from New Caledonia, Tonga or Gold Coast (northern and southern migration, east Australia). Assignment of these whales to breeding ground(s) is currently in progress.

Area V feeding grounds – Ross Sea Region

From the ~6,000 nm voyage throughout the Ross Sea region, we undertook a total of 496 hours of dedicated watches over the 31 days spent south of 60°S (14 February – 16 March 2018). We recorded a total of 64 groups of cetaceans representing four species of baleen whale (humpback n = 24, blue n = 2, fin n = 17, minke n = 8, unidentified n = 10) and two species of toothed whale (Type B killer whale n = 2, pilot whale n = 1) (Figure 1). Using the best estimate of group size, there was a cumulative total of 295 individual whales observed, with fin whales the most frequently observed species (n = 17 groups) and with the highest cumulative abundance (n = 122). Fin whales had the largest average group size (mean = 7.2, SD = 10.4, range = 1-40), followed by minke (mean = 3.3, SD = 3.6, range = 1-12) and humpback whales (mean = 2.8, SD = 1.8, range = 1-8).

Due to time constraints from a multi-disciplinary voyage, we were only able to collect tissue biopsy samples and identification photographs from humpback whales where there was dedicated time allocated. We sampled 11 humpback whales for genotyping, breeding ground assignment and aging, including 10 samples with blubber that will be analysed for progesterone concentrations (Pallin et al. in review). We photo-identified 30 individual whales by fluke. These images will be matched to existing catalogues throughout the region and will be deposited with the IWC-SORP Secretariat and the Antarctic Humpback Whale Catalogue curated by the College of the Atlantic.

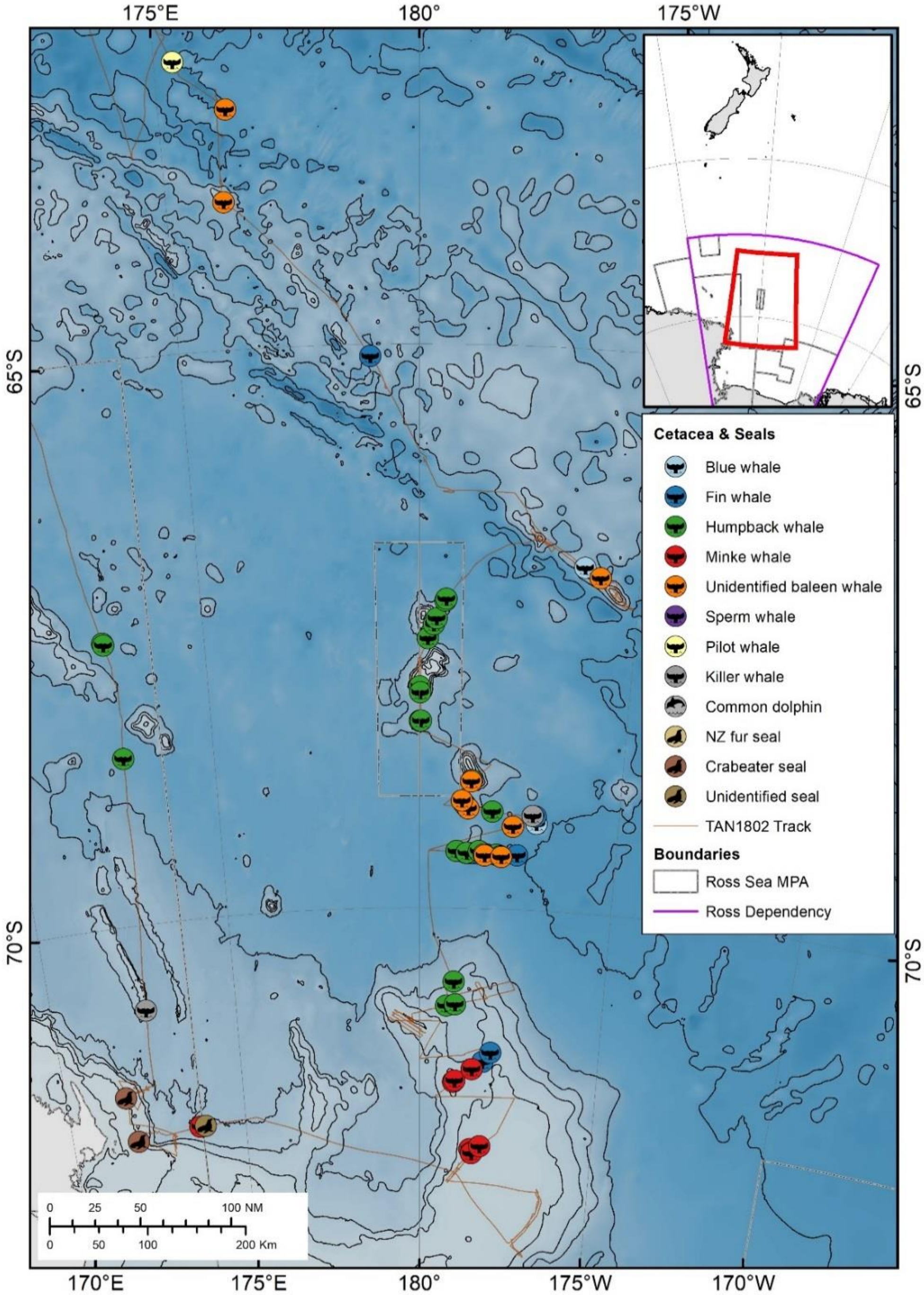

Figure 1 Location of cetacean sightings from the Ross Sea region voyage 9th February to 21st March 2018. The detailed map region is highlighted by the red line in the insert. Map provided by Arne Pallentin, NIWA.

Chesterfield-Bellona Reef complex

The Chesterfield-Bellona archipelago, located west of mainland New Caledonia (Figure 2), has been identified as one of two humpback whale 'hotspots' targeted by 19th century commercial whaling in the South Pacific

(Townsend 1935). Two scientific expeditions conducted in 2002 and 2010, confirmed that humpback whales are still present in the zone (Oremus & Garrigue 2014) but their population of origin is unknown. Determining whether they belong to the New Caledonia endangered sub-stock, to the healthy east Australian stock, or from a largely separate breeding population has implications for their conservation status.

Expedition MARACAS 3 was carried out aboard the *O.V. Alis*, 7-27 August 2017. An at sea survey was conducted over 18 days, totalling more than 175 hours and 2,000 km of effort, including 82 h in Chesterfield, 47 h in Bellona and 18 h on the unsheltered shallow banks located between the two plateaus. In total, 45 pods totalling 63 humpback whales were studied. Adults accounted for 73% of the whales observed, and juveniles and calves represented 6% and 21%, respectively.

Thirty eight individuals were genotyped, including 10 males and 28 females (sex ratio 1:2.8). Ten individuals had previously been observed in the New Caledonian South Lagoon between 1997 and 2017. One genotyped female was previously biopsied in Area V of Antarctica in the summer 2010 in the vicinity of the Balleny Islands (Constantine *et al*., 2014). Twenty haplotypes were identified, 19 of which were already known from New Caledonia. The remaining haplotype derived from one individual that was unknown in New Caledonia and the South Pacific.

This study revealed a connection between the humpback whales encountered in Chesterfield-Bellona archipelago and the New Caledonian South Lagoon breeding sub-stock E2. In order to estimate the potential connection between the Chesterfield-Bellona humpback whales and neighbouring breeding stocks, knowledge of the breeding Great Barrier Reef population is essential. Moreover, a larger sample size from Chesterfield-Bellona would enhance our understanding of the structure of these whales and assist in assessing their conservation status.

A full expedition report is appended to this document (Annex 6) and further results can be found in Garrigue *et al*., SC/67b/SH17.

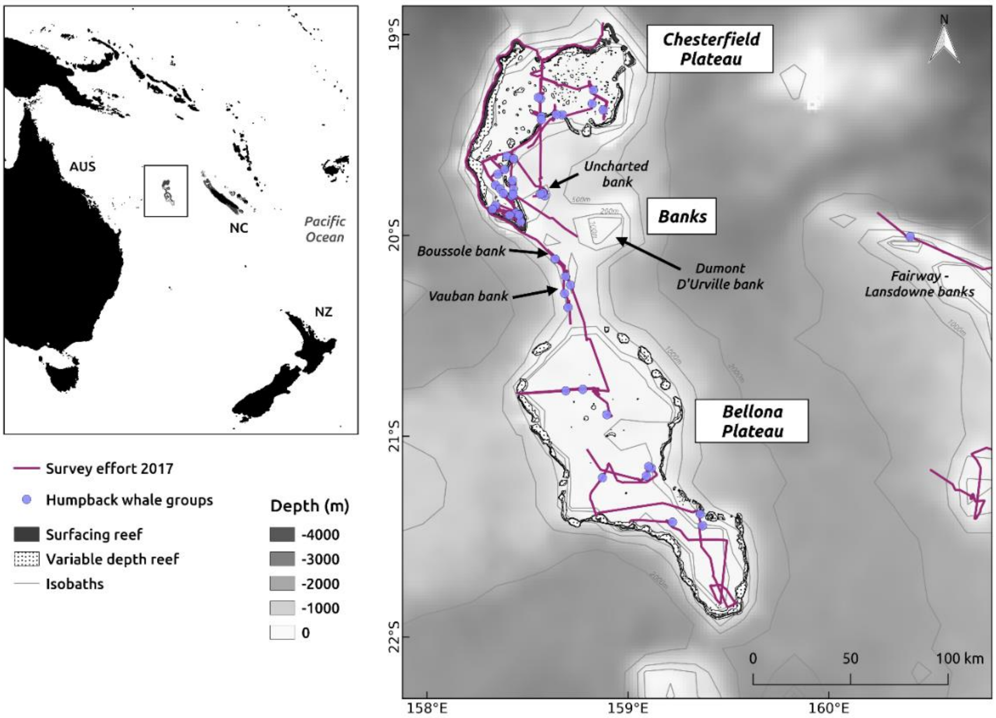

Figure 2 Survey effort and locations of humpback whale sightings during the Maracas 3 expedition n the Chesterfield-Bellona archipelago between 7th and 27th of August 2018. The position of the archipelago is shown by a square between Australia and New Caledonia. Map provided by Solène Derville, IRD.

Great Barrier Reef genetic sampling

Oceania humpback whales are listed as endangered but different sub-populations within the region are showing differing rates of recovery leading to considerable complexity in modelling population status, understanding interchange between sub-populations and migratory pathways. There is an identified gap in that there are no primary genetic samples from the East Australian (E1) breeding ground which is limiting our ability to characterise this population and how it might be interacting with the other sub-populations of Oceania. The collection of genetic samples will allow an insight into the relationship between EA and the New Caledonia breeding ground (E2), which appear to be closely linked, and also aid in the development of improved mixed stock models for whole of Oceania.

Fieldwork was carried out from 16th July – 4th August and 3rd September – 22nd September 2017; a total of 6 weeks of fieldwork conducted during 2017. During this period, 118 pods of humpback whales consisting of 271 (228 adults and 42 calves) individuals were sighted. A total of 31 genetic samples, 66 photo-identifications, 8 h 31 mins of hand deployed acoustic recordings targeting social sounds and singers were collected.

With the addition of the 31 genetic samples collected during 2017, a total of 92 genetic samples have now been collected from the E1 breeding stock within the Great Barrier Reef Marine Park. After obtaining CITES and export/import permits late in 2017, a sub-sample from each has been transferred to the Cetacean Conservation and Genomics Laboratory at Oregon State University for analysis. The remainder of the samples will be transferred to the Australian Marine Mammal Centre for archiving. Preliminary analysis of the E1 samples has been undertaken, with full analysis including population level comparison underway.

Conclusions

The Kermadec Islands are a significant migratory corridor for humpback whales throughout Oceania and for at least some individuals from east Australia. The 2017 data revealed a similar diversity of breeding ground origins for whales migrating past the Kermadecs. There are now resights of whales at the Kermadecs across multiple years, suggesting fidelity to this migratory corridor by some individuals. It remains a logistical challenge to survey the Antarctic waters south of the South Pacific, but it is critical that we ascertain the stock structure, pregnancy rates and environmental variables that affect the distribution of whales. Further tag deployments from Raoul Island may be the best way to understand Antarctic habitat use. The 2018 New Zealand MBIE funded voyage to study the Ross Sea Region MPA enabled basic data collection on all whales encountered, but there was also prey-field mapping that will be used to examine the distribution of all four species of baleen whale we encountered, including humpback whales.

The Fiordland region will now include capacity for New Zealand Department of Conservation rangers to collect tissue biopsy samples from whales as they are encountered during other on-water research. Photo-identification images are incorporated in the New Zealand catalogue (curated by Nadine Bott) and the genetic samples will be included in the South Pacific Whale Research Consortium genetic catalogues. Whilst analysis is not complete, we suspect that theses whales are part of some east Australian whale's southern migration path (Gales et al. 2009). One whale was observed over four days in Dusky Sound and foraging has been observed in this area; so whales may remain for short periods of time either resting or foraging before completing their migration to the Southern Ocean.

The number of whales in the Chesterfield-Bellona archipelago remains low but surveys of this region and of the Great Barrier Reef breeding grounds have provided important information about stock structure and connectivity to neighbouring breeding grounds. The high female to male ratio is of interest and further work will reveal the significance of this area to females. The humpback connectivity project will now expand to include other Antarctic regions and build on the advanced use of tissue biopsy samples to answer questions about age, reproductive status and diet.

The outcomes of the research will allow for an improved understanding of the structure and status and migratory paths and feeding grounds of the Oceania humpback whales, will result in an improved assessment of status, and lead to better conservation and management. Specifically, it would allow the more appropriate allocation of historical catches made in Areas I-VI. This would improve the accuracy of recovery assessments and estimates of pre-whaling abundance.

Challenges

Securing dedicated ship time to the Southern Ocean will always be the greatest challenge. These waters are remote and largely inaccessible. The Ross Sea Region Marine Protected Area has provided a platform in 2018 and limited time in 2019, but demands on understanding other components of the ecosystem limits our ability to collect data on whales in these waters. All remote field stations have similar challenges.

Outlook for the future

The humpback connectivity research has moved into plans for a collaborative circum-polar analysis of whale telemetry data to ascertain broad patterns of movements on the feeding grounds. With a number of multi-year and opportunistic tag deployments, this approach will advance this project beyond the Oceania region. Future research should find innovative ways to study the environmental parameters of importance to these whales on their feeding grounds (Andrews-Goff in prep) and how changes in Southern Ocean productivity might influence these whales in the future. The large genetic and photo-identification databases are valuable, even for small datasets and these must continue to be open access.

IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project. IWC-SORP gratefully acknowledges contributions from Pew Charitable Trusts, the New Zealand Ministry for Business, Innovation and Employment, the New Zealand Department of Conservation, the Australian Antarctic Division, the University of Auckland and the International Fund for Animal Welfare (IFAW). Constantine et al. and Paton et al. were both awarded grants from the IWC-SORP Research Fund in 2017 to support this Theme; see SC/67b/SH18 for more details. Expedition MARACAS 3 is a component of the WHERE Project funded by the New Caledonian Government, the Ministère de la Transition Ecologique et Solidaire, the World Wildlife Fund for Nature, and Opération Cétacés.

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Riekkola et al. (2017) Oral presentation during the Australasian Society the Study of Animal Behaviour Conference, Katoomba, NSW, Australia, July 2016 (**Best student presentation award**).

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ANNEX 5 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2017/18

IWC-SORP Project 5. Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean

The IWC-SORP acoustic trends steering group: Susannah Buchan[1], Ken Findlay[2], Danielle Harris[3], Brian Miller[4], Flore Samaran[5], Ana Širović[6], Kathleen Stafford[7], Ilse Van Opzeeland[8]

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5 ENSTA Bretagne Lab-STICC UMR CNRS 6285, France
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8 Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Executive summary

In 2017/18 the Acoustic Trends Working Group conducted high-level review of the project work completed to date and synthesized an ambitious work plan for the next 3 years of the project. The work plan focuses on continuation and expansion of long-term data collection, and development of novel, efficient, and standardized analysis of acoustic data collected in the Antarctic. Standardized analysis methods will build upon the Library of Annotated recordings that was started in 2016/17. Work on this Annotated Library continued in 2017/18 with the initial Library estimated to be completed by the end of the 2018 calendar year.

In 2017/18, members of the Acoustic Trends Project deployed 3 autonomous recording devices in the Southern Ocean at 3 different recording sites, and the group recovered 2 previously deployed autonomous recorders as planned (data volume from of approximately 18,000 hours of underwater sound). Group members have also deployed a number of autonomous recorders at low and mid-latitudes in the Indian, Atlantic, and Pacific oceans, and the data from these instruments are expected to value-add and supplement those from the Southern Ocean Hydrophone Network.

In 2017/18, the group produced four peer reviewed papers, four conference presentations, three manuscripts submitted to the scientific committee of the IWC, and presently has numerous manuscripts that have been submitted to journals and are under peer review.

The steering group of the Acoustic Trends Project has continued to forge strong links with other IWC-SORP and international programs. In December 2017 the IWC-SORP Acoustic Trends Working Group became a Capability Working Group of the Southern Ocean Observing System (SOOS), and presented our work to members of the International Quiet Ocean Experiment (IQOE). This marks the first official joint IWC-SORP/SOOS working group. Additionally, in 2017/18 the group provided advice to colleagues from Norway and New Zealand regarding upcoming deployments of moored acoustic recorders around Antarctica.

Introduction

Passive acoustic monitoring is a robust means of monitoring blue and fin whales in remote areas, such as the Southern Ocean, over long time periods. The analysis of data sets that are available to date (including those collected specifically for this project) has revealed insight into the geographic and seasonal occurrence of blue and fin whales around the Antarctic and throughout the southern ocean e.g. (Buchan et al., 2017; Leroy et al., 2016; Samaran et al., 2013; Shabangu et al., 2017; Širović et al., 2004, 2009; Thomisch et al., 2016)However, the lack of concurrent spatial and temporal overlap in monitoring, and the differences between instruments and analysis methods used, underlines the need for coordinated efforts when using passive acoustic data to monitor trends in abundance. To best utilize passive acoustic data in the long term, the placement and maintenance of a circumpolar Antarctic monitoring system named the Southern Ocean Hydrophone Network (SOHN) was proposed by the IWC-SORP Acoustic Trends Steering Group (Opzeeland et al., 2013).

Objectives

The Blue and Fin Whale Acoustic Trends Project aims to implement a long term acoustic research program that will examine trends in Southern Ocean blue and fin whale population growth, distribution, and seasonal presence through the use of passive acoustic monitoring techniques. The achievement of this program requires a coordinated multinational effort to collect long-term acoustic data throughout the Southern Ocean and the development of novel automated methods for systematically and robustly analyzing large acoustic data sets. The Steering Group of the Acoustic Trends Project works towards these objectives by coordinating international capacity to collect data, conduct analyses, and develop novel and efficient methods for analyzing data and interpreting results.

Specific objectives for 2017/18 were continued data collection at long-term SOHN sites; increased spatial coverage and number of recording stations for the hydrophone network; continued development and implementation of an annotated library of underwater recordings; continued analysis of existing data; and the development and implementation of a new 3-year strategic plan focused on a new standardized analysis framework.

Results

Steering Group Meeting: 2017

A meeting of the working group of the SORP Acoustic Trends Project was held from 5-8 May 2017 in Bled, Slovenia. Details on this meeting can be found in the meeting report (submitted to IWC-SC/67a). The meeting was funded by IWC-SORP with further funding from IWC, AAD, ENSTA-Bretagne, and Europole Mer. At this meeting the working group:

- Conducted a brief high-level review of the project work completed to date.
- Identified gaps in existing data collection efforts and developed a new plan to expand the data collection of Southern Ocean Hydrophone Network (SOHN).
- Identified a need for additional coupled behavioural and acoustic studies to enable a more robust interpretation of acoustic data.
- Developed a new framework for standardised analysis of long-term Antarctic acoustic recordings, with a view towards development of call density and animal abundance estimates.
- Synthesized a forward-looking work plan for the next 3 years for the Acoustic Trends Project implementing the above work.

Annotated library of acoustic detections

In late 2016 The SORP Acoustic Trends Steering Group was awarded a grant of £22,000 from the IWC-SORP Research Fund for the creation of an annotated library of acoustic detections. Several intercessional meetings of the steering group were held to discuss the implementation of this library, and annotation of acoustic data from four circumpolar sites is presently underway. Annotations of data is expected to continue until mid-2018. Details of planned and completed work can be found in the Annotated Library Progress Report (SC/67b/SH18).

Antarctic data collection (>60°S)/Southern Ocean Hydrophone Network: 2017/18

In 2016/17, members of the Acoustic Trends Project deployed serviced 2 annual recording stations, commenced data collection at 1 new long-term recording site, and with data collection continuing from 17 multi-year recording sites. . The data volume from all instruments recovered in 2018 totaled approximately 18,000 hours of underwater recordings.

The Australian Antarctic Division recovered and replaced two moored acoustic recorders at its two long-term recording sites in East Antarctica (along resupply routes to Casey and Mawson stations).

ENSTA Bretagne in collaboration with the Australian Antarctic Division deployed a moored acoustic recorder at a new long-term recording site along the resupply route to Dumont D’Urville Station.

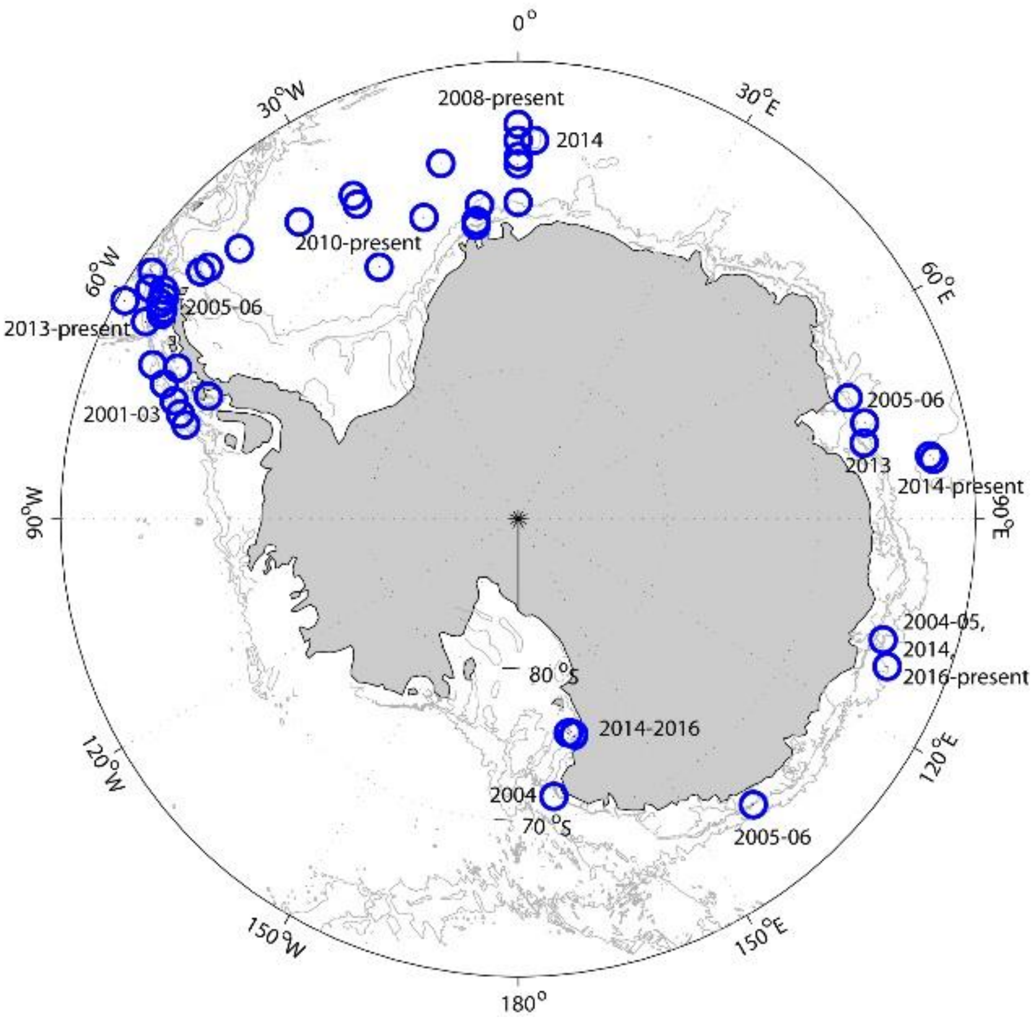

Figure 1 Passive acoustic data collected south of 60° S from 2001-2016. Figure produced during 2017 Acoustic Trends Working Group Meeting.

In collaboration between Scripps Institution of Oceanography and Fundación Cethus, a High-frequency Acoustic Recording Package was deployed in January 2017 near Elephant Island (60° 52.136'S, 56° 00.628'W). Efforts were made to recover the HARP during the 2018 voyage of the vessel "Tango", but after numerous attempts to release it the operation had to be abandoned without success. For more details on this collaboration and details on the analysis of occurrence of D calls from three years of recordings see report submitted by Reyes Reyes et al. to this meeting.

The Alfred-Wegener Institute will recover the 17 Sonovault recorders that were deployed in 2016/17 (in 13 moorings) in the Atlantic section of the Southern Ocean during the 2018/19 Polarstern cruise.

Low-latitude data collection (<60°S) 2017/18

Group members have also deployed a number of autonomous recorders at low and mid-latitudes in the Indian, Atlantic, and Pacific oceans, and the data from these instruments are expected to value-add and supplement those from the Southern Ocean Hydrophone Network.

- An AAD moored acoustic recorder was deployed at 53°00' S, and 076°09'E (off Heard Island) in cooperation with Austral Fisheries, FV Atlas Cove. It is expected to record from Sep 2017 – Jun 2018.
- An AURAL was deployed at 46°32'S, and 051°30E' (off Crozet Island). It is expected to record from Jan 2018 – Jan 2019.

Conclusions

Through the many varied contributions of the steering group and working group members, the progress of the project has continued at an increasing pace. Data collection has continued via the SOHN, and the spatial coverage and number of sampling sites is increasing.

Analysis of recent and historical data by the group have yielded new insights into the distribution, habitat, and trends in the calls of blue whales. Method development, such as (1) the evaluation of the performance of manual and automated detectors and (2) novel density estimation approaches that may be used for Antarctic deployments, has also continued. Several intercessional meetings of the steering group were held throughout the year, and these have helped with coordination of effort, dissemination of recent results, and have increased the responsiveness and agility of the steering group and the project.

The steering group has maintained and continued to forge strong links with other IWC-SORP and international programs such as the steering committee of the IQOE (International Quiet Ocean Experiment). The IWC-SORP Acoustic Trends Working Group is now also a Capability Working Group for the SCAR/SCOR Southern Ocean Observing System (SOOS). The group is also consulting with voyage planners and providing advice on acoustic data collection and opportunities for several Antarctic voyages that will take place in 2019 (e.g. IWC-SORP Voyage 2019, SC/67b/SH07; CCAMLR Krill 2019; WHALE:SWIM 2018/19 voyages; NIWA Tangaroa 2019)

Challenges

As in previous years, the steering group has overcome many challenges in 2017/18, however many still remain. The demand for data from acoustic recorders and opportunity to deploy instruments continues to outstrip the supply capability of the group. Additionally, the location and density of SOHN recording sites is still concentrated in the Atlantic sector, and has not yet achieved the desired density of circumpolar coverage in the Pacific and southwest Indian sectors of the Southern Ocean. IWC management areas I and VI have no recording sites, and area III only has recording sites in close proximity to adjacent recording sites in area II. Thus, the development of recording sites in IWC management areas I, III and VI should remain as high-priority areas for expansion of the SOHN.

The opportunity to collect a wider variety of calls from more diverse species also poses a challenge to the analysis capacity of the group. While the group has made excellent progress on acoustic trends of Antarctic blue whale song, trends in D-calls, and trends in the calls produced by fin whales remain an ongoing challenge. Furthermore, some instruments that are presently deployed can provide additional recording bandwidth and durations that enable detection of calls and thus investigation of acoustic trends for Antarctic minke whales, humpback whales, sei whales, Antarctic pinnipeds, and large toothed whales such as sperm whales and killer whales. Expansion of the analysis capacity of the group will be required if the scope of the project is expanded to include these additional species.

Outlook for the future

As per the strategic plan 2017-2020: The project will not only continue to expand spatial and temporal coverage of data collection, but also focus on improving data collection with a view towards testing links among acoustical, biological, and ecological trends. Testing these links will likely require dedicated ship time to deploy acoustic recording tags on animals, and/or a combined visual and acoustic survey. However, such studies could add tremendous value to the long-term data collected by the moored acoustic recorders of the SOHN.

A new analysis framework has been designed and agreed upon, its implementation is expected to occur over the next three years. This new analysis framework will be more general and less proscriptive than the group's previous vision for a 'Blueprint of Analysis Methods'. However, the new analysis framework affords more flexibility, which is required to address the wide variety of instruments, duty cycles, sites, and detection algorithms that contribute data to this project**. Implementation of this framework will require additional resources, ideally in the form of a 2-year postdoctoral researcher**. Funding for such a position has been sought from the IWC-SORP Research Fund and Universidad de Concepcion, with supervision and in-kind contributions provided by the project steering group.

The new analysis framework requires and will build upon the Annotated Library of Recordings. Work on the Annotated Library will be ongoing throughout 2017/18 with the aim of creating a fit-for-purpose tool to assess the performance of automated detection algorithms for blue and fin whale calls across a wide variety of recordings made in different years, locations, and using different instruments.

Project outputs

Papers

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ANNEX 6 - FIELD WORK REPORT FOR THE 2017 HUMPBACK WHALE EXPEDITION IN THE CHESTERFIELD-BELLONA ARCHIPELAGO: MARACAS (APPENDIX TO IWC-SORP Project 4. What is the distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica? Phase 1: East Australia and Oceania)

Fieldwork report for the 2017 humpback whale expedition in the Chesterfield-Bellona archipelago: MARACAS

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Citation

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SUMMARY

The expedition MARACAS 3 is part of the WHERE project. It was carried out on the *O.V. Alis* from August 7th to August 27th, 2017. The survey at sea was conducted over 18 days, totalising more than 175 hours and 2,000 km of effort, including 82 h in Chesterfield, 47 h in Bellona and 18 h on the unsheltered shallow banks located between the two plateaus. In total, 45 pods totalising 63 humpback whales were studied. Thirty eight individuals were genotyped, of which ten had previously been observed in the New Caledonian South Lagoon. Twenty haplotypes were identified, all of which being already known from New Caledonia with the exception of one that has never been encountered in the South Pacific studies to date.

This study reveals a connexion between the humpback whales encountered in Chesterfield-Bellona archipelago and the New Caledonian South Lagoon breeding sub-stock E2. In order to estimate the potential connexion between the Chesterfield-Bellona humpback whales and neighbouring breeding stocks, knowledge on the breeding Great Barrier Reef population is essential.

Finally, a larger sample size from Chesterfield-Bellona would benefit to the understanding of the structure of these whales in order to enforce their conservation status.

BACKGROUND AND OBJECTIVES

In April 2014, the government of New Caledonia created the Natural Park of the Coral Sea which covers 1.3 million km2, equivalent to 95% of New Caledonian waters and 12.7% of the French maritime space. It includes 55% of the New Caledonian coral reefs. This decision was taken in concert with Australia, as an international effort following a recent trend in marine conservation which aims at protecting both coastal and pelagic ecosystems within giant Marine Protected Areas (giant MPAs; http://bigoceanmanagers.org/). (0). One of the main objectives identified in the management plan for the park is to create a network of Marine Protected Areas (MPA) to control human activities within the park

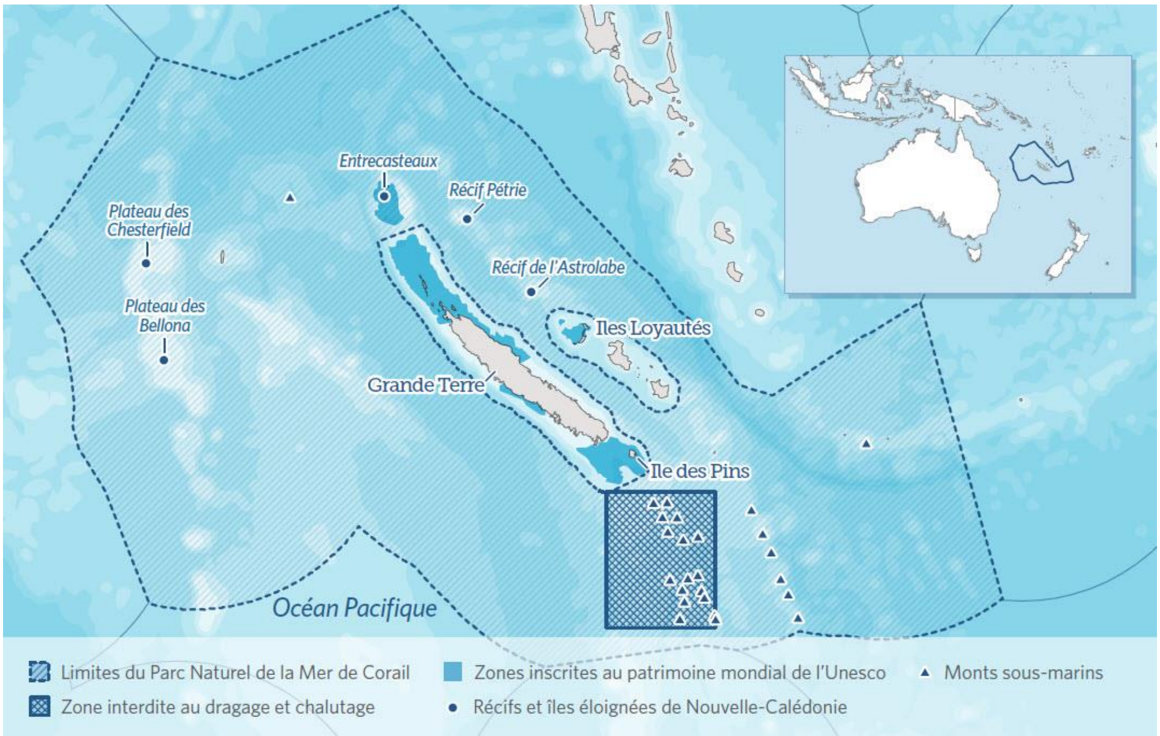

Figure 1 Natural park of the Coral Sea (The Pew Charitable Trust)

Describing preferential habitats and predicting the spatial range of species are key steps towards the management of protected areas and the conservation of endangered species. Yet, the current knowledge of the ecology and habitats of marine mammals within the Coral Sea is limited.

For the past twenty years, studies on marine mammals in New Caledonia have focused on territorial and provincial waters. The data collected during this period has led to the estimation of relative species richness (Garrigue 2007) and abundance of some emblematic species (Oremus et al. 2009, Constantine et al. 2012, Cleguer 2015). The data collected in oceanic habitats of the EEZ are more recent and sparsely distributed. For the most part, they correspond to the REMMOA aerial survey conducted in November-December 2014 (Van Canneyt et al. 2015). For technical reasons, this campaign did not cover the whole EEZ: remote areas such as the Chesterfield-Bellona reef complex were not included. Moreover, this campaign was limited to the end of the austral spring and therefore couldn't account for all species likely to inhabit the EEZ at a given stage of their biological cycle (feeding, reproduction, migration etc.). For instance, migrating species of Mysticetes only present in tropical waters during the austral winter and were not observed during these surveys.

Among these great migrating cetaceans, humpback whales are particularly interesting case-studies. Depleted severely by commercial whaling during the 20th century (more than 210,000 whales taken in the Southern hemisphere between 1904 and 1972; (Baker & Clapham 2002), the species currently reaches a fraction of its initial population size. In Oceania, humpback whales were one of the main targets of whalers since the 19th century. Despite the ban on whaling in 1963, the URSS continued its illegal whaling activities until 1973 (equivalent to about 70,000 individuals). Since then, humpback whale populations have been slowly recovering. Most stocks are now increasing and the species has been recently reclassified from “vulnerable” to “least concern” in the IUCN Red List, with the exception of the Arabian Sea and Oceania populations which are still considered as endangered due to their low to null rate of increase (Childerhouse et al. 2009). Indeed, in the South Pacific the recovery rate varies greatly between stocks: it reaches 10.6% per year on the Australian East coast (Noad et al. 2011) against 5% in the Oceania sub-populations including French Polynesia, Tonga and New Caledonia (Constantine et al. 2012). The recent reconstruction model developed under the IWC show that Oceania sub-population represent less than 50% of the pre-exploitation stock(Jackson et al. 2015).

The Chesterfield-Bellona archipelago located West of New Caledonia mainland has been identified as one the two hotspots targeted by 19th century commercial whaling of humpback whales in the South Pacific(Townsend 1935). Also, two scientific missions conducted in 2002 and 2010 have confirmed that whales are still present in the zone (Oremus & Garrigue 2014)but their population of origin is unknown. Whether they belong to the New Caledonia endangered sub-stock, to the healthy East Australian one or form a largely separate breeding population would completely change their conservation status.

This is why we launched the project WHERE: “Humpback **W**hale **H**abitat **E**xploration to improve spatial management in the natural park of the Co**R**al S**e**a” to collect essential data on the spatial ecology of humpback whales’ distribution at a large scale to set up appropriate measures of management for these species. Our project is based on a multidisciplinary approach combining molecular ecology, bioacoustics, satellite telemetry, and statistical spatial modelling. We plan to conduct some scientific expeditions in various remote study sites scattered within the New Caledonian Exclusive Economic Zone (EEZ) to collect data allowing individual identification of humpback whales (using photo-identification and genotype) and to deploy satellite tags and acoustic recording equipment. The expected results will allow the estimation of the distribution, preferential habitats and movements of humpback whales at a large scale, and to evaluate the connectivity within the EEZ and with neighbouring reproductive stocks.

The objectives of the project WHERE are listed as follows:

1. Estimate the distribution of humpback whales in the EEZ through the description of preferential habitats and their use. Results will allow the identification of different “hotspots” within the park and the level of protection required for each of them.
2. Evaluate the connectivity within the EEZ and between the EEZ and neighbouring breeding regions of the South Pacific. Results will allow the identification of the breeding stocks from which humpback whales of the Coral Sea originate and will help adapt management to the conservation status of these specific populations.

3. Identify the migratory routes used by humpback whales in New Caledonian waters. Results will inform managers for the conception of a MPA network efficiently protecting migrating marine mammals.
4. Collect baseline data on the distribution of other cetaceans in the EEZ. Results will allow a better knowledge of data-deficient cetacean species and will be included in future discussions surrounding MPA design in the EEZ.

This report presents the preliminary result of the second expedition conducted in the Chesterfield-Bellona archipelago in 2017 to collect data on humpback whale. It focuses on genetic data collected as part of the IWC-SORP project entitled "**Who are the real East Australian (E1) breeding group of humpback whales? Genetic characterisation of E1 and the influence of E1 across Oceania**" under the commitment of Dr Dave Paton from the Blue Planet Marine

METHODS

Data collection

Oceanographic vessel *O.V. Alis* was used for the expedition as well as its semi-inflatable boat (0).

Figure 1 *N.O. Alis* and semi-inflatable used for for MARACAS 3.

The geographical position of cetacean group encounters was recorded on line transects from O.V. Alis and during focal follows from the semi-inflatable boat. Data collected during focal follow are:

- Date ;
- Time and geographic location in latitude and longitude of beginning of encounter using a GPS (WGS84) ;
- Social group type (single, group of two, group of three or more, mother with calf, mother with calf and escort, competitive group, mother with calf in competitive group, unknown);
- Group composition (number of individuals, size and social category of each individual; 0);
- Behaviour ;
- Time and geographic location in latitude and longitude of the end of encounter;

Size was estimated as follow: adult, juvenile or calf.

Table 1 Social category used.

Social category	Description
Single	Solitary animal
Singer	Adult male observed singing
Member of a group of two	One animal in a pair of adults

Member of a group of 3 or more	One adult in a group or 3 or more
Mother	One adult accompanied with an animal of no more than 1/3 of its length and in close proximity
Calf	Animal of small size (less than a third the size of an adult) and always found in close proximity with an adult (the mother)
Yearling	Medium sized animal (less than half the size of an adult) usually found with an adult; this individual was born in the previous breeding season
Solitary escort of a female with calf	Adult whale following a mother with calf
Principal escort	Adult whale found at the lead position of a competitive group, considered to have the best chances of breeding with the female on this occasion
Challenger	Adult challenging the principal escort
Secondary escort	All adult whales which are part of a competitive group but are neither the principal escort nor the challenger
Nuclear animal	Adult whale at the front of a competitive group and followed by other individuals in this group. This is likely to be a female. However this category is not necessary represented in a competitive group.
Unknown member of a competitive group	Adult whale found in a competitive group but which status in this group could not be estimated
Unknown	Individual which social status could not be estimated

Photos were collected on each individual when possible using a digital CANON 40D and 50D with 100 X 400 mm and 100 X 200 mm lenses. Photo-identification was collected using the underside of the fluke (Katona et al. 1979) but dorsal fins photographs were also compared within the survey in order to distinguish individuals and evaluate potential resights of whales that did not show the underside of their caudal. Ultimately, these comparisons allowed the estimation of the number of different individuals encountered.

Whenever possible, skin samples were collected using a crossbow (Lambertsen 1987) or a modified 0.22 calibre capture veterinary rifle ©paxarm (Krützen 2002). When surface activity occurred, sloughed skin was collected at the water surface instead.

Five deployments of an autonomous acoustic recorder "SoundTrap 3000" were conducted in order to record song of adult males at different locations within the Chesterfield-Bellona archipelago.
The people involved in this project are listed in 0.

Table 2 People involved for the expedition MARACAS 3 or for the data analysis.

Name	Fonction, organisations
Claire Garrigue	Principal investigator, IRD
Claire Bonneville	Biologist, Opération Cétacés
Solène Derville	Biologist, IRD
Rémi Dodémont	Skipper, Opération Cétacés
Sylvain Dromzee	Biologist, IRD
Véronique Pérard	Skipper, Opération Cétacés
Marc Oremus	Biologist, WWF France
Mike Williamson	Biologist, Opération Cétacés

Genetic analysis

Molecular biology analysis (DNA extraction, molecular sexing, d-loop amplification, microsatellite amplification, and mtDNA sequencing) were performed at the Plateforme du Vivant (IRD, Nouméa, New Caledonia). Microsatellite genotyping and alleles definition were conducted at the CCGL (Cetacean Conservation Genomic Laboratory) of the Marine Mammal Institute (Oregon State University).

A total of 38 biopsies from different individuals sampled in Chesterfield-Bellona area in 2016 and 2017 were analysed. Population structure were performed with the available dataset from the New Caledonian South Lagoon study site, using microsatellites genotypes (N= 810) and mitochondrial control region haplotypes (N= 767). Regional differentiations were estimated using the additional dataset from Eden and Tasmania (Schmitt et al. 2014), consisting in 129 microsatellite genotypes and 96 mitochondrial control region haplotypes.

DNA extraction and molecular sexing

DNA was extracted from biopsy samples with Proteinase K digestion followed by Phenol/Chloroform/Isoamyl alcohol protocol (Sambrook et al. 1989) adapted to small samples (Baker et al. 1993). DNA was subsequently quantified with a Nanodrop 2000 (ThermoScientific). Individual's gender was determined using molecular sexing methods adapted from (Garrigue et al. 2004). Zfx/Zfy and SRY genes were simultaneously amplified with primers P15-EZ – P23EZ (Aesen & Medrano 1990) and Y53-3c – Y53-3d (Gilson & Syvanen 1998). PCR amplification were carried out in a 10 µL containing 1X PCR Buffer, 2.5 mM MgCl2, 0.2 mM dNTP, 0.4 mM of each primer, 0.025 U Platinum Taq DNA Polymerase (Invitrogen by Thermo Fisher Scientific) and approximately 2 ng of genomic DNA. Temperature profiles consisted of initial denaturation at 94 °C for 10 min, followed by 35 cycles denaturation at 94 °C for 45 sec, primer annealing at 60 °C for 45 sec and polymerase extension at 72 °C for 1 min and a final extension at 72 °C for 10 min. Results of molecular sexing were visualized on 2% agarose gel coloured by Midori Green Advance DNA Stain.

Microsatellite genotyping

Samples were genotyped at 16 previously published microsatellite loci proven to be polymorphic for this species (0). Amplifications were carried out in a 15 µL containing 1X PCR Buffer, 0.2 mM dNTP, 0.4 mM of each primer, 0,025 U Platinum Taq DNA Polymerase Polymerase (Invitrogen by Thermo Fisher Scientific) and approximately 2 ng of genomic DNA. Concentration in MgCl2 and thermal cycles varied between loci and are shown in 0. Four multiplex preparations were used, with co-loading sets of loci that presented no overlapping alleles and/or were labelized differently[5]. An ABI 3730 xl sequencer (Applied Biosystems) with formamide and 500 LIZTM size standard (Applied Biosystems) was used for genotyping. A subset of samples (4 to 6 known individuals) were added to each tray to be used as reference in order to calibrate the size of the alleles. The software GENEMAPPER V3.7. (Applied Biosystems) has been used to size allele: peaks were visually assessed and bins were manually checked. Samples with fewer than 12 microsatellite loci were removed from analysis. The program CERVUS (Kalinowski et al. 2007, Oremus et al. 2007) was used to find replicated genotypes between the Chesterfield-Bellona archipelago and New Caledonia South Lagoon individuals genotyped between 1995 and 2012. CERVUS provided exact matches, and fuzzy matches considering genotyping or alleles sizing errors. The electropherograms of the mismatching loci were then reviewed and either corrected or repeated. Because of some incomplete genotypes, we required a minimum overlap of 8 loci to identify replicated genotypes.

Microsatellite loci used for individual genotyping.

Locus	Label	Source	[Mg] (mM)	Thermal cycle
464/465	FAM	Schloterrer et al, 1991	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
Ev1	NED	Valsecchi & Amos, 1996	4	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
Ev14	VIC	Valsecchi & Amos, 1996	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
Ev21	FAM	Valsecchi & Amos, 1997	1,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
Ev37	NED	Valsecchi & Amos, 1996	3,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'

[5]Multiplex 1 (Ev21, Ev104, Ev94, rw4-10, Ev1), Multiplex 2 (GT211, rw48, GT575, GATA28, GT23), Multiplex 3 (rw31, Ev96, GATA417, Ev37, Ev14), Multiplex 4 (464/465)

Ev94	FAM	Valsecchi & Amos, 1996	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
Ev96	FAM	Valsecchi & Amos, 1996	1,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
Ev104	FAM	Valsecchi & Amos, 1997	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
GATA28	NED	Palsbøll et al. 1997	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
GATA417	FAM	Palsbøll et al. 1997	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
GT211	FAM	Bérubé et al. 2000	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
GT23	VIC	Bérubé et al. 2000	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
GT575	FAM	Bérubé et al. 2000	1,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
rw31	FAM	Waldick et al. 1999	1,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 40'') x 35 ; 72 °C for 30'
rw4-10	VIC	Waldick et al. 1999	3	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'
rw48	NED	Waldick et al. 1999	2,5	94 °C for 3' ; (94 °C for 30'', 50 °C for 30'', 72 °C for 30'') x 35 ; 72 °C for 10'

Mitochondrial control region DNA sequencing

Haplotypes of individuals sampled in the Chesterfield-Bellona archipelago were obtained by sequencing 800 bp of mitochondrial control region DNA with primers M13Dlp1.5 (tPro Whale, 5'-TGT AAA ACG ACA GCC AGT TCA CCC AAA GCT GRA RTT CTA-3') and Dlp8G (5'-GGA GTA CTA TGT CCT GTA ACC A-3')(Garrigue et al. 2004). PCR amplification was carried out in 25 µL containing 1 X PCR Buffer, 2.5 mM $MgCl_2$, 0.2 mM dNTP, 0.4 mM each primers, 0.025 U Platinum Taq DNA Polymerase (Invitrogen by Thermo Fisher Scientific) and approximately 2 ng of genomic DNA. Temperature profiles consisted of initial denaturation at 94 °C for 2 min followed by 35 cycles denaturation at 94 °C for 30 sec, primer annealing at 55 °C for 40 sec and polymerase extension at 72 °C for 40 sec and a final extension at 72 °C for 10 min. Sequencing of PCR products was conducted on a 3130 Genetic Analyzer (Applied Biosystem). Haplotypic sequences were visualized and manually edited with Geneious R7. A Clustal W alignment using sequences from Chesterfield-Bellona and sequences from (Olavarría et al. 2007) was performed in order to highlight polymorphic sites and name haplotypes with nomenclature of reference in the South Pacific. Sequences presenting indecision on polymorphic sites (contamination or heteroplasmy[6] (Baker et al. 2013) were removed from the dataset.

Statistical analyses

The expected probability of identity (P_{ID}) for each locus was calculated using GenAlEX (Peakall & Smouse 2006). Genetic diversity was estimated on mtDNA and nuDNA. The program DnaSP 5.10.(Librado & Rozas 2009) was used to determine polymorphic sites (s), haplotypes (*h*), and haplotypic diversity (*Hd*) on mtDNA. Expected heterozygosities (*He*) and observed heterozygosities (*Ho*) were estimated, both by locus and overall loci, with Arlequin 3.5. (Excoffier & Lischer 2010). The significance of deviation from Hardy-Weinberg expectation in microsatellite allele frequencies was estimated, again by locus and overall loci (F_{IS}, (Weir & Cockerham 1984) with FSTAT (Goudet 2002).

Regional differentiations were estimated between the South Lagoon of New Caledonia, Chesterfield-Bellona archipelago and the migratory corridor of South Eastern Australia at both mitochondrial and nuclear levels. Differentiation indices (F_{ST} on mtDNA and nuDNA, ϕ_{ST} for mtDNA) were calculated using Arlequin 3.5. (Excoffier & Lischer 2010). The significance of regional differentiation was tested with 1,000 random permutations using an Analysis of Molecular Variance (AMOVA). At nuclear level, samples from the three study areas only shared eight loci (Ev1, Ev14, Ev37, Ev94, Ev96, GATA417, GT211, GT575), which were used to perform the differentiation analysis. Genotypes that did not successfully include these eight loci were removed from analysis, reducing the dataset of Chesterfield-Bellona archipelago to 32 genotypes and the dataset of the South Lagoon of New Caledonia to 706 genotypes.

A haplotypic network was modelled using the Chesterfield-Bellona archipelago sequences and South Lagoon sequences commonly shared with Chesterfield-Bellona with PopART 1.7. (http://popart.otago.an.nz).

[6] Presence of a secondary peak at greater than 30 % of the primary peak confounding the resolution of a single haplotype.

RESULTS

Sampling effort

The field work carried out during MARACAS 3 began on August 7th and ended on August 27th, 2017. The plateaus of Bellona and Chesterfield were surveyed during this expedition as well as off-shore banks located between the two (0). The scientific team boarded the *O.V. Alis on* August 7th in Noumea harbour, and reached Chesterfield on August 10th. On the way back, the vessel left Chesterfield on August 24th and arrived in Noumea on August 27th. Activities undertaken during the expedition are presented in 0.

Activities conducted during MARACAS 3 in 2017 (Sampling effort, LT: line transect, FF: focal follow).

Date	Sampling effort	Wind	Platform	Activity
07/08/17	Departure and transit		N.O. Alis	Transit, Research: TL
08/08/17	8h39	<10kt	N.O. Alis	Transit, Research: TL
09/08/17	10h19	SSE 10-20kt	N.O. Alis	Transit, Research: TL, SF
10/08/17	9h31	SE 20kt	N.O. Alis	Research: TL
11/08/17	10h28	ESE 10-20kt	N.O. Alis	Research: TL
12/08/17	9h26	E 10kt	N.O. Alis, Annexe	Research: TL, SF, deployment of 2 automatic hydrophone recorders
13/08/17	9h45	SSE 15kt	N.O. Alis	Research: TL, SF
14/08/17	10h36	SE 12kt	N.O. Alis, Annexe	Research: TL, SF
15/08/17	10h28	SE 10kt	N.O. Alis, Annexe	Research: TL, SF
16/08/17	10h42	ESE 15kt	N.O. Alis	Research: TL, SF
17/08/17	9h20	E 12kt	N.O. Alis, Annexe	Research: TL, SF
18/08/17	10h14	5kt	N.O. Alis, Annexe	Research: TL, SF
19/08/17	10h45	SW 15kt	N.O. Alis, Annexe	Research: TL, SF
20/08/17	6h49	SSW 15-20kt	N.O. Alis, Annexe	Research: TL, SF
21/08/17	10h20	SSE 15-20kt	N.O. Alis	Research: TL, SF
22/08/17	10h11	SE 10-12kt	N.O. Alis, Annexe	Research: TL, SF
23/08/17	9h37	SSE 15-20kt	N.O. Alis, Annexe	Research: TL, SF
24/08/17	8h37	E 15kt	N.O. Alis, Annexe	Research: TL, SF
25/08/17	9h35	NE 12kt	N.O. Alis	Research: TL
26/08/17	-	>20kt	N.O. Alis	No observation
27/08/17	Arrival Noumea			
TOTAL	175h31			

Sampling effort accomplished during MARACAS 3 covered 175h31 including 132h14 of line transect and 43h16 of focal follows. The sampling effort in the Chesterfield-Bellona archipelago and off-shore banks was conducted during 15 days, between the 10th and the 24th of August.

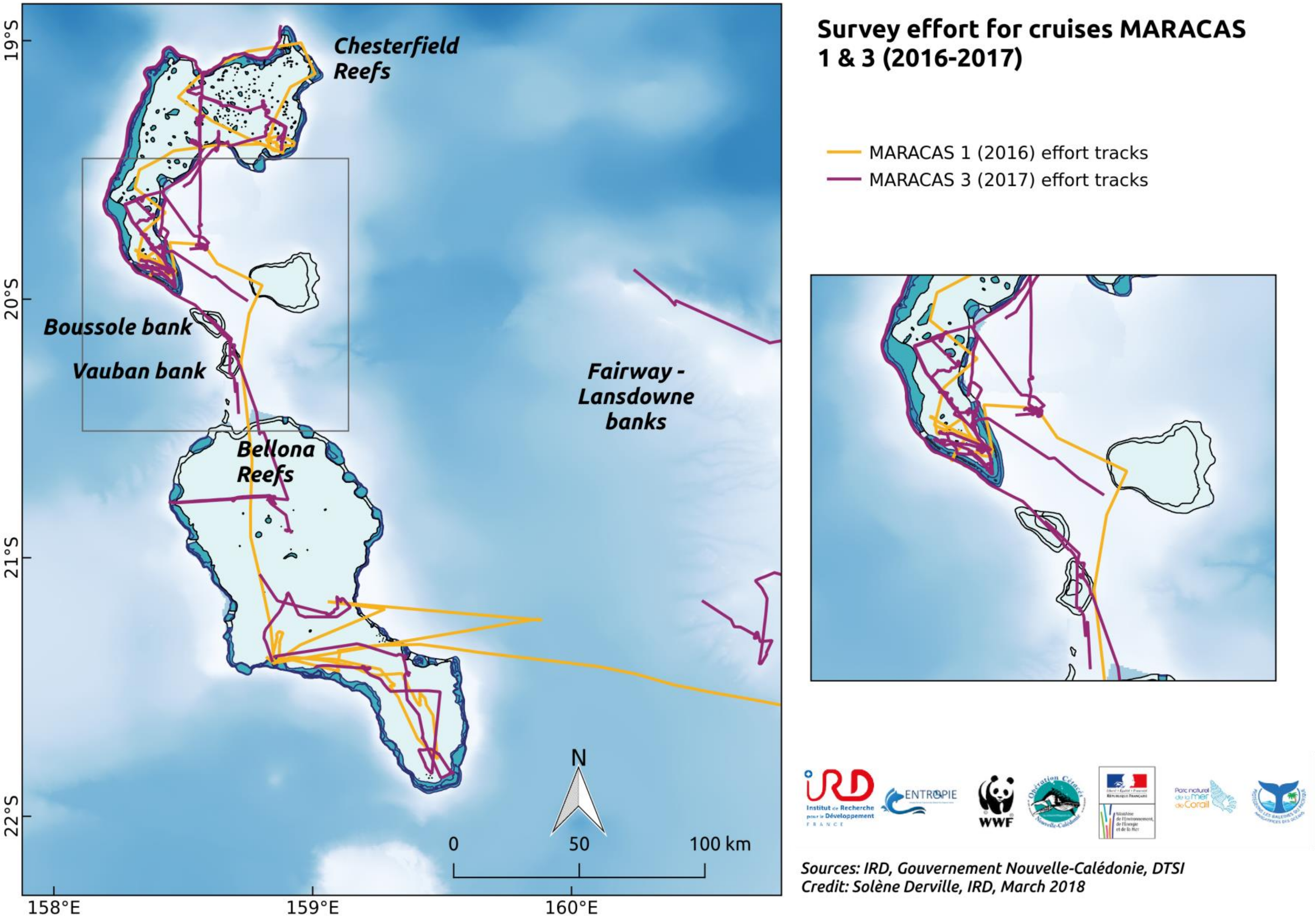

Figure 1 Sampling effort during MARACAS 1 in 2016 and MARACAS 3 in 2017.

The amount of time on-effort was 146h24, during which we covered a distance of 1,624 km in Chesterfield, Bellona and on the off-shore banks (0).

Time and distance on-effort, and conditions of observations during MARACAS 3 in 2017.

	Time on effort	Distance on-effort (km)			% conditions of observation during sampling		
		Total	ALIS	Semi-inflatable	Good	Medium	Weak
Chesterfield	81h48	858	747	110	52	46	2
Bellona	46h42	550	493	56	77	23	0
Off-shore bancs	17h54	216	189	27	46	54	0

Data collected

Groups of humpback whales were observed on Bellona-Chesterfield plateaus, as well as on the off-shore banks (0). Sixty three whales were distinguished using photos, 29 of which were individually identified by the ventral side of their fluke (0). The other 34 were not individually photo-identified, however the photos of their dorsal fins were used to count the total number of different whales encountered during MARACAS 3. Adults accounted for 73% of the whales observed, and juveniles and calves represented 6%and 21% respectively.

Number of groups of humpback whales observed, number of individuals differentiated, number of photo-ID whales and of samples collected during MARACAS 1 & 3.

Date	Number of groups	Number of whales differentiated (fluke + dorsal)	Number of new photo-identified whales (fluke)	Number of photo-identified whales previously catalogued (fluke)	Number of whales identified only by dorsal fin only	Number of skin samples collected
MARACAS 1	13	18	4	3	11	8
MARACAS 3	45	63	21	8	34	32

Forty skin samples were collected during MARACAS 1 and 3 (0).

Five acoustic deployment of an autonomous acoustic device "SoundTrap 3000" were conducted during the expedition: two on Chesterfield plateau, two on Bellona plateau and one on the off-shore banks. A total of 367h49 of recordings were collected. Their analysis is currently in progress at the University of Queensland, under Dr Michael Noad’s supervision.

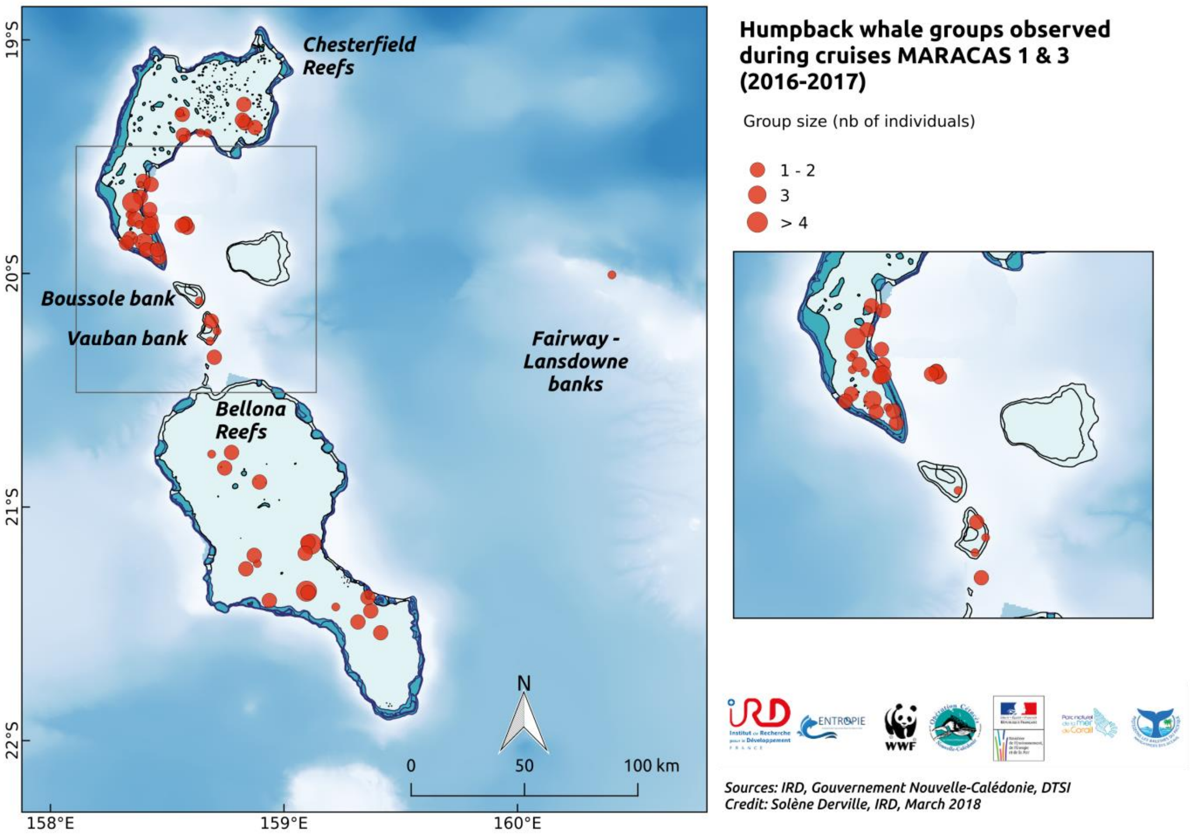

Figure 2 Spatial distribution of the groups of humpback whales encountered during MARACAS 1 and 3 in 2016 and 2017

Genetic diversity

Genetic analysis was conducted on the samples collected during both years of survey, 2016 and 2017. The Probability of Identity (P_{ID}) calculated for a minimum of 8 loci was less than 1 x 10^{-9}, hence ensuring that individual whales were robustly identified based on the genotypes considered in this study.

Number of samples collected, number of genotyped individuals, number of males, and number of females during the Chesterfield-Bellona surveys, 2016 and 2017.

# samples			# Individuals genotyped			# Males			# Females		
2016	2017	**Total**	2016	2017	**Total**	2016	2017	**Total**	2016	2017	**Total**
8	32	**40**	7	31	**38**	3	7	**10**	4	24	**28**

Thirty-eight different individuals were identified within the 40 samples, including 10 males and 28 females (sex ratio 1:2.8; 0).

Microsatellite polymorphism analysis

Out of the 16 microsatellite loci that were genotyped, 15 were used for analysis, as the allele sizing failed for the locus Ev104 (Valsecchi 1996). One sample (Mno17NC360) was removed from analysis of nuDNA, because only 11 loci were successfully sequenced, so it did not pass the quality control.

Success rate in genotyping samples from Chesterfield-Bellona archipelago varied between 93% and 100% depending on the locus analysed (0). The number of alleles per locus varied from 4 to 17. The lowest number of alleles was encountered on Ev1 (Valsecchi 1996) and the highest on Ev37 (Valsecchi 1996). Diversity of microsatellite loci was high, with an average of 9.13 alleles per locus and average observed heterozygosity of 0.735. No loci showed a significant expectation from Hardy-Weinberg equilibrium (F_{IS} by locus, p> 0.05). The fixation index F_{IS}, calculated for all loci, showed a slight excess of homozigosity (F_{IS}= 0.024) but this value was not significant.

Success rate, number of allele per locus (A), expected heterozygosity (He), observed heterozygosity (Ho), FIS per locus and overall loci.

Locus	Success rate	A	He	Ho	F_{IS} (W&C)
464/465	100%	6	0.602	0.686	-0.142
Ev1	93%	4	0.570	0.528	0.075
Ev14	100%	8	0.790	0.703	0.112
Ev21	96%	5	0.692	0.625	0.098
Ev37	100%	17	0.935	0.974	-0.041
Ev94	93%	10	0.833	0.778	0.068
Ev96	93%	12	0.911	0.917	-0.007
GATA28	100%	9	0.451	0.474	-0.052
GATA417	96%	14	0.911	0.889	0.025
GT211	96%	9	0.834	0.730	0.126
GT23	100%	9	0.789	0.737	0.067
GT575	100%	11	0.826	0.816	0.012
rw31	96%	7	0.608	0.559	0.082
rw4-10	100%	10	0.806	0.895	-0.112
rw48	100%	6	0.725	0.711	0.020
All	98%	9.13	0.752	0.735	0.024

Mitochondrial control region DNA analysis

Out of 38 different individual, 32 mtDNA control region PCR products were sequenced as the MtDNA sequences were already known for the six remaining. One sequence presenting a heteroplasmy was removed from analysis, thus reducing the total sample size to 37 sequences.

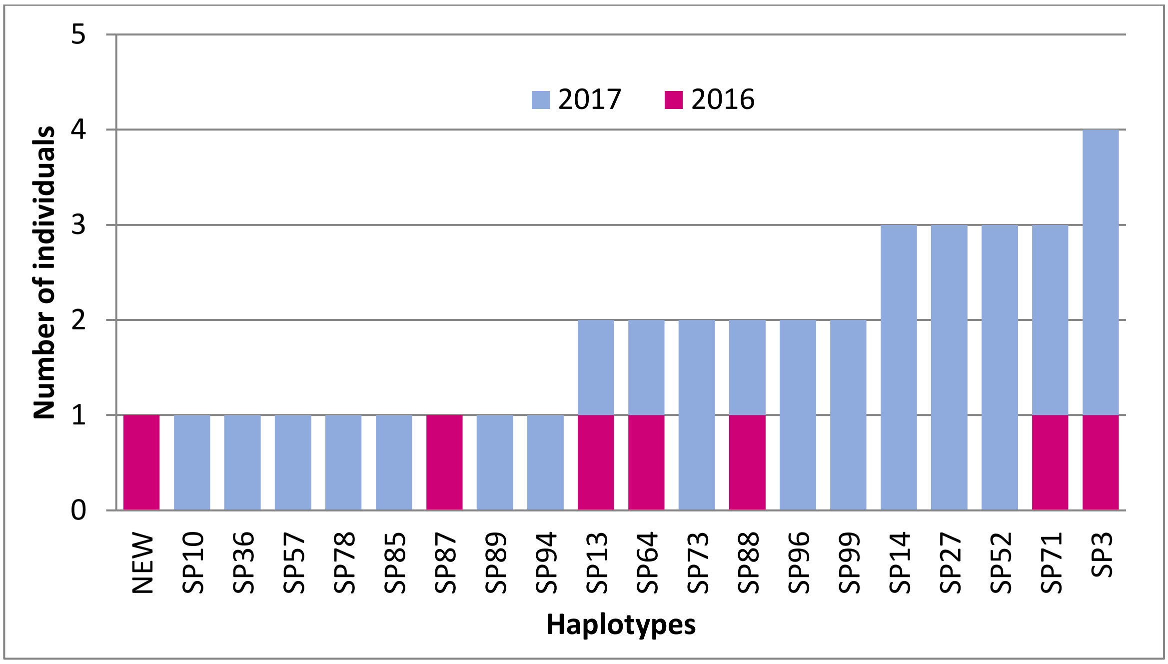

Figure 3 Occurrence of the haplotypes identified within the humpback whale samples collected in Chesterfield-Bellona archipelago.

Clustal W alignment conducted on 460 bp allowed the characterization of 20 haplotypes defined by 43 polymorphic sites in whales sampled in the Chesterfield-Bellona archipelago. Five haplotypes were common between 2016 and 2017, one haplotype was only encountered in 2016 and 12 haplotypes were only found in 2017 (0). Haplotypes were known from (Olavarría et al. 2007) except one (NEW) corresponding to a male encountered in 2016. Haplotypic diversity (*Hd*) calculated on Chesterfield-Bellona was equal to 0.9640.

Connectivity

The comparison of 38 genotypes collected in Chesterfield-Bellona study area with the genetic database of New Caledonia revealed some connectivity within the EEZ of New Caledonia. Ten of the 38 individuals genotyped in 2016 and 2017 were previously observed in the coastal waters of New Caledonia (0). All of these whales were observed in the New Caledonian South Lagoon between 1997 and 2012, but none of them were observed in other areas of the EEZ (e.g., southern seamounts). They had been previously sighted over one year (N=8), two years (N=1) or four years (N=1) in the New Caledonian South Lagoon. Out of these ten individuals, nine were females, encountered in Chesterfield-Bellona archipelago as mother (N=5), pair member (N=2), or singleton (N=2). The only recaptured male was observed on the plateau as a pair member. One genotyped female was previously biopsied in Area V of Antarctica in summer 2010 in the vicinity of the Balleny's Islands (Constantine et al. 2014).

Recapture history of whales genotyped in Chesterfield-Bellona archipelago during the surveys MARACAS 1 & 3.

Whale ID	Group type	Date	Localisation (decimal degre)		Size	Sex	Social type
HNC428	Competitive group + mother calf	12/09/2006	166.94	-22.4944	adult	F	Mother
HNC428	Pair	18/08/2017	158.57	-19.4077	adult	F	Pair
NI9918	Mother-calf group	29/08/1999	167.044	-22.6686	adult	F	Mother
NI9918	Mother-calf group	29/08/1999	167.129	-22.6253	adult	F	Mother
NI9918	Mother-calf group	19/08/2017	158.397	-19.6054	adult	F	Mother

HNC147	Pair	24/07/1998	167.027	-22.3641	adult	F	Pair
HNC147	Singleton	24/07/1998	167.043	-22.445	adult	F	Singleton
HNC147	Mother-calf group	20/08/2017	158.342	-19.8499	adult	F	Mother
HNC147	Mother-calf-escort group	23/08/2017	158.386	-19.6721	adult	F	Mother
HNC147	Competitive group + mother calf	23/08/2017	158.352	-19.6952	adult	F	Mother
HNC668	Singleton	25/07/2010	167.073	-22.585	adult	F	Singleton
HNC668	Pair	25/08/2016	159.414	-21.5382	adult	F	Pair
HNC319	Pair	28/07/2005	166.924	-22.4648	adult	M	Pair
HNC319	Pair	28/07/2005	166.904	-22.4629	adult	M	Pair
HNC319	Pair	28/07/2005	166.924	-22.4726	adult	M	Pair
HNC319	Singleton	29/07/2005	166.956	-22.4038	adult	M	Singleton
HNC319	Pair	30/08/2012	166.918	-22.4267	adult	M	Pair
HNC319	Pair	25/08/2016	159.414	-21.5382	adult	M	Pair
HNC908	Pair	07/08/2012	166.992	-22.6272	adult	F	Pair
HNC908	Mother-calf group	12/08/2017	158.776	-20.7662	adult	F	Mother
HNC279	Mother-calf group	15/08/2003	167.039	-22.51	adult	F	Mother
HNC279	Mother-calf group	16/08/2003	166.915	-22.4178	adult	F	Mother
HNC279	Singleton	13/08/2017	159.222	-21.4278	adult	F	Singleton
HNC123	Singleton	29/07/2000	166.943	-22.4534	adult	F	Singleton
HNC123	Singleton	17/07/2002	167.066	-22.5126	adult	F	Singleton
HNC123	Pair	20/08/2002	166.903	-22.4523	adult	F	Pair
HNC123	Singleton	07/09/2002	167.081	-22.6184	adult	F	Singleton
HNC123	Mother-calf group	09/09/2005	166.26	-21.562	adult	F	Mother
HNC123	Pair	19/08/1997	167.072	-22.5817	adult	F	Pair
HNC123	Pair	26/08/1997	166.92	-22.4186	adult	F	Pair
HNC123	Mother-calf group	19/08/2017	158.564	-19.7942	adult	F	Mother
HNC123	Mother-calf group	22/08/2017	158.876	-19.3748	adult	F	Mother
HNC563	Pair	27/07/2009	167.074	-22.5687	adult	F	Pair
HNC563	Mother-calf group	22/08/2017	158.822	-19.3433	adult	F	Mother
HNC1145	Mother-calf group	17/08/2015	166.944	-22.4411	adult	F	Mother
HNC1145	Singleton	18/08/2017	158.554	-19.3125	adult	F	Singleton

Among the 20 haplotypes encountered in Chesterfield-Bellona archipelago, 19 were shared with individuals observed in the New Caledonian South Lagoon (0). One haplotype derived from one individual was unknown from New Caledonia and for the South Pacific (NEW). The 19 known haplotypes were shared by 1 to 4 individuals within the Chesterfield-Bellona archipelago, and by 4 to 35 individuals from of the New Caledonian South Lagoon.

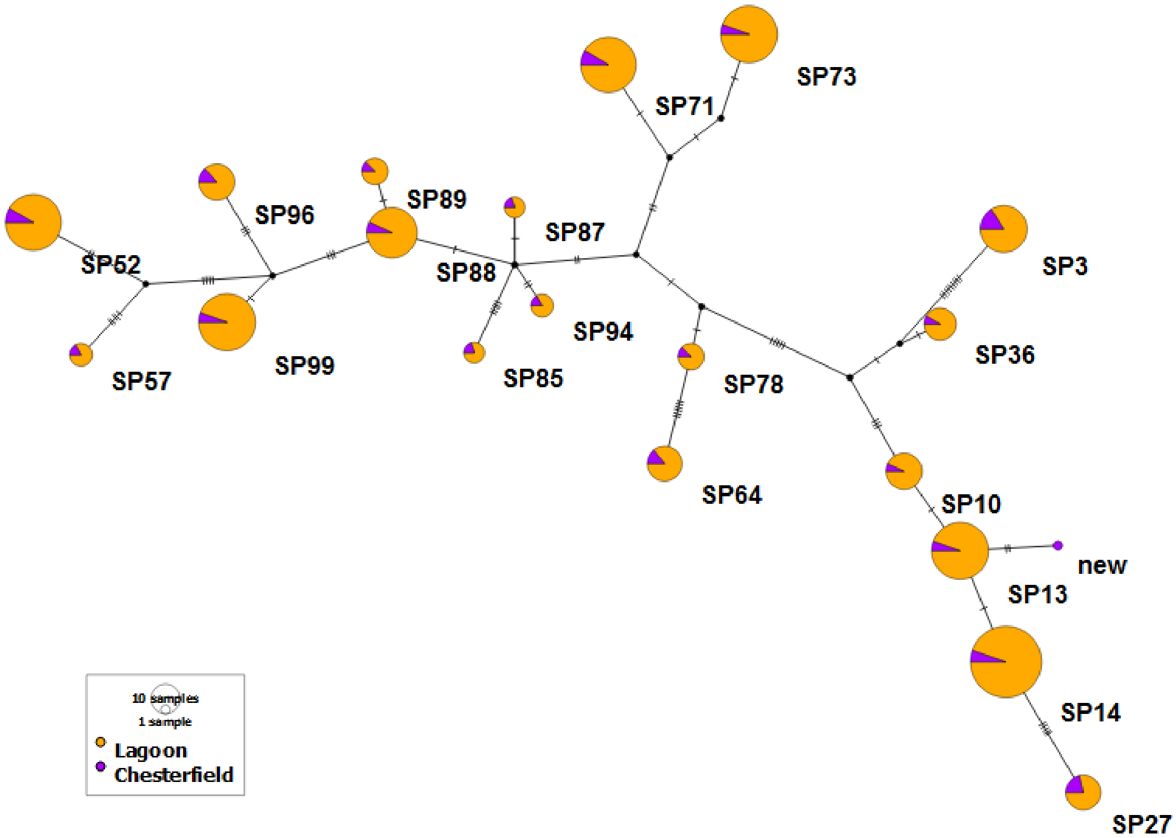

Figure 4 Haplotypic network estimated from individuals encountered in the Chesterfield-Bellona archipelago(N= 20). One is uniqueand 19 are shared with the South Lagoon of New Caledonia. Haplotypes that areonly found in the South Lagoon of New Caledonia are not represented in the network.

The AMOVA showed a significant overall differentiation among the three areas: of the South Lagoon of New Caledonia, the Chesterfield-Bellona archipelago and the migratory corridor of South-East Australia, at the haplotype (F_{ST} = 0.00813, p<0.001) and nucleotide levels (ϕ_{ST} = 0.01717, p<0.001). Pairwise comparison calculated on mtDNA showed no significant difference between whales sampled in the South Lagoon and the Chesterfield-Bellona archipelago (0, p> 0.05). In contrast, significant differentiation was highlighted between the migratory corridor of South-East Australia and the South Lagoon of New Caledonia and the Chesterfield-Bellona archipelago both at haplotype and nucleotide levels

At the nuclear level, the AMOVA showed significant overall differentiation among the three compared areas (F_{ST}= 0.00152, p<0.05), that might be explained by the differentiation existing between the South Lagoon and the migratory corridor of South-East Australia (0. F_{ST}= 0.00206, p>0.01). No differentiation was highlighted between Chesterfield-Bellona archipelago and the South Lagoon of New Caledonia or the migratory corridor of South-East Australia (p>0.05).

Pairwise F_{ST} values (above diagonal) and ϕ_{ST} values (bellow diagonal) for mitochondrial DNA control region sequences between humpback whales from the South Lagoon of New Caledonia, the Chesterfield-Bellona archipelago, and the migratory corridor of South-East Australia. N: Number of individuals used for the analysis. Bold values are significant at * <0.05, **<0.01, ***<0.001 levels.

	South Lagoon (N = 767)	**Chesterfield-Bellona (N = 37)**	**South East Australia (N = 96)**
South Lagoon (N = 767)		0.00164	**0.01026 *****
Chesterfield-Bellona (N = 37)	-0.00080		**0.01525 ****

South East Australia (N = 96)	**0.02349 *****	**0.03002 ***	

Pairwise F_{ST} values calculated for 8 microsatellite loci between humpback whales from South Lagoon of New Caledonia, Chesterfield-Bellona archipelago, and the migratory corridor of South-East Australia. N: Number of individuals used for the analysis. Bold values are significant at * <0.05, **<0.01, ***<0.001 levels.

	South Lagoon (N = 706)	**Chesterfield-Bellona (N = 32)**	**South East Australia (N = 129)**
South Lagoon (N = 706)			
Chesterfield-Bellona (N = 32)	-0.00103		
South East Australia (N = 129)	**0.00206** **	0.00356	

SYNTHESIS AND DISCUSSION

Genetic diversity of the Chesterfield-Bellona archipelago

The expeditions MARACAS 1 & 3 confirmed that humpback whales are still inhabiting the Chesterfield-Bellona archipelago and present a relatively high genetic diversity (*Hd*= 0.9640). This value is lower than the haplotypic diversity measured in the South Lagoon (*Hd*= 0.9730, (Bonneville et al. 2017). This difference might be explained by the smaller sample size collected to date in Chesterfield-Bellona archipelago (N=37) compared to the South Lagoon of New Caledonia (N= 767). However, this index is still higher than that of other humpback whale populations considered as genetically isolated (e.g., ASHW stock *Hd* = 0.691; (Rosenbaum et al. 2009, Pomilla et al. 2014).

Observed heterozygosity in the Chesterfield-Bellona archipelago was high (*Ho*= 0.735) and also comparable to that measured in the New Caledonian South Lagoon (*Ho*= 0.747, (Bonneville et al. 2017). The fixation index F_{IS} was slightly positive (F_{IS}= 0.024), which suggests a possible Wahlund effect consisting in a reduction of the observed heterozygosity in a population caused by subpopulation structure (Trudelle et al. 2018). As a result, if several genetically differentiated subpopulations are erroneously pooled together in a single population, a deficit in heterozygote might be detected in the entire sample, even if each subpopulation are in Hardy-Weinberg equilibrium. Though the F_{IS} was not significant (p>0.05), it could suggest a mixing between Eastern-Australia and New Caledonia populations in the Chesterfield-Bellona archipelago. Again, a larger sample size is required to conclude on the genetic diversity and heterozygosity estimated from whales visiting the Chesterfield-Bellona.

Connectivity with the New Caledonian South Lagoon

Results obtained with photo-identification and genotyped individual comparison between New Caledonia and the Chesterfield-Bellona archipelago in 2016 and 2017 reveal a connectivity between the two areas (31% and 26% for both methods respectively) but this link has not been highlighted within a given season (Garrigue et al, in prep). All haplotypes found in Chesterfield-Bellona are shared with New Caledonia, (N = 19) with the exception of one (NEW) that is unknown from previous studies conducted in the South Pacific breeding grounds (Olavarría et al. 2007).The absence of any significant differentiation on mtDNA (F_{ST} and ϕ_{ST}, p>0.05) and nuDNA (F_{ST} p>0.05) between the Chesterfield-Bellona archipelago and the New Caledonian South Lagoon also suggest that humpback whales encountered in the archipelago belong to the same population. These results should be considered with caution given the strong sampling bias between these two areas (32 genotypes and 37 mtDNA sequences in Chesterfield-Bellona archipelago against 706 genotypes and 767 mtDNA sequences in of the New Caledonian South Lagoon). Specifically, the use of a 20 years-dataset from New Caledonia South Lagoon increases the probability of recapturing roaming individuals only by chance, as a result of the long-term sampling of the New Caledonian population. Indeed, previous analysis conducted in New Caledonia have shown that the genetic diversity in humpback whales differs between some particular years, thus suggesting exceptional visits of humpback whales from other areas (Bonneville et al. 2017). Moreover, some studies suggest that the increasing number of humpback whales in New Caledonia over time could only be explained by temporary immigration phenomenon or influx, independent from intrinsic demographical growth (Garrigue et al. 2012), (Clapham & Zerbini 2015). The specific genetic comparison between the New Caledonian South Lagoon and the Chesterfield-

Bellona archipelago within the same year (i.e. 2017) would facilitate the understanding of the link between these two areas.

Connectivity with the east coast of Australia

Limited exchanges between New Caledonia and the migratory corridor of Australia have been highlighted using photo-identification and genotyping (Olavarría et al. 2006, Garrigue et al. 2011). To date the genetic comparison between East Australian humpback whales and the New Caledonian breeding sub-stock E2 have been conducted using samples from the east Australian migratory corridor but not from the reproductive area of the Great Barrier Reef (Chittleborough 1965, Dawbin 1966, Smith et al. 2012). Previous genetic analysis between New Caledonia and the migratory corridor of Eastern Australia around Stradbroke Island have shown no significant differentiation between the two areas and suggest that some of the humpback whales from New Caledonia might use the East Australian migratory corridor in their southbound migration. (Valsecchi et al. 2010). On the opposite, the differentiation observed between whales sampled in the South East Australia migratory corridor (Eden and Tasmania) and in New Caledonia (Bonneville et al. 2017) would suggest that part of the sub-stock E2 may join the Eastern Australia southbound migration but would not interbreed. Therefore, a better understanding of the population structure potentially existing between sub-stock E2 and - the Great Barrier Reef reproductive area - appears to be essential to understand the population structure and the migration of the two breeding sub-stocks.

A better understanding of the population structure potentially existing between New Caledonia (E2) and the Great Barrier Reef reproductive area appears to be essential to estimate the origin of the Chesterfield-Bellona archipelago humpback whales. The preliminary analysis of the mtDNA component showed a significant differentiation between Chesterfield-Bellona archipelago and migratory corridors of South-East Australia but no differentiation was found using nuDNA. These first results might suggest a sex-biased dispersal through the Coral Sea but more samples are required to confirm the status of humpback whales encountered in the Chesterfield-Bellona archipelago.

A possible difference in sex dispersal?

Last but not the least, the important number of females resighted between the Chesterfield-Bellona archipelago and the New Caledonian South Lagoon has to be considered with respect to maternal fidelity in Oceania. Females are known to be phylopatric and as a result, would display an increasing mtDNA genetic structure, as it is found in other cetacean species (e.g. spinner dolphin, (Oremus et al. 2007) as well as humpback whales (Baker et al. 1998). As a result, sex-specific comparisons between areas are expected to show an absence of differentiation between females from the same population and a strong difference between those from distinct populations. The preliminary results presented in this report would support this hypothesis: mtDNA comparisons show a significant difference between Chesterfield-Bellona archipelago and the migratory corridor of South-East Australia but not with South Lagoon of New Caledonia but a sex specific analysis is required to highlight a sex-biased dispersal in the Coral Sea. To date, sample size per gender from the Chesterfield-Bellona archipelago (N = 10 males and N = 28 females) is too small to undertake such comparison needed to understand the migratory pattern of humpback whales in the region.

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