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# Annual Report of the Southern Ocean Research Partnership (IWC-SORP) 2016/17

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INTERNATIONAL WHALING COMMISSION

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# Annual Report of the Southern Ocean Research Partnership (IWC-SORP) 2016/17

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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 12 member countries in the Partnership: Argentina, Australia, Brazil, Chile, France, Germany, Italy, New Zealand, Norway, South Africa, the United States and Belgium joined the Partnership in October 2016. This paper reports on the continued progress of IWC-SORP and its five ongoing research themes[1] since the Scientific Committee meeting in 2016. This progress includes the production of 30 peer-reviewed scientific papers in 2016/17, bringing the total number of peer-reviewed publications related to IWC-SORP produced since the start of the initiative to ca. 94. Moreover, 101 IWC-SORP related papers have been submitted to the Scientific Committee, 14 of them this year. Fieldtrips to the western Antarctic Peninsula, McMurdo Sound, Marion Island, the Chesterfield-Bellona Reef in the Coral Sea and East Australia have taken place in the past year, and four IWC-SORP researchers participate in the Antarctic Circumpolar Expedition voyage. 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 humpback whales; biopsy samples have been collected from killer whales and humpback whales; and hundreds of hours of acoustic recordings have been made. More information can be found at: http://www.marinemammals.gov.au/sorp

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

## 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, Brazil, Chile, France, Germany, Italy, New Zealand, Norway, South Africa and the United States of America. Belgium were warmly welcomed to the Partnership in October 2016.

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; 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 2016. Further details of this work can be found on the IWC-SORP website presently hosted by the Australian Antarctic Division at http://www.marinemammals.gov.au/sorp.

## BRIEF SUMMARY OF PROGRESS

Overall, IWC-SORP projects have produced 94 peer-reviewed publications to date and 101 IWC-SORP related papers have been submitted to the Scientific Committee, 14 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/OXX. A financial report of the IWC-SORP Research Fund as of 31 March 2017 is detailed in SC/67a/OXX. 640,421GBP remain unallocated and unspent.

### Funding and vessel time secured during 2016/17

In 2016/17, IWC-SORP researchers have received voluntary contributions from the Government of Australia, WWF-Australia, the International Fund for Animal Welfare. Details in SC/67a/OXX.

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.)
- *RV Maria S. Merian* - 2019 (Herr et al.)
- *RV Investigator* - 2019 (Nicol, Double, Bell 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 are given below. Full project reports are included in Annexes 1 to 5.

#### *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.

[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.

In 2016/17 work on the Antarctic Blue Whale Project has focused on fieldwork, the analysis of photo-identification and acoustic 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 proposals to secure ship-time for future research voyages.

*Prefecto García* voyage 2017

Visual and acoustic surveys of cetaceans were conducted on board the Argentinean Coast Guard (Prefectura Naval Argentina) cutter GC-189 *Prefecto García*,12 January - 4 February, 2017, 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 80 h and 6,651 nm. On-effort cetacean sightings included three odontocete and four mysticete species, encompassing a total of 156 encounters. A total of 167 h of acoustic recordings were collected with the towed hydrophone array. These acoustic data also make an important contribution to the IWC-SORP Acoustic Trends Project.

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

Analysis of data collected during the 2015 New Zealand-Australia Antarctic Ecosystems Voyage has continued during 2016/17, the focus being the development of methods to quantify the distribution and density of Antarctic blue whales during the voyage for comparison with the distributions of krill measured on the voyage. Additionally, manual validation of all Antarctic blue whale calls from a subset of 56 hours of passive acoustic data from the 2015 voyage has been conducted yielding 6420 identified low-frequency sounds, most of which were blue whale calls. These annotated data will serve as a test-data set for characterising the performance of automated algorithms for detection and classification of the calls of Antarctic blue whales. Funding was received from the IWC-SORP Research Fund to continue these analyses and publish manuscripts in 2017/18.

Antarctic blue whale photo-identification

In 2016, new photographs of Antarctic blue whales from the South African Antarctic Blue Whale Survey (Findlay et al., 2014) and from the personal files of Paul Ensor (Cruise Leader, IWC/SOWER). Paula Olson identified and compared individual identification photographs of Antarctic blue whales from the new collections with those already in the Antarctic Blue Whale Catalogue. A total of 25 new identifications were made bringing the total number of photo-identified Antarctic blue whales up to 441 whales, represented by 336 left sides and 321 right sides. The minimum (321) and maximum (441) number of unique individuals represents 15% and 19%, respectively, of the most recent accepted estimate of abundance of Antarctic blue whales, 2,280 in 1997/1998 (Branch, 2007).

Platforms of opportunity

Partnerships with tourist ships, fishing vessels and naval vessels are yielding increasing amounts of data for the circumpolar estimation of Antarctic blue whale abundance and other IWC-SORP projects. Blue whale sightings information have also been submitted by vessels operating around the west Antarctic Peninsula 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.

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

The 20th century commercial whaling industry reduced great whale populations to low abundances in the Southern Hemisphere. The Antarctic blue whale population was probably reduced to less than 1% of its original abundance. The effect of this exploitation on this population has been explored through comparisons of historical and contemporary genetic diversity (Sremba et al. 2012, Sremba et al. 2015). From bones collected near former whaling stations on the South Atlantic island located between 54.4296°S and 36.5879°W, we previously identified 11 mitochondrial DNA (mtDNA) haplotypes no longer found in the contemporary population. In February 2016, additional samples were collected from the Antarctic Peninsula and the South Atlantic island located between 54.4296°S and 36.5879°W. Using conventional PCR and mtDNA control region sequencing, we identified 37 humpback whales, 14 blue whales, 16 fin whales, 1 minke whale and 1 sperm whale. With funding from the Southern Ocean Research Partnership (IWC-SORP) the 14 blue whale bones will

be used for Next Generation Sequencing to further characterize pre-whaling genomic diversity. This work is detailed in Sremba et al. SC/67a/SHXX.

11 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. 13-26.

***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 McMurdo Sound, the western Antarctic Peninsula and around sub-Antarctic, Marion Island.

Pitman and Durban

The main objectives of the project are to assess the taxonomic status, diversity, prey preferences, and abundance of killer whales in Antarctica in order to quantify their overall trophic impact on prey populations within the context of climate change and fisheries management objectives. A total of 442 individual Type C killer whales have now been identified from photographs of killer whales in McMurdo Sound. It is thought that there may now be enough historical images dating back to 2002 to determine if a postulated decline in McMurdo killer whale population (due to toothfish fishing in the Ross Sea) has in fact occurred.

Dalla Rosa

During February-March 2017, 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 550 nautical miles of cetacean search effort was conducted, resulting in 286 on-effort sightings of five cetacean species. Four sightings corresponded to killer whales (3 type B and 1 type A), totaling about 100 individuals. Over 3,000 photographs were taken for individual identification, and five biopsy samples were obtained. These photographs are currently being analysed, but contain at least 40 type B and 10 type A individuals. Our killer whale photo-identification catalogue should be updated by the end of April, when it will be shared with other colleagues for the purposes of this IWC-SORP project's collaborative efforts on abundance estimation of all killer whale ecotypes. In addition, one LIMPET-SPLASH satellite tag was deployed on an adult male type A killer whale in the Bransfield Strait on March 6th. As of April 1st the tag was still transmitting, and the whale was heading north.

De Bruyn and Reisinger

At the time of writing, fieldwork is being carried out on Marion Island for the 2017 field season, partially funded by a grant awarded from the IWC-SORP Research Fund. 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 ~73,000 images and 62 individuals have been identified. Over 4 years, 26 satellite tags have been deployed and these have revealed seasonal site fidelity as well as rapid, long-distance movements and deep diving over seamounts. 49 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 $\delta$15N values higher than any seals, penguins or Patagonian toothfish. However $\delta$15N 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 2016/17 austral summer. Funding is being sought to continue this fieldwork in 2017/18.

Overall, 30 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. 27-43.

***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.

Between 1 January and 30 May, 2017, a constant presence and active research were maintained around the Antarctic Peninsula:

As part of the NSF LTER program personnel were deployed on the *LM Gould* and at Palmer Station. Collaborators from Duke University collected biopsy samples and flew UAS (unmanned aerial systems) missions over humpback whales for photogrammetry purposes. The images from this work will be utilized to generate accurate length and girth estimates for each whale that can be linked to biopsy samples to determine sex and pregnancy status. Body condition measurements from whales throughout the feeding season will then be compared to better understand when whales are growing and putting on weight. This can then be linked to current as well as previous environmental conditions to determine the impacts that variability in the system (e.g. sea ice cover) has on baleen whale growth and behaviour. At Palmer Station, photo-identification and biopsy samples were collected from humpback and minke whales from 1 January – 8 April. Concurrent to this, regular echo sounder surveys of krill abundance were performed to allow the local abundance of whales to be related to changes in the availability of prey locally.

In February and March 2017, research was also conducted by Ari Friedlaender, Duke University, Michael Double and Elanor Bell, Australian Antarctic Division, on three expeditions aboard vessels chartered by One Ocean Expeditions. Three multi-sensor video recording suction cup tags provided by the World Wildlife Fund were deployed on humpback whales. These tags provided high-resolution sensor data to quantify the underwater dive behaviour of the whales for 24-36 hours. In addition, the tags were used to collect animal-borne video for between 6 to 9 hours per deployment, to corroborate sensor data and provide a visual experience from the whale's perspective of its environment and behaviour. Four LIMPET tags were also deployed on Antarctic minke whales. This is the second season in a row that this number of tags have successfully deployed been deployed on minke whales, significantly increasing our total number of deployments and data for the species. This resounding success validates and justifies the tremendous value of working from tour ships, One Ocean Expeditions specifically, to augment our data collection. Additionally on the One Ocean Expedition trips, we collected UAS images and video concurrent with biopsy sampling to compare with the similar information collected in January by similar means.

At the time of writing, there is another research team aboard the *LM Gould* deploying late season satellite tags and collecting biopsy samples from humpback whales.

There are currently 5 students and postdoctoral researchers using the data from this project for a number of purposes and publications.

25 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. 44-54.

*IWC-SORP sincerely thanks WWF-Australia for its generous contribution of 15,989 GBP to purchase the three video suction cup tags repeatedly deployed during the 2016/17 season.*

***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***

In 2016/17, there were three primary research components to this project:

Kermadec Islands - Rochelle Constantine, Leena Riekkola, Alex Zerbini, Virginia Andrews-Goff, Ari Friedlaender
Analysis has continued of the satellite tag data from the 18 tags successfully deployed on whales migrating south past Raoul Island (Kermadecs) in 2015 (see Constantine et al. 2016, SC/66b/SH05), including further analysis of the tissue biopsy samples. Constantine et al. (2016) reported the use of genetic profiling and photo-identification to determine breeding ground links spanning ~3,600km of Oceania waters (from New Caledonia to the Cook Islands). The telemetry data revealed feeding ground destinations spanning ~3,500km of the Southern Ocean (from the Ross Sea to Bellingshausen Sea regions) covering IWC Areas V, VI and I. A mixed-stock analysis showed similar levels of assignment to the breeding grounds of New Caledonia (35%) and Tonga (41%), with American Samoa-Samoa-French Polynesia genetic cluster (13%) and east Australia (12%) showing similar results.

39 biopsy samples were analysed for progesterone levels, including males (n = 3) and calves (n = 5) to act as control samples. Of 31 adult females, 17 (54.8%) were pregnant. Of the 31 samples, 11 females were accompanied by a young-of-year calf and five (45.5%) of these females were pregnant.

78 samples, including eight replicate samples as a control, were analysed using epigenetic methods (see Polanowski 2014) by Dave Chandler and Simon Jarman. Of the 70 individuals, the ages ranged from <1 (young-of-year) to 67 years old with most whales in the 5-35 year old range.

Analysis of the satellite telemetry data has shown the occurrence of different behavioural states across the migration with 86% of transits and 4% of area restricted searches (resting, foraging and/or milling) and 10% of locations uncertain. A linear mixed effect model was used to compare the mean travel speed between sex-classes (male, female, mother-calf pair, and unknown) within latitude bands of 10 degree intervals. The mean swimming speed (±SD) of 2.4km/h (± 1.8) was recorded across all whales and tracks. All whales showed slower swimming speeds at low and high latitudes, and faster swimming speeds at mid-latitudes.

Chesterfield-Bellona Reef complex – Claire Garrigue
Field work was conducted from 22 August to 4 September 2016 with nine days spent in the Bellona and Chesterfield reef complex. A total of 88:16 hours of line transect observation time was conducted covering similar distances in both areas (757km – Chesterfields and 650km - Bellona). Humpback whales were observed on seven of nine survey days. Individual data were collected on nine groups of humpbacks with seven whales photo-identified by fluke and a further 11 identified by dorsal fin for the purposes of counting total numbers sighted. Of all whales encountered, 72% (n = 13) were adults and 28% (n = 5) were calves. Of the seven adults identified by fluke, three (2 females and 1 male) matched to the New Caledonia southern lagoon catalogue and four were newly identified individuals that will be matched to other catalogues throughout the region.

Seven skin samples were collected. These samples will be genotyped and sex-identified using standard protocols and then matched to Oceania and Australian genotype catalogues.

Whale song was heard in 61% of 49 hydrophone deployments. There were seven song sessions recorded with three covering the full song-length (range = 28 – 44 mins), the other four were either too short or poor quality. These acoustic recordings will be analysed along with other acoustic data throughout the region as part of a long-term study on humpbacks throughout Oceania.

East Australia breeding grounds – David Paton
Three weeks of humpback whale surveys were undertaken during the peak of the breeding season from 9 to 30 August, 2016. The first two weeks (9-22 August) were focused around the Whitsunday Islands (20.2°N 148.9°E) and the final week (23-30 August) were focused off Mackay in the Percy Islands within the Swains section of the Great Barrier Reef Marine Park. This was identified as the core range of the E1 breeding stock (Smith et al. 2012).

A total of 67 pods of humpback whales containing a total 146 whales (including 30 calves) were observed during the survey. This number was lower than expected and the general density of pods observed was lower than that observed in the same region during previous surveys. A total of 26 genetic samples were collected during the 2016 field season (including sloughed skin and biopsy samples) for an overall total of 62 samples from the region (including 2011, 2014 and 2016 sampling).

Photo-identification images of whale flukes are being processed and will be matched to existing catalogues throughout the region and to Antarctic catalogues to determine connectivity to breeding grounds, migratory corridors and feeding grounds. There will be a ten week field season in the same region in 2017 to complete data collection for this project; samples will then be analysed by Scott Baker and Debbie Steel and compared to large genotype catalogues from Australia, Oceania and Antarctica.

Together, the three components provide major contributions to understanding the stock recovery (e.g., Jackson et al. 2008, IWC 215) of humpback whales and their connectivity between breeding grounds, migratory corridors and feeding grounds.

10 peer-reviewed publications have been generated by the IWC-SORP Oceania humpback whale project to date. IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project. A full project report is included in Annex 4, pp. 55-61.

*IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project.*

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

The Blue and Fin Whale Acoustic Trends Project has continued to develop and mature a long term acoustic research program to understand trends in Southern Ocean blue and fin whale distribution, seasonal presence, and population growth through the use of passive acoustic monitoring techniques. This international collaboration has continued to deliver:

1) analysis and interpretation of existing ad-hoc acoustic datasets in from the Southern Ocean,
2) the development and implementation of an ongoing network of long-term circumpolar underwater listening stations, and
3) development of novel and efficient methods for standardized analysis of acoustic data collected in the Antarctic and sub-Antarctic.

In 2016/17, members of the Acoustic Trends Project deployed 23 autonomous recording devices in the Southern Ocean at 19 different recording sites, and the group recovered 17 previously deployed autonomous recorders from various recording sites around Antarctica. The data volume from all instruments totalled approximately 150,000 hours of underwater recordings. 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.

The steering group of the Acoustic Trends Project has continued to forge strong links with other IWC-SORP and international programs. Such collaborations include acoustic monitoring for whales during the Antarctic Circumnavigation Expedition; contribution of metadata to a new IWC working group on southern ocean Fin whales around the West Antarctic Peninsula; contribution of underwater recordings to the IWC working group investigating the potential for acoustic population assessment of Pygmy blue whales; and continued collaboration with the IWC-SORP Antarctic Blue Whale Project.

The project has generated 18 peer-reviewed publications to date and three PhD dissertations were submitted or are nearing completion by students from three different countries, using the ATP data. A full project report is included in Annex 5, pp. 62-72.

*IWC-SORP sincerely thanks the International Fund for Animal Welfare (IFAW) for its generous contribution of 7,519 GBP to facilitate the research conducted during the ACE voyage.*

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

SC/67a/SHXX Bell E (2017) Annual Report of the Southern Ocean Research Partnership 2016/17.

SC/67a/EMXX Friedlaender AS, Heaslip S, Johnston D, Read A, Nowacek D, Durban J, Goldbogen J, Gales N (2017) Differential foraging strategies by sympatric krill predators in a rapidly changing polar environment.

SC/67a/SHXX Herr H, Bell E, Burkhardt E, Butterworth D, Dalla Rosa L, Donovan G, Findlay K, Friedlaender A, Iñíguez M, Jackson J, Kelly N, Miller B, Olson P, Pérez-Alvarez MJ, Reyes V, Rodriguez-Fonseca J, Samaran F, Širović A, Williams R, Zerbini A (2017) Southern Hemisphere Fin Whales: review of available data.

SC/67a/SHXX Herr H, Bell E, Burkhardt E, Butterworth D, Dalla Rosa L, Donovan G, Findlay K, Friedlaender A, Iñíguez M, Jackson J, Kelly N, Miller B, Olson P, Pérez-Alvarez MJ, Reyes V, Rodriguez-Fonseca J, Samaran F, Širović A, Williams R, Zerbini A (2017) Southern Hemisphere Fin Whales: development of a study proposal for the West Antarctic Peninsula.

SC/67a/SHXX Melcon M et al. (2017) Visual and acoustic records of sperm whales during the SORP cruises from 2014-2017 through the Western Antarctic Peninsula.

SC/67a/SHXX Miller B, Miller E, Calderan S, Leaper R, Stafford K, Širović A, Rankin S, Findlay K, Samaran F, Van Opzeeland I, McCauley R, Gavrilov A, Harris D, Gedamke J, Bell E, Andrews-Goff V, Double M (2017) Circumpolar acoustic mapping of endangered Southern Ocean whales: Voyage report and preliminary results for the 2016/17 Antarctic Circumnavigation Expedition.

SC/67a/XXYY Olson P, Findlay K, Venter K, Ensor P Double M, Matsuoka K, Pastene L (2017) Photo-identification of Antarctic Blue Whales: new data from 1980-2014.

SC/67a/OXX Penfold K (2017) [IWC-SORP Research Fund] Financial position to 31st March 2017.

SC/67a/SHXX Samaran F, Berne A, Leroy E, Marcia M, Royer JY, Stafford K (2017) Antarctic blue whales (*Balaenoptera musculus intermedia*) recorded north of the Equator in the Atlantic Ocean.

SC/67a/SHXX Samaran F, Stafford K, Miller B, Van Opzeeland I, Findlay K, Harris D, Širović A (2017) Report of the Meeting of the Acoustic Trends Steering Group. 5-8 May 2017. Bled Slovenia.

SC/67a/SHXX Sremba AL, Pitman R, Wilson P, Martin AR, Jackson J, Baker CS (2017) Species identification of whale bones from former whaling stations of South Georgia and the Antarctic Peninsula by mtDNA barcoding.

SC/67a/Forinfo04 Thomisch K, Boebel O, Clark CW, Hagen W, Spiesecke S, Zitterbart DP, Van Opzeeland I (2016) Spatio-temporal patterns in acoustic presence and distribution of Antarctic blue whales *Balaenoptera musculus intermedia* in the Weddell Sea. Endangered Species Research 30: 239-253.

SC/67a/Forinfo Weinstein B, Friedlaender AS (*In press*) Dynamic foraging of a top predator in a seasonal polar marine environment. Oecologia.

SC/67a/Forinfo Weinstein B, Johnston D, Double M, Friedlaender AS (2017) Identifying overlap between humpback whale foraging grounds and the Antarctic krill fishery. Biological Conservation 210: 184-191.

**IWC-SORP RELATED PAPERS SUBMITTED TO SC IN PREVIOUS YEARS**

SC/61/SH17 Gales N, Double M, Robinson S, Jenner C, Jenner M, King E, Gedamke J, Paton D, Raymond, B. (2009) Satellite tracking of southbound East Australian humpback whales (*Megaptera novaeangliae*): challenging the feast or famine model for migrating whales.

SC/62/SH3 Garrigue C, Peltier H, Ridoux V, Franklin T, Charrassin J-B (2010) CETA: a new cetacean observation program in East Antarctica.

SC/63/O12 Childerhouse S (2011) Annual Report of the Southern Ocean Research Partnership 2011.

SC/63/O13 Childerhouse S (2011) Southern Ocean Research Partnership Revised project plans.

SC/63/SH16 Constantine R *et al.* (2011) Comprehensive photo-identification matching of Antarctic Area V humpback whales.

SC/63/SH10 Steel D et al. (2011) Initial genotype matching of humpback whales from the 2010 Australia/New Zealand Antarctic Whale Expedition (Area V) to Australia and the South Pacific.
SC/64/O13 Bell E (2012) Annual Report of the Southern Ocean Research Partnership 2011/12.
SC/64/O14 Baker CS, Galletti B, Childerhouse S, Brownell RL Jr, Friedlaender A, Gales N, Hall A, Jackson J, Leaper R, Perryman W, Steel D, Valenzuela L and Zerbini A (2012) Report of the Living Whales Symposium: Advances in non-lethal research techniques for whales in the Southern Hemisphere.
SC/64/SM06 Chambellant M, Garrigue C, Peltier H, Charrassin JB, Ridoux V (2014) First photo-ID catalogue of killer whales (*Orcinus orca*) in East Antarctica.
SC/64/IA10 Kelly N, Murase H, Kitakado T, Kock K-H, Williams R, Feindt-Herr H and Walløe L (2012) Estimating abundance and distribution of Antarctic minke whales within sea ice areas: data requirements and analysis methods.
SC/64/SH10 Kelly N, Miller B, Peel D, Double MC, de la Mare W and Gales N (2012) Strategies to obtain a new circumpolar abundance estimate for Antarctic Blue Whales: survey design and sampling protocols.
SC/64/SH11 Miller BS, Kelly N, Double MC, Childerhouse SJ, Laverick S and Gales N (2012) Development of acoustic methods: cruise report on SORP 2012 Antarctic Blue Whale voyages.
SC/64/SH12 Miller BS (2012) Real-time tracking of Blue Whales using DIFAR sonobuoys.
SC/64/SH13 Wadley V, Lindsay M, Kelly N, Miller N, Gales N, de la Mare W and Double MC (2012) Abundance estimation of Antarctic Blue Whales: preliminary voyage plan for SORP in March 2013.
SC/64/SH14 de la Mare WK (2012) Estimating relative abundance from historic Antarctic whaling records.
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## ANNEX 1 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2015/16

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

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[6]*Instituto Baleia Jubarte, Brazil*
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[8]*NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA, USA*
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[11]*British Antarctic Survey, Cambridge, UK*

#### 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 2016/17

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, identification of whales from platforms of opportunity, and proposals to secure ship-time for future research voyages.

***2017 "Prefecto García" voyage to the Western Antarctic Peninsula - Vanesa Reyes Reyes, Marta Hevia, Alexander Marino, J Hurwitz, Simone Baumann-Pickering, John Hildebrand, Mariana Melcón, Ana Širović, Jennifer Trickey, 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, four 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 GC-189 "Prefecto García" between 12 January and 4 February, 2017, 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 80 h and 6,651 nm (Figure 1).

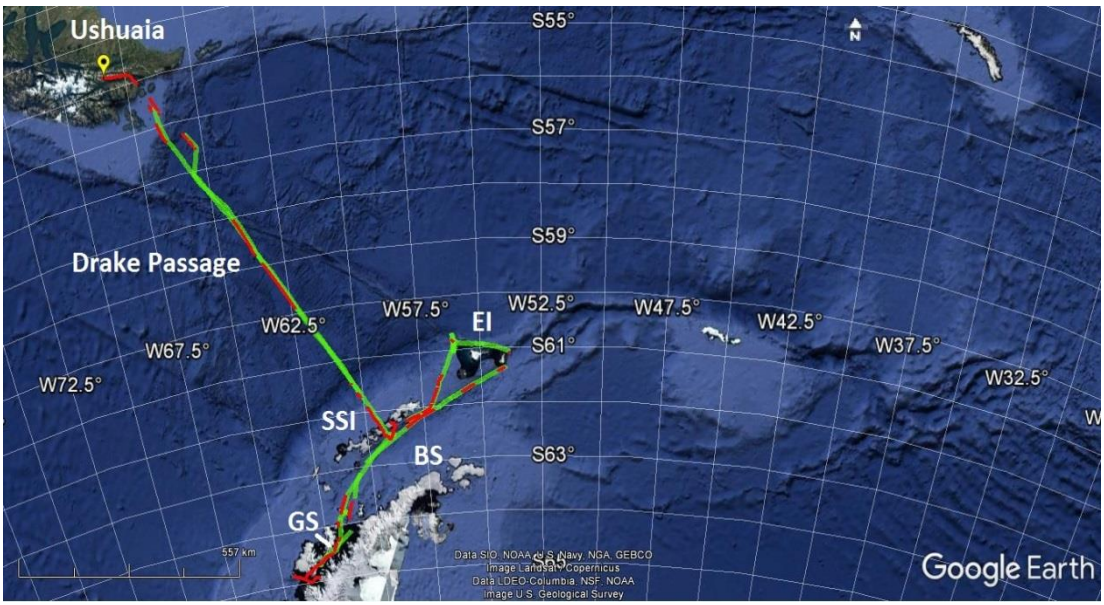


**Figure 1** On-effort visual (red lines) and acoustic tracks using a towed hydrophone array (green lines). SSI: South Shetland Islands/Islas Shetland del Sur; EI: Elephant Island/Isla Elefante; BS: Bransfield Strait/Mar de la Flota; GS: Gerlache Strait/Estrecho de Gerlache.

On-effort cetacean sightings included three odontocete and four mysticete species, encompassing a total of 156 encounters (Table 1; Figure 2).

**Table 1** Total number of individuals sighted for each species, total number of sightings, and group sizes.

| Scientific name | Common name | Number of sightings | Number of individuals | Group size | |
|---|---|---|---|---|---|
| | | | | Range | Mean ± SD |
| *Balaenoptera physalus* | Fin whale | 7 | 11 | 1-2 | 1.6 ± 0.5 |
| *Balaenoptera borealis* | Sei whale | 2 | 3 | 1-2 | 1.5 ± 0.7 |
| *Balaenoptera acutorostrata* | Minke whale | 5 | 7 | 1-2 | 1.4 ± 0.5 |
| *Megaptera novaeangliae* | Humpback whale | 109 | 220 | 1-21 | 2 ± 2.1 |
| Unidentified cetacean | Unidentified cetacean | 3 | 3 | 1-1 | 1 ± 0 |
| Unidentified Balaenopteridae | Unidentified Balaenopteridae | 8 | 11 | 1-2 | 1.4 ± 0.5 |
| Unidentified mysticete | Unidentified mysticete | 4 | 5 | 1-2 | 1.3 ± 0.5 |
| *Ornicus orca* | Killer whale | 5 | 17 | 1-6 | 4.3 ± 2.2 |
| *Lagenorhynchus australis* | Peale's dolphin | 5 | 14 | 1-4 | 2.8 ± 1.1 |
| *Lagenorhynchus obscurus* | Dusky dolphin | 7 | 25 | 1-9 | 3.6 ± 3.2 |

A total of 167 h of acoustic recordings were collected with the towed hydrophone array. Detections included sounds recorded during an encounter with five Antarctic type B killer whales, and another encounter containing clicks from an unidentified odontocete species (Figure 2).

In addition, acoustic recordings were collected with a dipping hydrophone from a small boat in the presence of minke and humpback whales in Bahía Paraíso and Caleta Cierva. Recordings will be analysed in the future.
On 23 January 2017, the HARP deployed in February 2016 was recovered and refurbished, and was redeployed nearby Elephant Island (60° 52.136'S, 56° 00.628'W) the following day. The recovered HARP recorded continuously over ten months (February-December 2016) at a sampling rate of 200 kHz, obtaining recordings from 10 to 100,000 Hz.

Acoustic data collected during that period and from February 2015 through January 2016 with a HARP located at 61° 27.469´ S, 57° 56.515´ W is being analysed. Results on sperm whales (SC/67a/SHX) will be presented during the SC67a meeting. A peer-reviewed paper on beaked whale acoustic presence at three recording sites in the South Shetland Islands/Islas Shetland del Sur is being prepared. Data on the seasonal distribution of sei, fin and blue whales will be analysed during this year and presented at the SC67b meeting.

High frequency modulated signals produced by killer whales in the north-western Antarctic Peninsula were characterized. Signals consisted of down-sweeps with 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 ms. Antarctic type A killer whales might be the most probable candidate for these signals but a visual confirmation is still needed. A peer-reviewed paper on these results was submitted for publication in the special issue "Sound in the Southern Seas" of the Acoustics Australia journal.

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

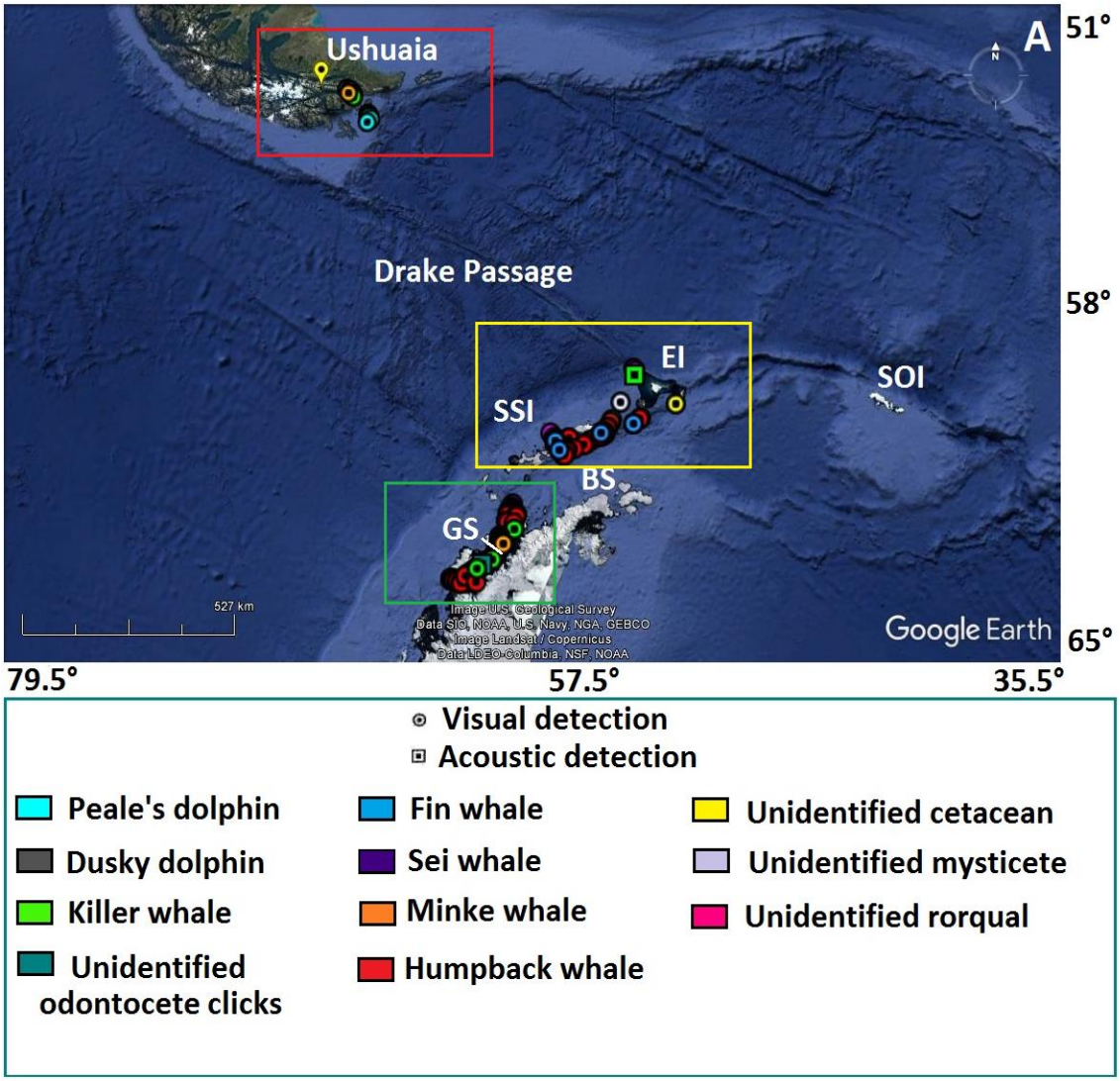
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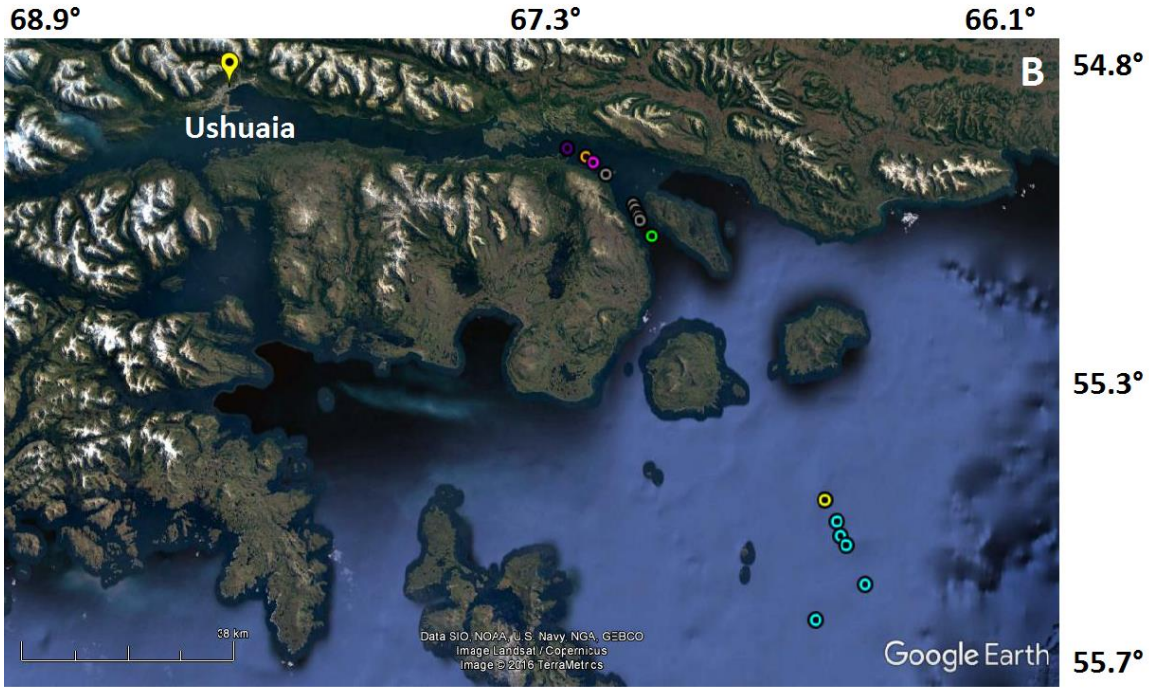
Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
Google Earth
65°
79.5°
57.5°
35.5°
Visual detection
Acoustic detection
Peale's dolphin
Dusky dolphin
Killer whale
Unidentified odontocete clicks
Fin whale
Sei whale
Minke whale
Humpback whale
Unidentified cetacean
Unidentified mysticete
Unidentified rorqual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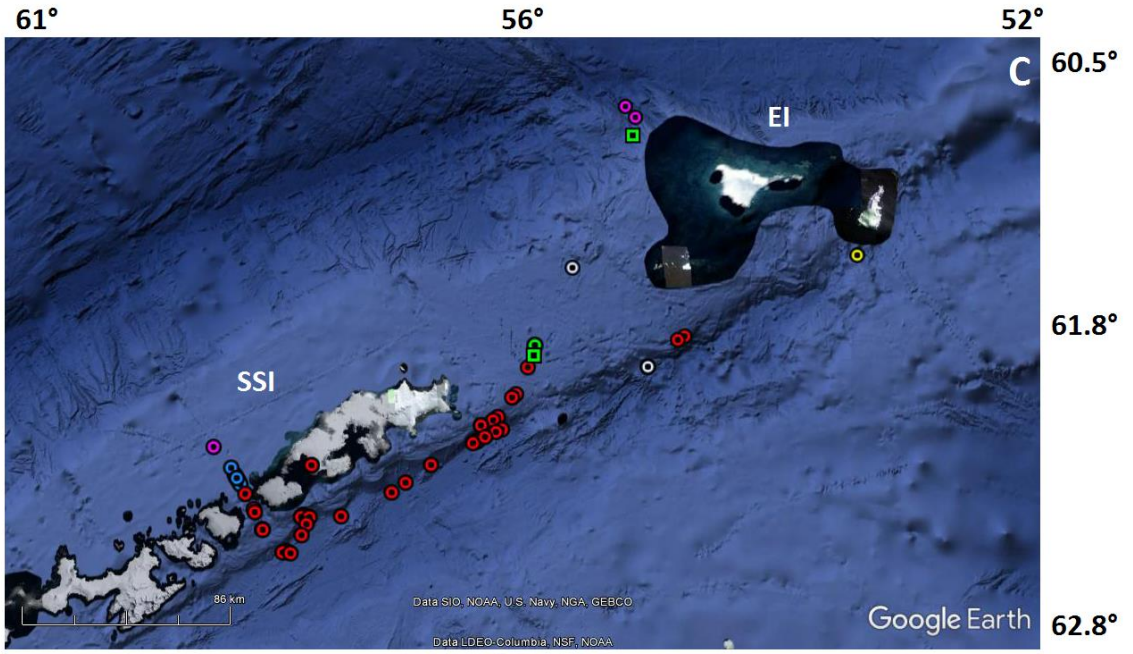
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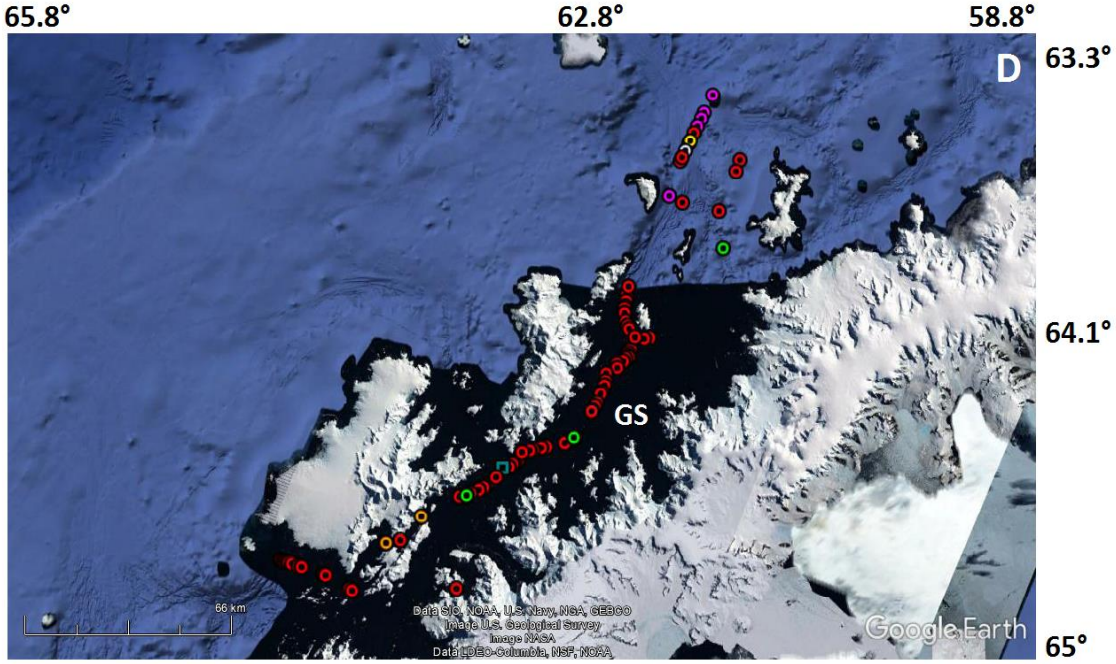


**Figure 2** Cetacean sightings (circles) and acoustic detections (squares) using a towed hydrophone array from the deck of the Argentinean Coast Guard (Prefectura Naval Argentina) cutter GC-189 "Prefecto García" between 12 January and 4 February, 2017 (A). Close-up of red (B), yellow (C) and green squares (D) in panel A. SSI: South Shetland Islands/Islas Shetland del Sur; EI: Elephant Island/Isla Elefante; BS: Bransfield Strait/Mar de la Flota; GS: Gerlache Strait/Estrecho de Gerlache; SOI: South Orkney Islands/Islas Orcadas del Sur.

Further results from the 2017 voyage of the *Perfecto García* are presented in SC/67ba/SHXX.

Challenges

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

Outlook for the future

A fifth voyage aboard an Argentinean vessel to the western Antarctic Peninsula is planned for the austral summer season 2018 and we expect to include genetic sampling. Analysis of acoustic data collected with the HARP during 2016 will be completed in order to assess the seasonal distribution of blue whales, fin whales, killer whales, sperm whales, beaked whales, and possibly other cetaceans.

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

Analysis of data collected during the 2015 New Zealand-Australia Antarctic Ecosystems Voyage has continued during 2016/17. Investigation of passive and active acoustic data from the 2015 voyage has focused on development of methods to quantify the distribution and density of Antarctic blue whales during the voyage for comparison with the distributions of krill measured on the voyage. Additionally, manual validation of all Antarctic blue whale calls from a subset of 56 hours of passive acoustic data from the 2015 voyage has been conducted yielding 6420 identified low-frequency sounds, most of which were blue whale calls. These annotated data will serve as a test-data set for characterising the performance of automated algorithms for detection and classification of the calls of Antarctic blue whales. Funding was received from the IWC-SORP Research Fund to continue these analyses and publish manuscripts in 2017/18.

***Photo-identification of Antarctic blue whales – Paula Olson, Paul Ensor***

Introduction

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, 2016). 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 key component of the Antarctic Blue Whale Project (Bell, 2016).

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 416 individual blue whales in the circumpolar Antarctic (Olson et al. 2016). 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, new photographs of Antarctic blue whales became available from the South African Antarctic Blue Whale Survey (Findlay et al., 2014) and from the personal files of Paul Ensor (Cruise Leader, IWC/SOWER). This project identified and compared individual identification photographs of Antarctic blue whales from the new collections with the Antarctic Blue Whale Catalogue. The addition of newly identified individuals and will increase the sample size needed to conduct a capture-recapture analysis.

Objectives

1. Compare identification photos of Antarctic blue whales collected during the 2013/2014 South African Antarctic Blue Whale Survey (Findlay et al., 2014) with the Antarctic Blue Whale Catalogue. Will work in collaboration with Dr. Ken Findlay regarding the results of the photo comparisons and the inclusion of the newly identified whales into the Antarctic Blue Whale Catalogue.

2. Identify individual Antarctic blue whales from personal slide photographs collected by Paul Ensor during the IWC/SOWER cruises 1980/1981 to 2004/2005. Compare the identified individuals from these new 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

Paul Ensor contributed 167 personal photographs, collected during 10 IWC/SOWER seasons from 1980/81 through 2004/2005. The photographs yielded 10 ID's: 9 newly identified blue whales and 1 previously identified blue whale (Table 2). This was not a resight; Ensor's photo was taken at the same time as the identification photo already in the Catalogue. The new ID photos were collected from 5 of the 6 Management Areas (all but Area II).

**Table 2** Number individual Antarctic blue whales identified from Ensor's photo collection and from the South African Antarctic Blue Whale Survey (SAABWS).

| Year | IWC Area | No. of photos | No. left side ID's | No. right side ID's | Total no. identified blue whales | Comments |
|---|---|---|---|---|---|---|
| **ENSOR** | | | | | | |
| 1980/1981 | V | 11 | 1 | 1 | 2 | |
| 1984/1985 | IV | 7 | 1 | 0 | 1 | |
| 1987/1988 | III | 20 | 1 | 1 | 1 | |
| 1988/1989 | Australia* | 14 | 0 | 0 | 0 | *Pygmy blue whales |
| 1989/1990 | I | 11 | 1 | 1 | 1 | |
| 1993/1994 | I | 7 | 0 | 0 | 0 | |
| 1994/1995 | IIE/IVW | 45 | 3 | 1 | 4 | |
| 1995/1996 | VI | 17 | 0 | 0 | 0 | |
| 1998/1999 | IV | 23 | 1 | 0 | 1* | *Previously ID'd whale #9901 |
| 2004/2005 | III | 12 | 0 | 0 | 0 | |
| ENSOR TOTAL | | 167 | 8 | 4 | 10 | |
| **SAABWS** | | | | | | |
| 2014 | III | 3,150[2] | 13 | 11 | 16 | |
| **GRAND TOTAL** | | | 21 | 15 | 26 | |

Sixteen individual blue whales were identified from photographs collected during the 2014 South African Antarctic Blue Whale Survey (Findlay et al., 2014) conducted in Management Area III (Table 2). This included 13 left side and 11 right side photos. One whale was re-sighted after a 3-day interval. There were no matches to the Antarctic Blue Whale Catalogue, resulting in 16 new ID's.

The total of 25 new ID's from these two photo collections brings the total number of photo-identified Antarctic blue whales up to 441 whales, represented by 336 left sides and 321 right sides. The minimum (321) and maximum (441) number of unique individuals represents 15% and 19%, respectively, of the most recent accepted estimate of abundance of Antarctic blue whales, 2,280 in 1997/1998 (Branch, 2007).

Conclusions

With the addition of 25 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% (14/441). There is evidence that the Antarctic blue whale population has indeed been increasing (Branch, 2007) which would explain the low re-sighting rate. Notable in the present study is that there were no re-sighted whales among the 16 whales identified in Area III during the South African survey in 2014. Area III has the largest representation in the Catalogue of identified whales with 184 individuals (before the present study), more than any other Area.

[2] Reported in Findlay *et al*., 2014.

The photographs from the 1980's and 1990's are a valuable contribution to the Catalogue; a future recapture of any of the identified whales from these decades 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).

More details from this project are presented in detail in Olson et al. SC/67a/XXYY.

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.

2. Finalise 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. 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, Robert Pitman, Peter Wilson, Robert Pitman, A Martin, Jennifer Jackson, C. Scott Baker***

The 20th century commercial whaling industry reduced great whale populations to low abundances in the Southern Hemisphere. The Antarctic blue whale population was probably reduced to less than 1% of its original abundance. The effect of this exploitation on this population has been explored through comparisons of historical and contemporary genetic diversity (Sremba et al. 2012, Sremba et al. 2015). From bones collected near former whaling stations on the South Atlantic island located between 54.4296°S and 36.5879°W, we have identified 11 mitochondrial DNA (mtDNA) haplotypes no longer found in the contemporary population. Here, we update our previous sampling with the species identification of whale bones from the Antarctic Peninsula and the South Atlantic island located between 54.4296°S and 36.5879°W, collected in February 2016. Using conventional PCR and mtDNA control region sequencing, we identified 37 humpback whales, 14 blue whales, 16 fin whales, 1 minke whale and 1 sperm whale. With funding from the Southern Ocean Research Partnership (IWC-SORP) the 14 blue whale bones will be used for Next Generation Sequencing to further characterize pre-whaling genomic diversity. More details are provided in Sremba et al. SC/67a/SHXX.

Challenges

The extraction of historical/ancient DNA has required considerable laboratory effort and the assembly of the next-generation sequencing has required considerable bioinformatics development. To validate the protocols used in the study, the PhD student and co-investigator Angie Sremba travelled to the Paleogenomcis lab at University of California Santa Cruz (UCSC) to review progress and seek advice from leading experts in the field, Professors Beth Shapiro and Ed Green. With this guidance, she has now developed a robust data pipeline for NGS sequence processing and assembly of mitogenomes from the ancient DNA. Sremba also travelled to the Southwest Fisheries Science Center, for collaboration with Aimee Lang, Brittany Hancock and Phil Morin at the Southwest Fisheries Science Center, for comparison to mitogenomes and nuclear loci from contemporary populations (see below).

Outlook for the future

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.

We plan to apply for funding for the continuation of this project. We plan to compare historical and contemporary nuclear diversity in the Antarctic blue whale by developing short- nuclear fragments to target in both the historical and contemporary population using a highly multiplex PCR, such as the GTSeq (Campbell et al. 2015). For the development of the nuclear markers, we will reconstruct a genome of the historical Antarctic blue whale to compare to the near complete blue whale genome (pers. communication P. Morin).

We also plan to continue to collect whale bone samples from the South Atlantic island located between 54.4296°S and 36.5879°W and the Antarctic Peninsula using active permit.

**Project outputs**

*Peer-reviewed papers*

Calderan S, Miller B, Collins K, Ensor P, Double M, Leaper R, Barlow J (2014) Low-frequency vocalizations of sei whales (*Balaenoptera borealis*) in the Southern Ocean. Journal of the Acoustical Society of America 136:EL418

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*Book chapters*

Melcón M, Reyes Reyes V, Iñíguez M (In Press) 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.

*Theses*

Douglas C (2017) Investigation of blue whale (*Balaenoptera musculus intermedia*) diving behaviour in a patchy krill (*Euphausia superba*) landscape. Honours Thesis, University of St Andrews, Scotland, United Kingdom.

*Conference presentations*

Calderan S, Miller BS (2015) Using PAMGuard and DIFAR sonobuoys to locate baleen whales: The PAMGuard DIFAR Module. Workshop conducted at the NOAA/NMFS Southwest Fisheries Science Center, 12 July, La Jolla CA, United States.

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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van der Linde, M, Schmitt, N, Double, MC (2015) New Zealand blue whales: residency, distribution, and feeding behavior of a little-known population. Oral presentation at the Biennial Conference on the Biology of Marine Mammals, San Francisco, CA, USA, December 13-18 2015.

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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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*Popular articles*

Cahalan S (2013) Protecting the icons of the deep. International Innovation: Environment April 2013.
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 2015/16**

**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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*[6] Gateway Antarctica, University of Canterbury, Private bag 4800, Christchurch, New Zealand*
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*[8]Ministry for Primary Industries, Wellington, New Zealand*

**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 2016/17**

***Robert Pitman and John Durban, McMurdo Sound and west Antarctic Peninsula***

Introduction

Since 2009, Pitman and Durban have annually conducted research on killer whales in Antarctic waters, mainly in the Antarctic Peninsula area on board the National Geographic Explorer (supported by Lindblad Expeditions/National Geographic Society), but also in the southern Ross Sea (McMurdo Sound). To date we have described five morphologically distinct types of killer whales from Antarctic waters (Pitman and Ensor, 2003; Pitman et al. 2007; Pitman et al. 2011, Durban et al. 2016), including three sympatric types in the coastal waters of the Antarctic Peninsula. In 2016 work continued to investigate the systematics and ecology of these different types using satellite tagging, photo-identification, biopsy sampling, acoustic recordings, focal-follow behavioural studies and aerial photogrammetry using a hexacopter.

Objectives

Our main objectives are to describe killer whale diversity and abundance in Antarctica and to quantify their overall impact through trophic interactions within the Antarctic ecosystem. Our research methods include compiling observations of foraging behaviour and prey preferences (Pitman and Durban 2010, 2012), school sizes, and habitat associations; 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) and chemical analyses to infer diet (Krahn et al. 2008), deploying satellite tags to learn of about movements and diving behaviour (Andrews et al. 2008; Durban and Pitman 2012); and photographing individuals to estimate their abundance and demography (e.g., Durban et al. 2010; Fearnbach et al. 2012), study movements and residency times (e.g., Durban et al. 2000), and estimate life history parameters.

Results

A total of 442 individual Type C killer whales have been identified from photographs of killer whales in McMurdo Sound. It is thought that there may now be enough historical images dating back to 2002 to allow us to determine if a postulated decline in McMurdo killer whale population (due to toothfish fishing in the Ross Sea) has in fact occurred.

***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. Although research focused mainly on humpback whales until recently, data on killer whale distribution and relative abundance have been collected throughout, along with photo-identification data.

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 2017, 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 550 nautical miles of cetacean search effort was conducted, resulting in 286 on-effort sightings of five cetacean species. Four sightings corresponded to killer whales (3 type B and 1 type A), totaling about 100 individuals. Over 3,000 photographs were taken for individual identification, and five biopsy samples were obtained. These photographs are currently under analyzes, but contain at least 40 type B and 10 type A individuals. Our killer whale photo-identification catalogue should be updated by the end of April, when it will be shared with other colleagues for the purposes of this SORP project's collaborative efforts on abundance estimation of all killer whale ecotypes.

In addition, one LIMPET-SPLASH satellite tag was deployed on an adult male type A killer whale in the Bransfield Strait on March 6th (Figure 1). As of April 1st the tag is still transmitting, and the whale is heading north (Figure 2).

**Figure 1** Type A killer whale instrumented with a LIMPET-SPLASH satellite transmitter on 6 March 2017, off King George Island, northern Antarctic Peninsula.

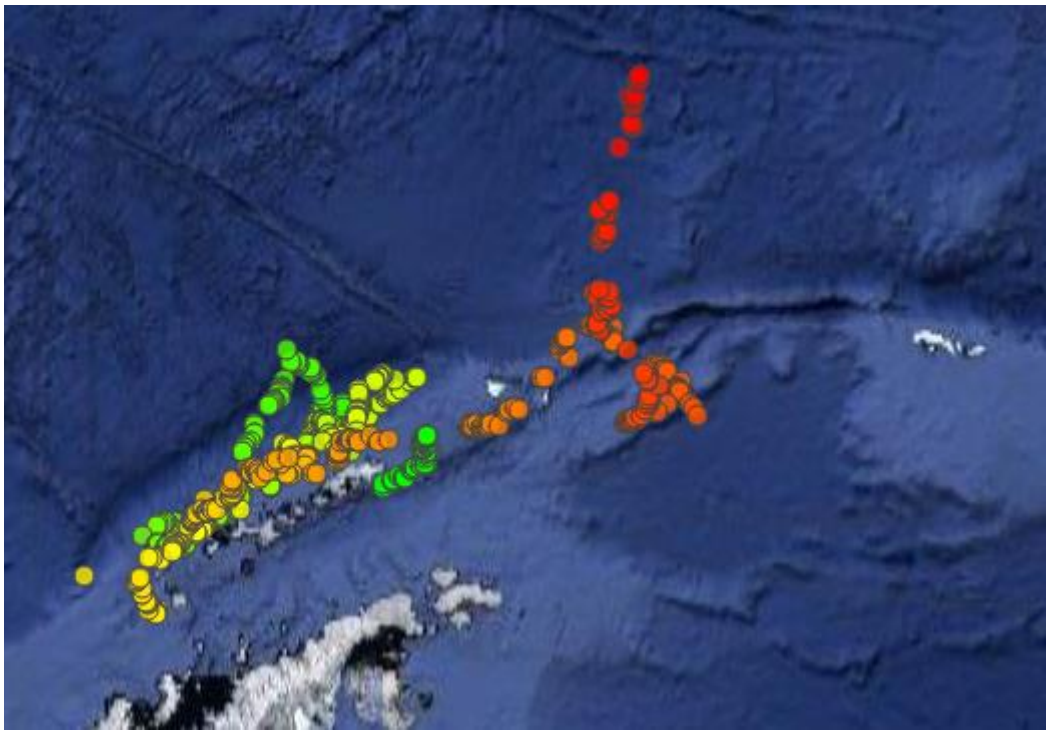


**Figure 2** Movements of a type A killer whale instrumented with a LIMPET-SPLASH satellite transmitter between March 6th and April 1st, 2017.

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 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 organisation.

Building on, and set within, our existing long-term killer whale research at Marion Island, here we seek to address three objectives related to movement and foraging ecology here we report on our killer whale work at Marion Island within the multifaceted programme that includes, but is not restricted to IWC-SORP support. We have used satellite tagging, biopsy sampling and photo-ID to address the social organization, population structure, movement, diving and diet of a population of killer whales. The project's image database contains ~73,000 images and 62 individuals have been identified. Over 4 years, 26 satellite tags have been deployed and these have revealed seasonal site fidelity as well as rapid, long-distance movements and deep diving over seamounts. 49 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-ID association data, has shown that Marion Island killer whales form small, fairly stable social units.

Objectives

The new objectives will be more specifically reported on within the next reporting cycle given that the current cycle of IWC-SORP support allowing for added satellite telemetry work, can only reap results from April 2017 onwards, associated with the ship voyage schedules. Therefore, here we report on our killer whale work at Marion Island within the multifaceted programme that includes, but is not restricted to the IWC-SORP support. Previous, and continuing objectives with direct relevance to new objectives reported on here:

- 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
- 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*

- ~73,000 images to date
- 62 unique individuals identified

| | 2008-2011 | 2011-2012 | 2012-2013 | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017* | All (2008-2017) |
|---|---|---|---|---|---|---|---|---|
| ***Observation sessions*** | | | | | | | | |
| Number | 481 | 210 | 273 | 231 | 216 | 170 | 196 | 1777 |
| Hours | 2,511 h | 1,145 h | 1,846 h | 1,380 h | 1,247 h | 916 | 951h | 9996 h |
| ***Sightings*** | | | | | | | | |
| Dedicated | 406 | 413 | 466 | 399 | 402 | 217 | 149 | 2452 |
| Opportunistic | 670 | 270 | 265 | 153 | 273 | 123 | 108 | 1862 |
| ***Images*** | | | | | | | | |
| Dedicated | 9,160 | 5,354 | 7,833 | 6,288 | 8,313 | 6453 | 6224 | 49625 |
| Opportunistic | 6,420 | 5,803 | 2,346 | 876 | 4,639 | 1918 | 1177 | 23179 |
| ***Tagging*** | | | | | | | | |
| Attempts | - | 25 | 7 | 10 | 6 | 0 | 2 | 50 |
| Successful | - | 10 | 6 | 6 | 2 | 0 | 2 | 26 |
| Tags lost (without transmitting) | - | 6 | 1 | 4 | 0 | 0 | 0 | 11 |
| Duration (average) | - | 7.5 d | 26.6 d | 8.2 d | 5.9 d | 0 | 30 d | 78.2 |
| ***Biopsy*** | | | | | | | | |
| Attempts | - | 63 | 9 | 18 | 15 | 9 | 14 | 128 |
| Samples | - | 24 | 5 | 6 | 6 | 7 | 8 | 56 |

*To 2017/03/15

*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 40 individuals, creating a weighted association network. There was strong social differentiation among individuals, with clearly preferred long-term associations between

individuals. Using a community detection algorithm, we defined 9 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. Fully reported in Reisinger et al. (2017).

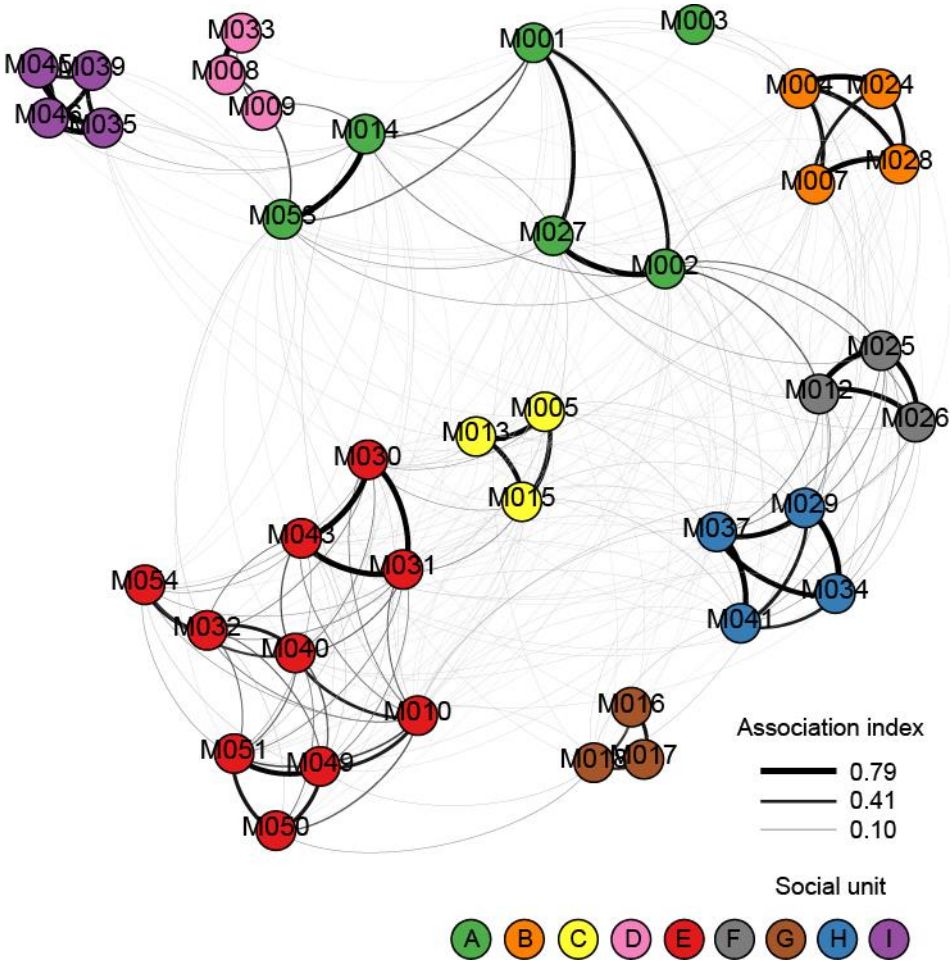



**Figure 3** Network graph showing the associations between killer whales at Marion Island. Individuals are represented by nodes (coloured circles) and associations by edges (lines) between nodes. Colours represent social units and edges are weighted by the half-weight association index.

*Movement and diving*

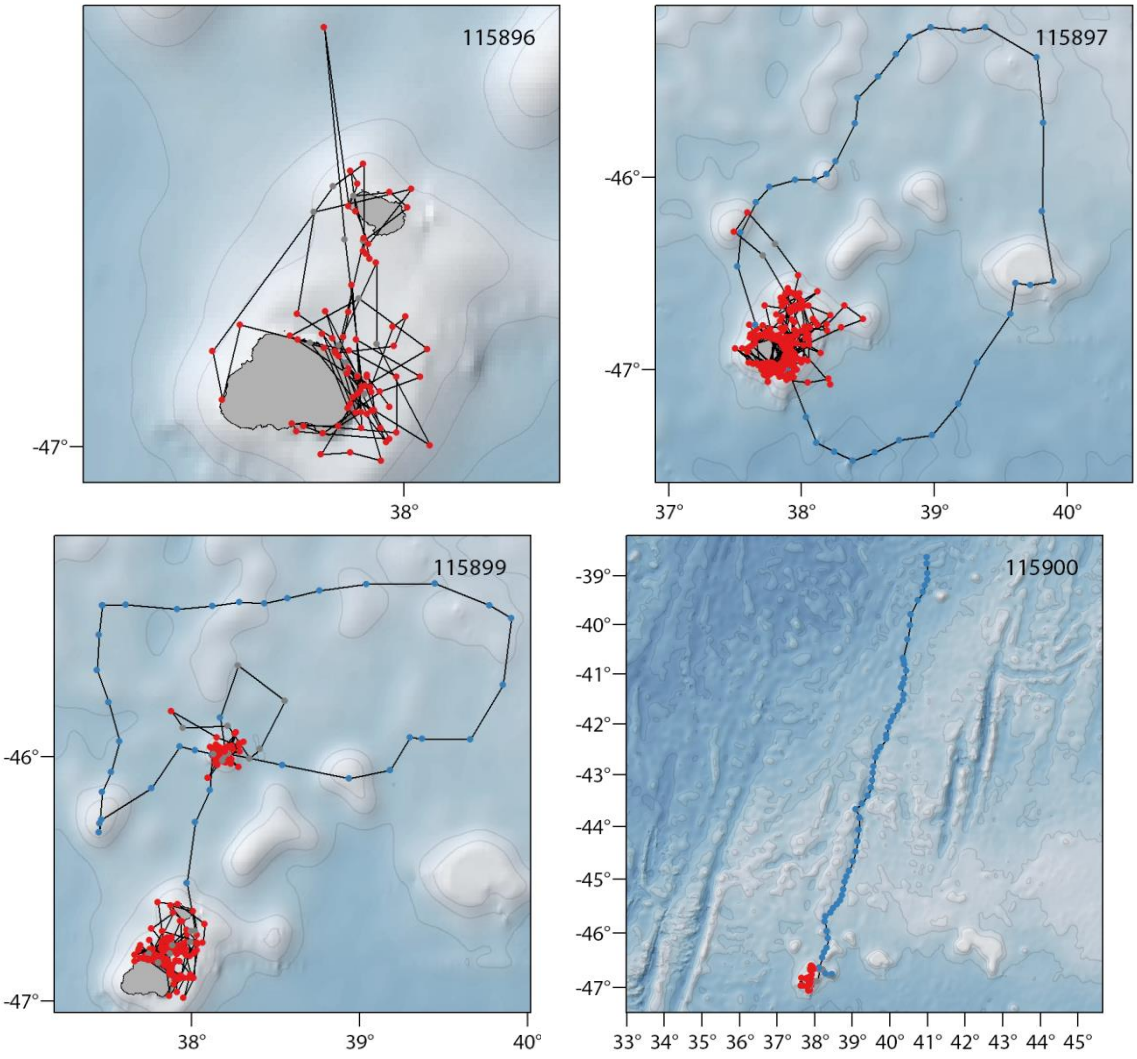
Based on 11 satellite tag deployments on 9 individuals, we used state-space switching models to generate position estimates from Argos location data. We simultaneously estimated two behavioural modes from the data: restricted behaviour and transit behaviour. We also constructed utilization distributions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

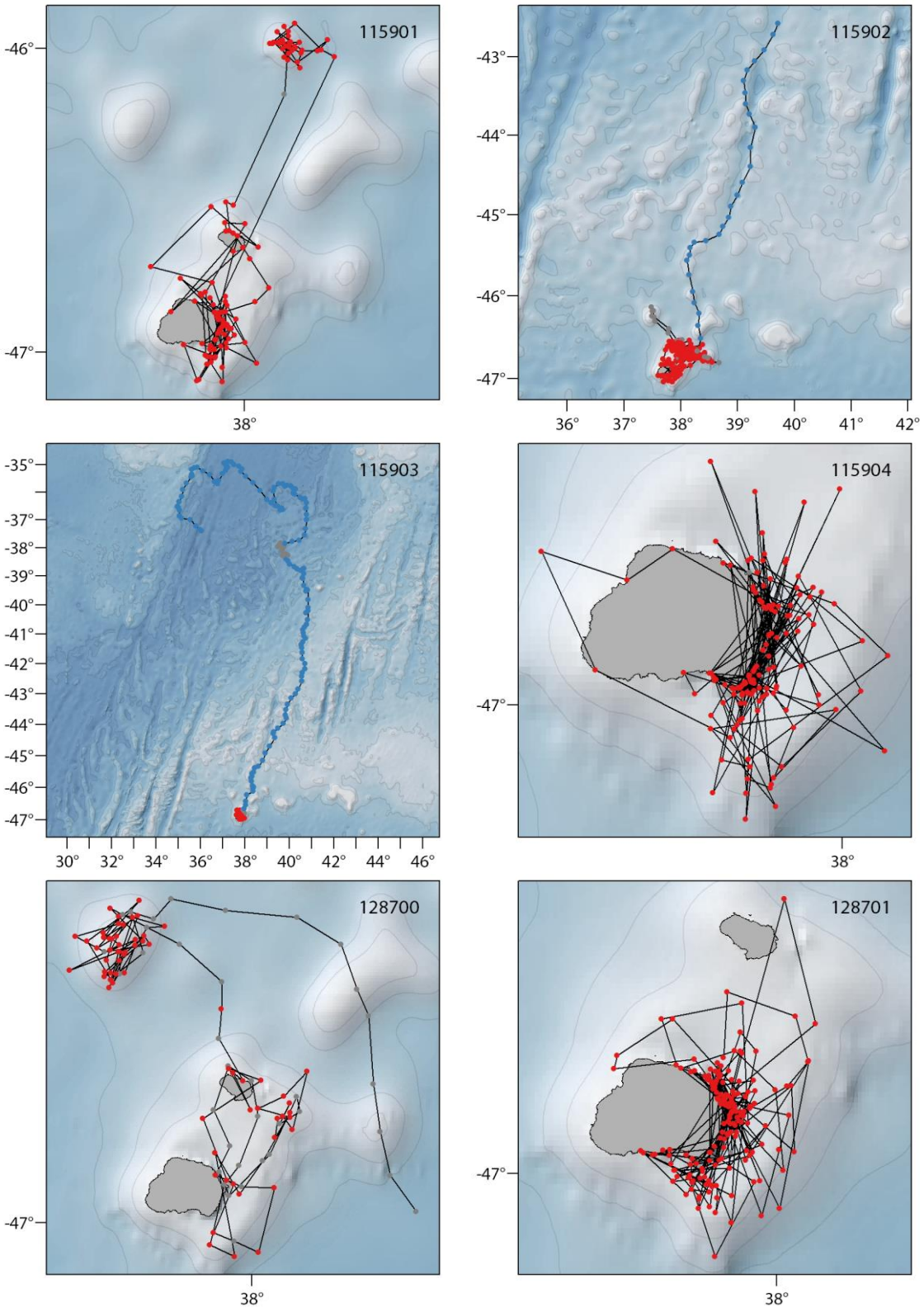
We tracked individuals for 5.6–53.2 days, during which time they moved 416–4,470 km (an average of 82.7 km day-1. Killer whales showed restricted behaviour close to the islands, particularly inshore (52% of position estimates <5 km from shore) where they can effectively hunt seals and penguins, and at 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. Fully reported in Reisinger et al. (2015).

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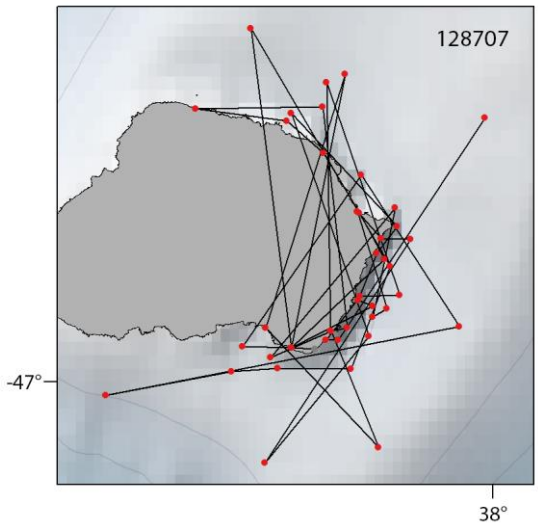


**Figure 4** Individual tracks of satellite-tagged killer whales at Marion Island. Points represent state-space switching model position estimates based on ARGOS position estimates, and are coloured by behavioural mode (red – restricted; blue – transit; grey – uncertain). Solid lines represent straight 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.

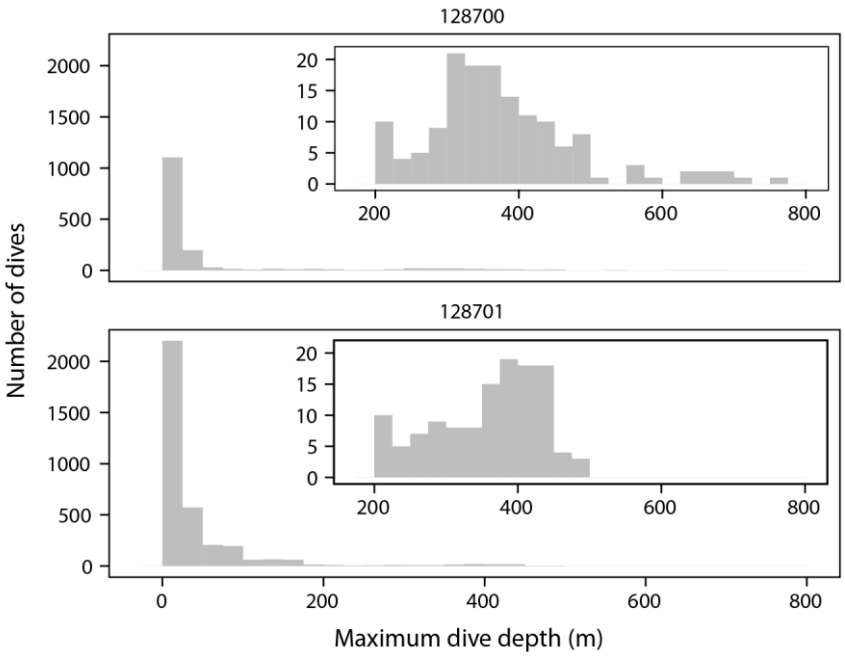


**Figure 5** Histogram showing the distribution of maximum dive depths of two killer whales around Marion Island. The 200–800 m depth range is enlarged in the insets.

*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. 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. Reported in Reisinger et al. (2016).

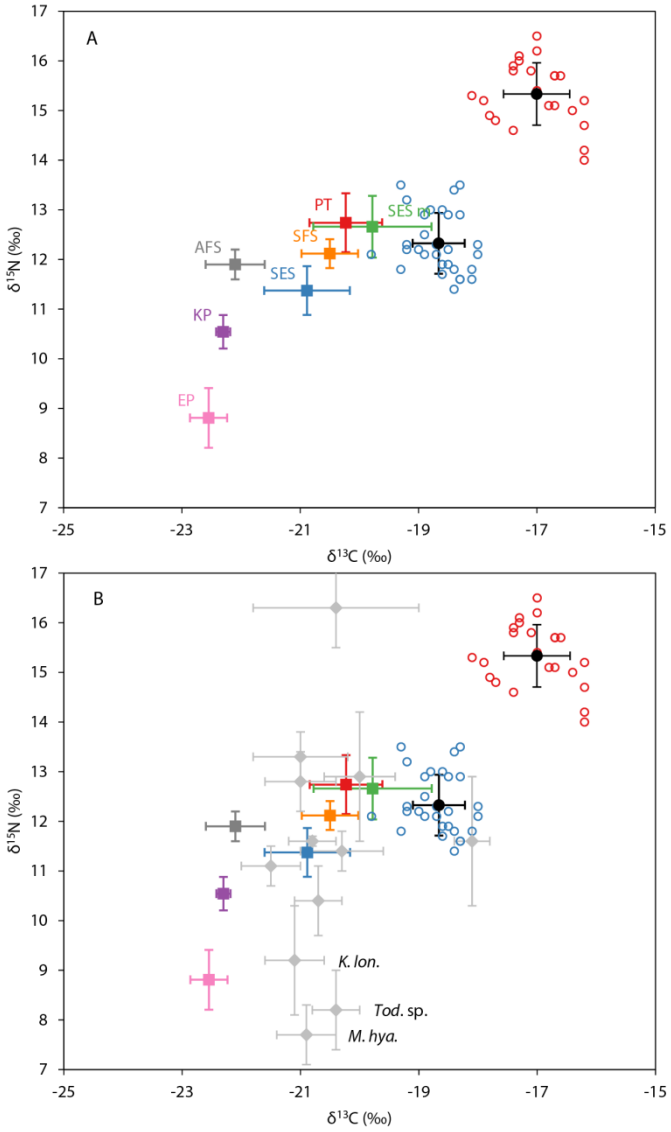


**Figure 6** Biplot of δ13C against δ15N showing mean values ± SD for killer whales (filled circles) and their prey (squares). Individual values for killer whale blubber (red) and skin (blue) are shown with open circles. PT – Patagonian toothfish; AFS – Antarctic fur seal; SFS – Subantarctic fur seal; 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*.

Conclusions

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 (~2 years) 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.
- Satellite tagging will 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. These aspects are of particular relevance for the latest IWC-SORP objectives.
- Quantitative fatty acid analyses need to be performed on blubber samples already in hand, but sampling of putative prey first needs to be improved and this is an expensive aspect.

***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 2016/17 austral summer. However, analysis of data from previous seasons continues 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 2015/16

### 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, have travelled 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 four 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 (IWC-SORP) and we continue to develop both our research methods and collaborative relationships towards this goal.

#### 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 2016-2017 we had a tremendously successful field season and significant analytical output. 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 currently have a team in the field on the LM Gould deploying late season satellite tags and collecting biopsy samples. Overall, we have maintained a constant presence around the Antarctic Peninsula from 1 January – 30 May 2017.

On the LTER research voyage, colleagues from Duke University collected biopsy samples and flew UAS (unmanned aerial systems) missions over humpback whales for photogrammetry purposes. The images from this work will be utilized to generate accurate length and girth estimates for each whale that can be linked to biopsy samples to determine sex and pregnancy status. We will then compare body condition measurements from whales throughout the feeding season to better understand when whales are growing and putting on weight. This can then be linked to current as well as previous environmental conditions to determine the impacts that variability in the system (e.g. sea ice cover) has on baleen whale growth and behaviour.
At Palmer Station, photo ID and biopsy samples were collected from humpback and minke whales from 1 January – 8 April. Concurrent to this, we performed regular echo sounder surveys of krill abundance so that we can relate the local abundance of whales to changes in the availability of prey locally.

Between February and March, Australian Antarctic Division colleagues (Mike Double and Elanor Bell) joined Ari Friedlaender on One Ocean Expedition trips. Four multi-sensor video recording suction cup tags provided by the World Wildlife Fund were deployed on humpback whales. These tags provide high-resolution sensor data to quantify the underwater dive behaviour of the whales for 24-36 hours. In addition, the tags collect animal-borne video for 6-9 hours to corroborate sensor data and provide a visual experience from the whale's perspective of its environment and behaviour. Additionally, four LIMPET tags were deployed on Antarctic minke whales. This is the second season in a row that we have successfully deployed this number of tags on minke whales, significantly increasing our total number of deployments and data for the species. This resounding success validates and justifies the tremendous value of working from tour ships, One Ocean Expeditions specifically, to augment our data collection.

Additionally on the One Ocean trips, we collected UAS images and video concurrent with biopsy sampling to compare with the similar information collected in January by similar means.

There are several students and researchers currently using the data from this project for a number of purposes and publications:

- Logan Pallin is utilising the biopsy samples and will be completing his Masters at Oregon State University. Logan's work focuses on determining sex ratios and pregnancy rates for humpback whales around the Antarctic Peninsula. He is using samples collected from 2010-2016: over 580 biopsies, an extremely robust data set. Logan will continue this work for his Ph.D. beginning next year with Dr Friedlaender.
- Natalie Mastick completed her Masters thesis focussing on understanding humpback whale foraging strategies including analyses of tag data from the Antarctic Peninsula.
- Dr Ben Weinstein joined Dr Friedlaender's lab as a post-doctoral researcher and is focusing on generating state-space movement models of satellite-tagged humpback whales to compare foraging regions to the krill fishery. Moreover, he is working to understand the dynamic foraging strategies of humpback whales throughout the feeding season.
- Dr. Renee Albertson completed a genetic mixed stock analysis of humpback whales from the Antarctic Peninsula finding supporting evidence for the vast majority of the population that feeds around the Antarctic Peninsula breed off the west coast of Central America.
- A recent post-doctoral researcher, Dr. Trevor Joyce, is working to analyse minke whale satellite tag data in conjunction with similar satellite tag data from different ecotypes of killer whales around the Antarctic Peninsula. The focus of this work is to define the ranges of each type of killer whale and relate these to the distribution and behaviour of Antarctic minke whales in a landscape of fear study.

Selected figures from a number of publications are shown below, highlighting different facets of the research conducted this year.

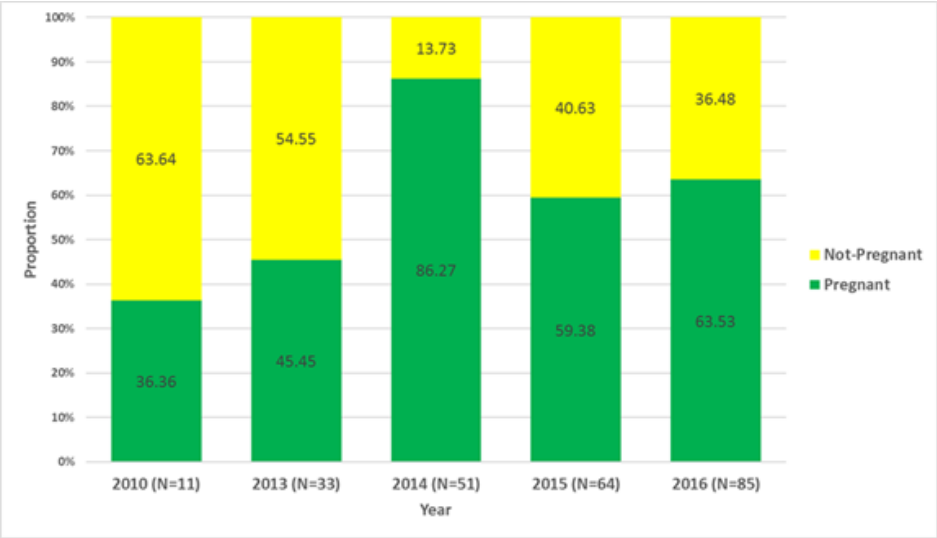


**Figure 1** Pregnancy rates for humpback whales sampled around the Antarctic Peninsula from 2010-2016, showing inter-annual variation and years with extremely high pregnancy rates (2014). From Pallin et al. in prep.

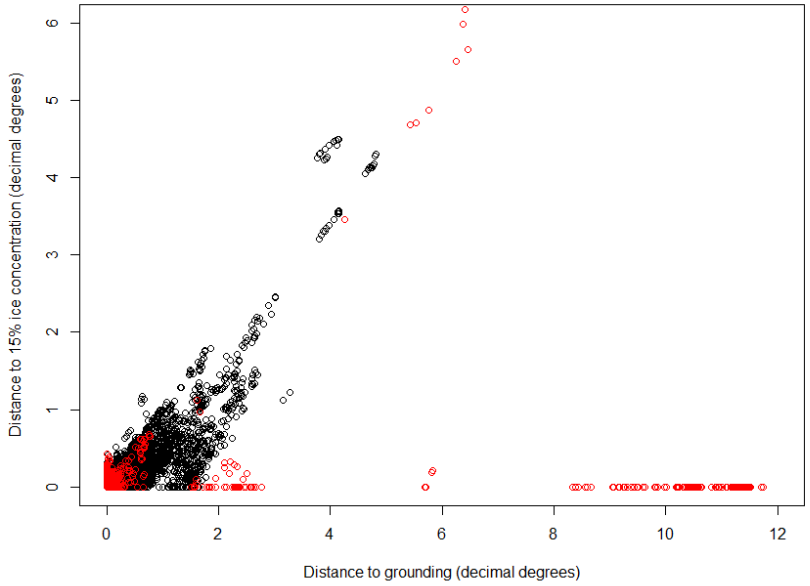


**Figure 2** Species-specific foraging patterns of humpback (black) and minke whales (red) around the Antarctic Peninsula. The graph shows that humpback whales forage in a manner that is not tied to sea ice as their proximity to both sea ice and shore increase concurrently, whereas minke whales increase their proximity from shore while remaining close to the ice edge. Taken from Friedlaender et al., in review.

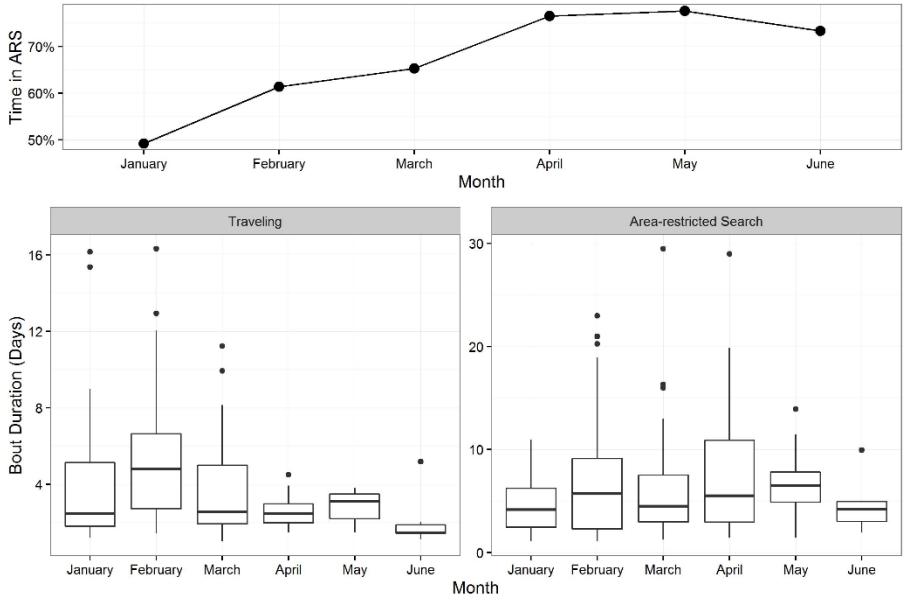


**Figure 3** Seasonal change in the composition of movement for humpback whales foraging off the West Antarctic Peninsula. Top: The change in the proportion of time spent in area-restricted search state for humpback whales foraging off the West Antarctic Peninsula. Bottom: Seasonal variation in bout duration. One bout is a set of consecutive observations in a single behavioural state. One area-restricted search data point (x=Feb, y=55.4) was removed for visualization. Taken from Weinstein and Friedlaender, in review.

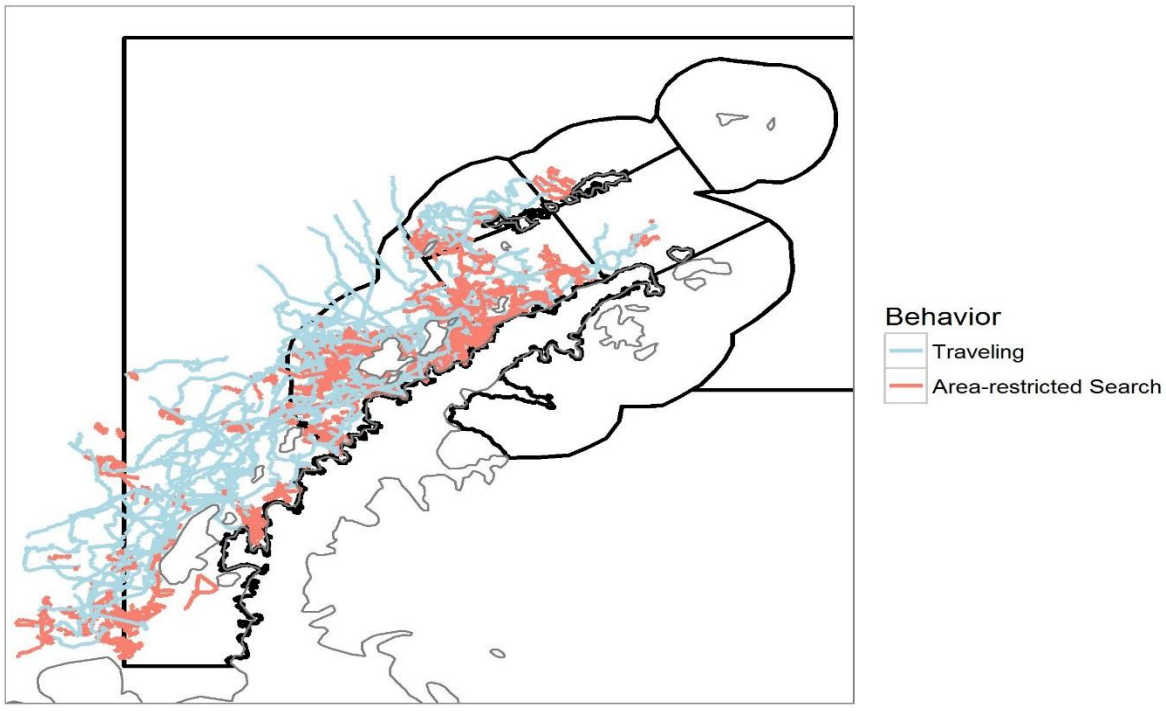


**Figure 4** Predicted behaviours for each filtered whale track based on the state-space model. If the mean probability of switching to the area-restricted state (ϕ_ARS) was greater than 0.5, the observation was labelled as area-restricted search. The eight CCAMLR small-scale management units for region 48.1 are shown in black lines. Taken from Weinstein et al., in press.

**Conclusions**

We continue to collect and published new information and push forward our understanding of the ecological role of cetaceans in the Antarctic marine ecosystem. 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 4 years under our current NSF LTER award, and perpetually through our collaboration with One Ocean Expeditions and the Australian Antarctic Division (AAD), and recent support from the World Wildlife Fund for Nature (WWF-Australia). 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. 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 and independent researchers.

**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.

**Outlook for the future**

Ari Friedlaender has 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 are severely limited in our ability to have fully dedicated ship time for extended periods and rarely have the opportunity to work with minke whales, but our access to humpback whales is significant. We are limited in one major respect that there is currently no organized quantitative prey mapping being done as part of the LTER program, hampering our ability to make linkages between whale behaviour and prey.

One more recent advance is our ability to use tour vessels to deploy tags, conduct UAS photogrammetry, and collect biopsy samples. In February and March 2017, Mike Double and Elanor Bell from the AAD joined Ari Friedlaender on two One Ocean Expedition trips to the WAP and were successful in deploying a number of LIMPET satellite-linked TDR tags on minke whales (n=4) for the second consecutive year. In addition, we collected a total of >200 biopsy samples and ~120 individual humpback whale UAS measurements that are currently being analysed. 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 will look to solidify our relationship with One Ocean Expeditions who have generously offered berths on a number of trips perpetually during Antarctic seasons. Furthermore, we will continue to build our relationship with WWF to help support cetacean research and conservation efforts in the region. Lastly, we have a research proposal that is pending with NSF that would be dedicated to studying the foraging behaviour of Antarctic minke whales. This project, should it receive funding, would offer a unique opportunity for dedicated time and effort to study the underwater behaviour of minke whales and concurrently link this to prey availability and sea ice conditions.

*IWC-SORP sincerely thanks WWF-Australia for its generous contribution of 15,989 GBP to purchase the three video suction cup tags repeatedly deployed during the 2016/17 season.*

**Project outputs**

*Papers*

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Friedlander AS (2016) Understanding the foraging ecology of baleen whales around the Antarctic Peninsula. American Cetacean Society.

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**ANNEX 4 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2015/16**

**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**

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## Introduction

Three primary research components were pursued by researchers engaged in the humpback whale connectivity project over the 2016/17 period: 1) ongoing analysis of data collected during the 2015 satellite tagging voyage to Raoul Island, New Zealand (29.2500 ºS 177.9167 ºW) led by Rochelle Constantine with Leena Riekkola, Alex Zerbini, Virginia Andrews-Goff and Ari Friedlaender, 2) a voyage from 22nd August to 4th September 2016 to the Chesterfield-Bellona reef complex west of New Caledonia, led by Claire Garrigue and, 3) a voyage to the east Australian Coral Sea humpback whale breeding grounds with a focus on collecting biopsy samples, led by Dave Paton.

### *Kermadec Islands*

The research on whales migrating south past Raoul Island has continued to analyse the satellite tag data from the 18 successful tag deployments (see Constantine et al. 2016 SC xxx), including further analysis of the tissue biopsy samples. A voyage to the Kermadec Islands enabled further collection of photo-identification images, tissue biopsies and song but there was no opportunity to tag more whales (Clark et al. 2017).

### *Chesterfield-Bellona Reef complex*

In 2014, the New Caledonian government, in collaboration with the Australian government, created the Coral Sea Natural Park (Figure 1). Assessment of areas throughout the park are underway in order to create a network of Marine Protected Areas and the Chesterfield-Bellona Reef complex is included in this assessment. This area was a hotspot for 19th century whaling (Townsend 1935). Voyages to this region in 2002 and 2010 confirmed low numbers of humpbacks in the region and even though east Australia or New Caledonia are the most likely breeding ground linkages, their origins remained unknown (Oremus & Garrigue 2014). As part of a larger New Caledonia EEZ assessment of humpback whales, the work reported here is the first voyage of the MARACAS programme focusing on the Chesterfield-Bellona reef voyage. Further research in the area is planned.

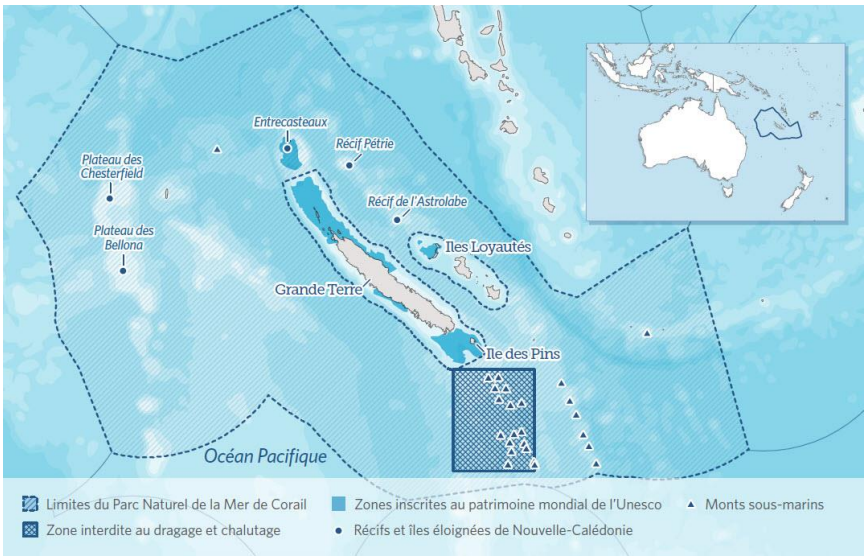

**Figure 1** The Coral Sea Natural Park, geographic location in the top right insert, with the park limits shown by the dotted line. The Chesterfield and Ballona Reef complex is labelled on the left side. The Pew Charitable Trust map.

***East Australia breeding grounds***

The breeding grounds of east Australian humpback whales are more challenging to define compared to those throughout the neighbouring Oceania region (e.g., Smith et al. 2012) with a notable lack of genetic samples for use in stock assignments throughout the region. With the increase in east Australian humpback population size and changes in the New Caledonia humpback population, determining geneflow and population connectivity to breeding grounds, migration paths and feeding grounds is critical for stock assessment and recovery. The objectives of this project are to genotype the humpbacks from the E1 breeding stock, ascertain whether the whales are connected to the Chesterfield Reef system (see project 2, above), match the samples to genotypes identified from the E1 migratory corridor (Anderson et al. 2010) and match to other Oceania breeding grounds. This report is the first of a two-year study.

**Preliminary results**

***Kermadec Islands***

Constantine et al. (2016) reported the use of genetic profiling and photo-identification to determine breeding ground links spanning ~3,600km of Oceania waters (from New Caledonia to the Cook Islands). The telemetry data revealed feeding ground destinations spanning ~3,500km of the Southern Ocean (from the Ross Sea to Bellingshausen Sea regions) covering IWC Areas V, VI and I.

In further analysis of the genotype data beyond mtDNA diversity (Table 1A – reported in Constantine et al. 2016), we used SPAM to undertake a mixed-stock analysis to assign probable breeding ground origins of the whales. We used data from Oceania breeding grounds and used samples collected from the east Australian migratory corridor as a proxy for breeding ground (note data from the breeding rounds will be available at the conclusion of Paton et al. research). The mixed-stock analysis showed similar levels of assignment to the breeding grounds of New Caledonia (35%) and Tonga (41%), with American Samoa-Samoa-French Polynesia genetic cluster (13%) and east Australia (12%) showing similar results (Table 1B).

**Table 1** Results of A) pairwise comparisons for mtDNA haplotype diversity ($F_{ST}$) between humpback whales sampled at the Kermadec Islands (n=68 with sequence) and the migratory corridors of east Australia and New Zealand, and breeding grounds of Oceania. The number in brackets is the number of individuals with sequence used for each population. B) Results of the SPAM mixed stock analysis assigning probability of breeding ground for the humpback whales samples at the Kermadec Islands.

**A.**

| | **Sampling site** | **$F_{ST}$** | **p-value** |
|---|---|---|---|
| Migratory corridor | East Australia (316) | 0.012 | 0.000 |
| Migratory corridor | New Zealand (150) | 0.008 | 0.007 |
| Breeding ground | New Caledonia (367) | 0.004 | 0.028 |
| Breeding ground | Tonga (337) | 0.005 | 0.025 |
| Breeding ground | French Polynesia - American Samoa - Samoa (302) | 0.022 | 0.000 |

**B.**

| **Population** | **Estimate** | **S.E.** | **C.V** |
|---|---|---|---|
| East Australia | 0.12 | 0.099 | 0.86 |
| New Caledonia | 0.35 | 0.142 | 0.41 |
| Tonga | 0.41 | 0.167 | 0.41 |
| French Polynesia - American Samoa - Samoa | 0.13 | 0.121 | 0.93 |

A total of 39 samples were analysed for progesterone levels, including males (n = 3) and calves (n = 5) to act as control samples. Of 31 adult females, 17 (54.8%) were pregnant. Of the 31 samples, 11 females were accompanied by a young-of-year calf and five (45.5%) of these females were pregnant. This work forms part of a larger analysis undertaken by Logan Pallin and Ari Friedlaender and leads to interesting discussions about the potential for pre-term foetal loss or higher calving rates in some populations compared to others. This work is ongoing.

A total of 78 samples, including eight replicate samples as a control, were analysed using epigenetic methods (see Polanowski 2014) by Dave Chandler and Simon Jarman. Of the 70 individuals, the ages ranged from <1 (young-of-year) to 67 years old with most whales in the 5-35 year old range.

Analysis of the satellite telemetry data using state-space models that simultaneously solve an observation model and a movement model (Jonsen et al. 2005), gives us more accurate estimates of the locations of the whales and associated uncertainty around the data. This has shown the occurrence of different behavioural states across the migration with 86% of transits and 4% of area restricted searches (resting, foraging and/or milling) and 10% of locations uncertain. Ongoing analysis of whale behaviour on the feeding grounds is underway. A linear mixed effect model with interaction (sex-class and latitude band) and blocking (PTT) was used to compare the mean travel speed between sex-classes (male, female, mother-calf pair, and unknown) within latitude bands of 10 degree intervals. The mean swimming speed (±SD) of 2.4km/h (± 1.8) was recorded across all whales and tracks. All whales showed slower swimming speeds at low and high latitudes, and faster swimming speeds at mid-latitudes (Table 2).

**Table 2** Mean travel speeds (km/h) for different sex-classes calculated from state-space modelled data. The number in brackets is the number of data points that were available for calculating means and for linear mixed effect model for each sex-class in each latitude band.

| | Latitude band (°S) | | | | | |
|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | 50 | 60 | 70 |
| Female | 1.16 (13) | 3.3 (98) | 3.95 (90) | 3.08 (146) | 2.29 (435) | 1.76 (92) |
| Male | 1.22 (41) | 3 (139) | 3.93 (117) | 4.02 (115) | 1.65 (755) | 1.75 (134) |
| Mother-calf | 0.81 (73) | 3.36 (147) | 2.7 (191) | 3.48 (115) | 1.72 (253) | 1.95 (3) |
| Unknown | 3.43 (6) | 3.03 (37) | 3.55 (59) | 2.65 (89) | 1.66 (249) | 0.86 (16) |
| Average | 1.1 | 3.2 | 3.4 | 3.3 | 1.8 | 1.7 |

***Chesterfield-Bellona Reef complex***

Field work was conducted from 22nd August – 4th September 2016 with nine days spent in the Bellona and Chesterfield reef complex. A total of 88:16 hours of line transect observation time was conducted covering similar distances in both areas (757km – Chesterfields and 650km - Bellona). Group composition, location and number of whales were recoded either along line transects or from small boat-based focal follows. Humpback whales were observed on seven of nine survey days. Individual data were collected on nine groups of humpbacks with seven whales photo-identified by fluke and a further 11 identified by dorsal fin for the purposes of counting total numbers sighted. Of all whales encountered, 72% (n = 13) were adults and 28% (n = 5) were calves. Of the seven adults identified by fluke, three (2 females and 1 male) matched to the New Caledonia southern lagoon catalogue and four were newly identified individuals that will be matched to other catalogues throughout the region.

A total of seven skin samples were collected; five using a biopsy system and two from sloughed skin. These samples will be genotyped and sex-identified using standard protocols and then matched to Oceania and Australian genotype catalogues.

Whale song was heard in 61% of 49 hydrophone deployments. There were seven song sessions recorded with three covering the full song-length (range = 28 – 44 mins), the other four were either too short or poor quality. These acoustic recordings will be analysed along with other acoustic data throughout the region as part of a long-term study on humpbacks throughout Oceania.

***East Australia breeding grounds***

Three weeks of humpback whale surveys were undertaken during the peak of the breeding season from 9th – 30th August 2016. The first two weeks (9-22 August) were focused around the Whitsunday Islands (20.2°N 148.9°E) and the final week (23-30 August) were focused off Mackay in the Percy Islands within the Swains section of the Great Barrier Reef Marine Park. This was identified as the core range of the E1 breeding stock (Smith et al. 2012).

A total of 67 pods of humpback whales containing a total 146 whales (including 30 calves) were observed during the survey. This number was lower than expected and the general density of pods observed was lower than that observed in the same region during previous surveys. A total of 26 genetic samples were collected during the 2016 field season (including sloughed skin and biopsy samples) for an overall total of 62 samples from the region (including 2011, 2014 and 2016 sampling).

Photo-identification images of whale flukes are being processed and will be matched to existing catalogues throughout the region and to Antarctic catalogues to determine connectivity to breeding grounds, migratory corridors and feeding grounds. There will be a ten week field season in the same region in 2017 to complete data collection for this project; samples will then be analysed by Scott Baker and Debbie Steel and compared to large genotype catalogues from Australia, Oceania and Antarctica.

**Conclusions**

The three projects reported here provide major contributions to understanding the stock recovery (e.g., Jackson et al. 2008, IWC 215) of humpback whales and their connectivity between breeding grounds, migratory corridors and feeding grounds. The Kermadec Island research will be completed in 2018 including analysis of the feeding ground habitat use, determining environmental drivers around distribution and movement patterns. The high rates of pregnancy is of interest and further analysis of samples from whales on their feeding grounds may advance our understanding of whether whales are losing their foetus somewhere along the migration path if their calf survives beyond a certain age, or whether there is just high levels of calf loss overall. There are whales that calve every year but this is not considered the norm. Perhaps calf loss within the first few months of life result in females being energetically able to carry their new foetus to term. Bottlenose dolphin females who lose a calf early in life will come into oestrous again sooner than those who lose an older calf (Mann et al. 2000); although humpbacks have a defined breeding season perhaps a similar process occurs and this is not unusual for mammals. Further investigation is required, so we will collect biopsy samples with progesterone during an Antarctic voyage to the Ross Sea region in February – March 2018.

The Chesterfield-Bellona Reef complex research will allow us to assign these whales to a breeding stock, most likely E1 or E2. Given the different rates of recovery for these two sub-populations these findings will also be important for the Coral Sea Marine Park MPA process and their protection of these reef complexes. Even though the sample sizes are small, matching three of seven whales to New Caledonia was an important finding. The tissue samples collected from both regions are important for assigning breeding ground connectivity and improving the accuracy of recovery assessments and estimates of pre-whaling abundance (e.g., Carroll et al. 2015, IWC 2015). Given the connectivity between east Australia, New Zealand and eastern Oceania (primarily New Caledonia; e.g., Constantine et al. 2007, Franklin et al. 2014, Garrigue et al 2011, Steel et al. 2014), these two new projects will fill much needed data gaps once data analysis is complete.

*IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project.*

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**ANNEX 5 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH PROJECTS FOR 2015/16**

**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: Brian Miller[6], Susannah Buchan[8], Ken Findlay[3], Jason Gedamke[4], Danielle Harris[5], Flore Samaran[1]*, Ana Širović[9] and Kathleen Stafford[2]*, Ilse Van Opzeeland[7]*
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*6 Australian Marine Mammal Centre, Australian Antarctic Division, Hobart, Australia*
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**Executive summary**

The Blue and Fin Whale Acoustic Trends Project has continued to develop and mature a long term acoustic research program to understand trends in Southern Ocean blue and fin whale distribution, seasonal presence, and population growth through the use of passive acoustic monitoring techniques. This international collaboration has continued to deliver:

1) analysis and interpretation of existing ad-hoc acoustic datasets in from the Southern Ocean,
2) the development and implementation of an ongoing network of long-term circumpolar underwater listening stations, and
3) development of novel and efficient methods for standardized analysis of acoustic data collected in the Antarctic and sub-Antarctic

In 2016/17, members of the Acoustic Trends Project deployed 23 autonomous recording devices in the Southern Ocean at 19 different recording sites, and the group recovered 17 previously deployed autonomous recorders from various recording sites around Antarctica. The data volume from all instruments totalled approximately 150,000 hours of underwater recordings. 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 2016/17, the group produced three peer reviewed papers, two 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. Additionally, three PhD dissertations were submitted or are nearing completion by students from three different countries, using the ATP data. In 2016/17 two IWC grants were received from IWC-SORP: 1) a grant to fund a 4-day meeting of the steering group in order to review the past 5 years of progress and develop a new strategic plan for the next 5 years, and 2) a grant to initiate an annotated library of acoustic recordings.

The steering group of the Acoustic Trends Project has continued to forge strong links with other IWC-SORP and international programs. Such collaborations include acoustic monitoring for whales during the Antarctic Circumnavigation Expedition; contribution of metadata to a new IWC working group on southern ocean Fin whales around the West Antarctic Peninsula; contribution of underwater recordings to the IWC working group investigating the potential for acoustic population assessment of Pygmy blue whales; and continued collaboration with the IWC-SORP Antarctic Blue Whale Project.

**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 has shown the geographic and seasonal occurrence of blue and fin whales around the Antarctic e.g. (Širović et al. 2004, 2009, Samaran et al. 2013, Leroy et al. 2016, 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 (Van 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 2016/17 focused on expansion of the steering group; increasing the spatial coverage and number of recording stations for the hydrophone network; the planning of a steering group meeting to develop a new 5-year strategic plan; and the development of an annotated library of underwater recordings.

**Progress and results for 2016/17**

***Meeting of the Steering Group for the Acoustic Trends Project***

The SORP Acoustic Trends Steering Group was awarded a grant of £9,000 from IWC for a 4-day workshop for members of the Acoustic Trends Steering Group before the 2017 Annual Meeting of the IWC SC (67a). The aim of this in-person meeting was to review progress of the project to-date, and to develop a new 5-year strategic plan. The report for this meeting is presented in SC/67a/SHXX.

***Annotated library of acoustic detections***

The SORP Acoustic Trends Steering Group was awarded a grant of £22,000 from IWC-SORP 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 the group has progressed the planning and design to the point where annotation of acoustic data can commence. Annotations of data is expected to continue until early 2018. Southern Ocean Hydrophone Network: 2016/17.

***Weddell Sea, West Antarctic Peninsula (AWI)***

In December 2016 twenty PAM units were recovered during Polarstern expedition PS103 (Figure 1), 19 of which were SonoVaults and one was an AURAL. Instruments were distributed over 16 moorings, with two moorings containing each three instruments attached at different depths. Two additional moorings could not be recovered. One of these failed to release. The attempt to recover the mooring using a remotely operated vehicle (ROV) failed due to a rupture in the rope that the ROV was to attach to the mooring for retrieval. There will be another attempt for retrieval in 2018/2019. The other mooring could not be recovered because the mooring could not be found at its position. Except for two recording units that did not record due to defective batteries, all retrieved devices recorded between 117 days and 635 days. A total of 7 TB and 123867 h (5963 days) of passive acoustic data were obtained from a total of 18 recorders.

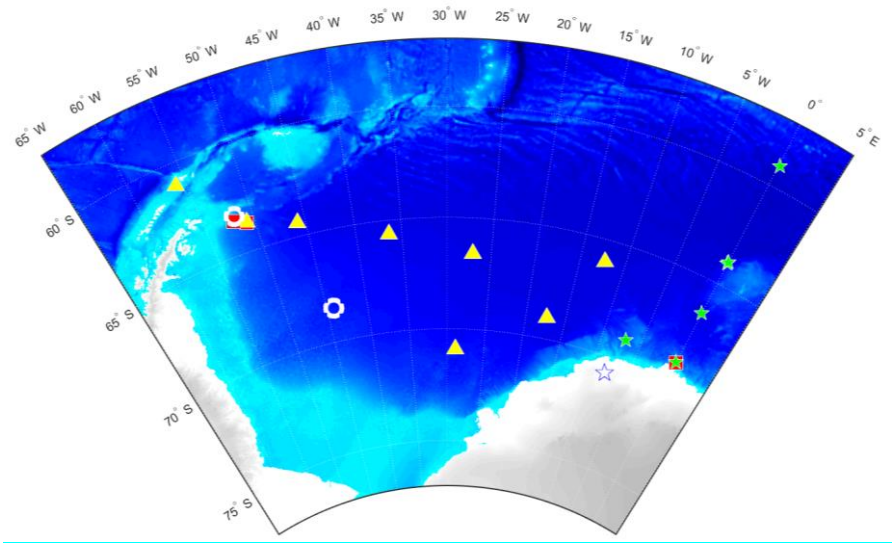


**Figure 2** Map showing the 16 locations of AWI acoustic recorders that were recovered during PS103. Red squares: recorders deployed in 2010 and recovered in 2016, yellow triangles: recorders which were deployed in 2012 and recovered in 2016, green stars: recorders deployed 2014 and recovered in 2016. Empty circles: moorings with recorders that could not be recovered. Blue star: position of the PALAOA observatory.

Acoustic recordings from all recovered units contained the acoustic signatures of Antarctic blue and fin whales, as well as acoustic contributions of other marine mammal species. In general, the recordings were of good quality. Some SonoVault recordings contained low-frequency noise within the frequency range from 3 to 10 Hz, which likely represented internal noise caused by the electronics. All passive acoustic data are in the process of being transferred to the AWI data silo after which they will be processed as part of the ongoing work at the Ocean Acoustics Lab. Data will be made accessible through the Pangaea database (P.I.: Ilse van Opzeeland).

During the same cruise, a further 17 Sonovault recorders were deployed on 13 moorings (Figure 2). SonoVaults were deployed with new mounts, consisting of two plastic clamps mounted at two positions around the housing. The clamps were then attached to a 5m Dyneema rope. Retrieval is planned for the 2018/2019 Polarstern cruise.

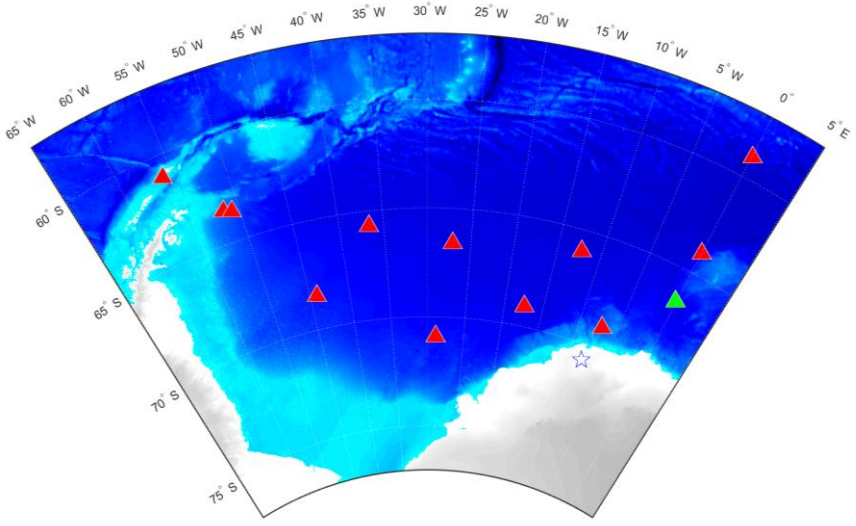


**Figure 2** Map showing the positions (triangles) of AWI recorders that were deployed in 2016. Red triangles: single recorder moorings, green triangles: mooring with 5 recorders attached at different depths. Blue star: position of the PALAOA observatory.

***Elephant Island, West Antarctic Peninsula (Tango Voyage)***

During January – February 2016, the Argentine Coast Guard cutter Tango recovered a HARP in the vicinity of the South Shetland Islands and redeployed one near Elephant Island (as detailed in SC/67a/XX). The HARP that was recovered collected data from February 2015 – January 2016. Analysis of data will be conducted during the summer 2017.

***Weddell Sea Aural deployments (ENSTA Bretagne, CNRS, LOCEAN-IPSL)***

During February 2017, the ENSTA Bretagne, in collaboration with CNRS, LOCEAN-IPSL (Paris) deployed 3 Aural instruments in the Weddell Sea (74°S, 28°W ; 74°S, 30°W; 75°S, 28°W) with the RRS James Clark Ross. The instruments will be recovered in 2018/2019. They were set up to record frequencies up to 2048 Hz and a duty cycle of 2, 3-hours periods per day. With this configuration the hydrophones should record for almost 2 years. Even though this deployment was not dedicated to SOHN, these data will be available for the project. East Antarctica (AAD, ENSTA Bretagne).

In January 2013 the AAD deployed the first of their custom Moored Acoustic Recorders (MARs) in the Antarctic outside of Prydz Bay along the resupply route between Hobart and Australia's Davis Station (Prydz2013, Figure 3). The site of the deployment was similar to the ARP recordings collected in 2005 & 2006 (Prydz05, Prydz06 listed in Opzeeland et al. 2013). In subsequent years the instrument was covered in ice and could not be retrieved, and in 2015 this prototype recorder was written off as lost. However, in November 2016 the location was free of ice, and one final recovery attempt was made. The attempt was a success, and the instrument was finally recovered intact after spending nearly 4-years at the bottom of the sea. The instrument recorded underwater sounds continuously at 12 kHz from 26 January 2013 until 22 November 2013, when its batteries were depleted.

The Australian Antarctic Division (AAD) also recovered the MARs deployed in 2016 on the resupply routes to Australia's Casey and Mawson Stations (Casey2016, Kerguelen2016, Figure 3). Upon recovery, replacement MARs were deployed to maintain continuous data collection until their recovery in 2017/18. Unlike prior years where 12 months of continuous data were recorded, the Casey2016 deployment only recorded for 8 months from December 2015 until July 2016. Data from the Kerguelen2016 deployment will be downloaded in April 2016, but are likely to have similar issues as those from Casey2016 with shortened recording duration. However, the issue responsible for the shortened recording duration has already been identified and fixed, and thus should not manifest in recordings for 2017 and beyond.

In Feb 2017 the AAD, in collaboration with ENSTA Bretagne & IPEV, attempted to commence the first of five continuous years of data collection at a new site along the resupply route to France's Dumont D'Urville Station (SOHN site name: DDU; Figure 3). However, weather during the voyage did not permit deployment of the MAR. The device was returned to the AAD, and data collection at Dumont D'Urville Station will be attempted again in 2017/18.

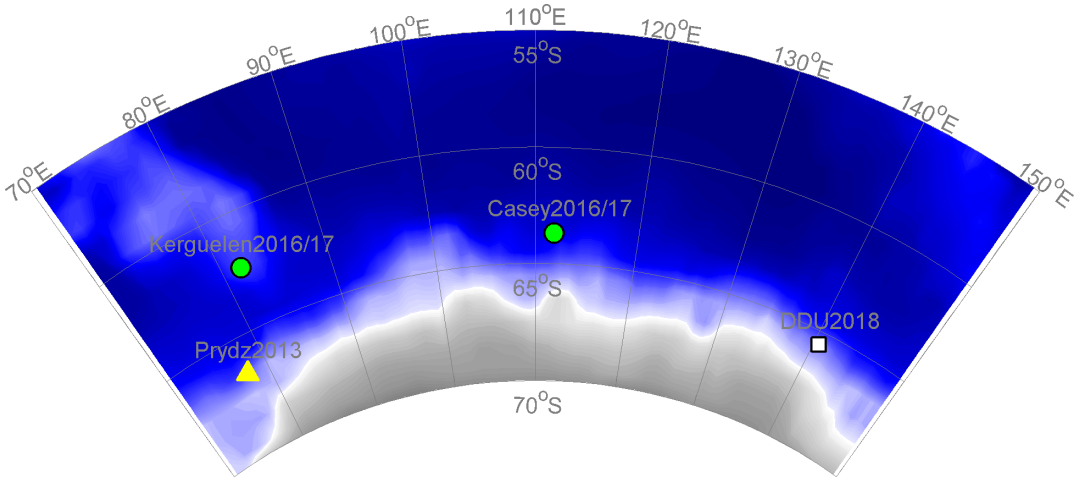


**Figure 3** Map of showing the locations of AAD acoustic recorders in the East Antarctica Sector (IWC Management areas IV and V. Yellow triangle: recorder deployed in 2012 and recovered in 2016. Green circles:

recoveries for 2016 with deployments for 2017. White square: aborted deployment attempted in 2017 to be re-attempted in 2018.

***Low Latitude (South Africa)***

Two Aural instruments will be recovered from the SAMBA mooring line in April 2017. These instruments have been in the water since November 2015 and recording over the period November 2015 to November 2016. It is hoped that the recovered recordings will build on the previous analyses of South African PhD candidate Mr Fannie Shabangu who submitted his dissertation "Acoustic assessment of seasonal occurrence and behaviour of Antarctic blue whales (Balaenoptera musculus intermedia) in the South-eastern Atlantic and Southern Oceans" in March this year. A MSc student will be analyzing these more recent data. No re-deployment is planned on this line for 2017 and a proposal for low-high latitude acoustic mooring deployments on the Good Hope Line (000° E/W) along with acoustic glider deployment is currently being drafted for the South African Antarctic Programme.

***Low latitude OHASISBIO network (University of Brest and ENSTA Bretagne)***

Since December 2009, a network of autonomous hydrophones —known as OHASISBIO— has been deployed at five sites in the southern Indian Ocean. This experiment was designed to monitor low-frequency sounds produced by seismic and volcanic events and by baleen whales. Hydrophones are configured to record continuously at a rate of 240 Hz and are deployed in the axis of the sound fixing and ranging (SOFAR) channel, from 500 to 1300 m below sea surface depending on the site. Instruments are distributed south of La Reunion Island in the Madagascar Basin (MAD, 26 05'S, 058 08'E) northeast of the St Paul and Amsterdam plateau (NEAMS, 31 35'S, 083 14'E), mid-way between the Kerguelen and Amsterdam islands (SWAMS, 42 59'S, 074 35'E), north of Crozet Island (NCRO, 41 00'S, 052 49'E) and west of Kerguelen Island (WKER, 46 38'S, 060 07'E). Acoustic analysis of Antarctic blue whale calls has already been published (Leroy et al., 2016). In 2017, the geometry of the OHASISBIO-network slightly changed and a new station was equipped south of Indian Ocean, ELAN, 56 30'S, 63 00'E.

***Low-latitude - Chilean Patagonia (COPAS, University of Concepcion)***

Mid-latitude coverage in Chilean Patagonia (43˚S) is provided by an bottom-mounted hydrophone (deep water SM3M Songmeter) owned and managed by the Sur-Austral program of the Center for Oceanographic Research in the Eastern South Pacific (or Centro de Investigación Oceanográfica en el Pacífico Sur-Oriental, COPAS) at the University of Concepcion, Chile. The COPAS Sur-Austral passive acoustic time series started in January 2016, with a year of back-up data to date. This instrument is scheduled for deployment through the end of 2019. Acoustic analysis for Antarctic blue whale song has not yet been carried out on this data, but is planned, provided that analyst time is available in the future. A previous study in this area by the Austral University of Chile confirms the occasional presence of Antarctic blue whale Z-calls (Buchan et al. in review).

***Antarctic Circumnavigation Expedition (ACE)***

Acoustic data from DIFAR sonobuoys were collected during ACE as part of the project titled: Acoustic Mapping of Southern Ocean Marine Mammals. These data are presented separately in SC/67a/SHXX. Here we include maps of locations of Antarctic blue and fin whales detected during ACE. Plans for future analyses of this data set may include comparison of detections from sonobuoys with that of moored acoustic recorders, to investigate propagation models and source levels of calls. Data from this survey will also be used to investigate relationships among the location of calling blue and fin whales and the remotely sensed environmental data.

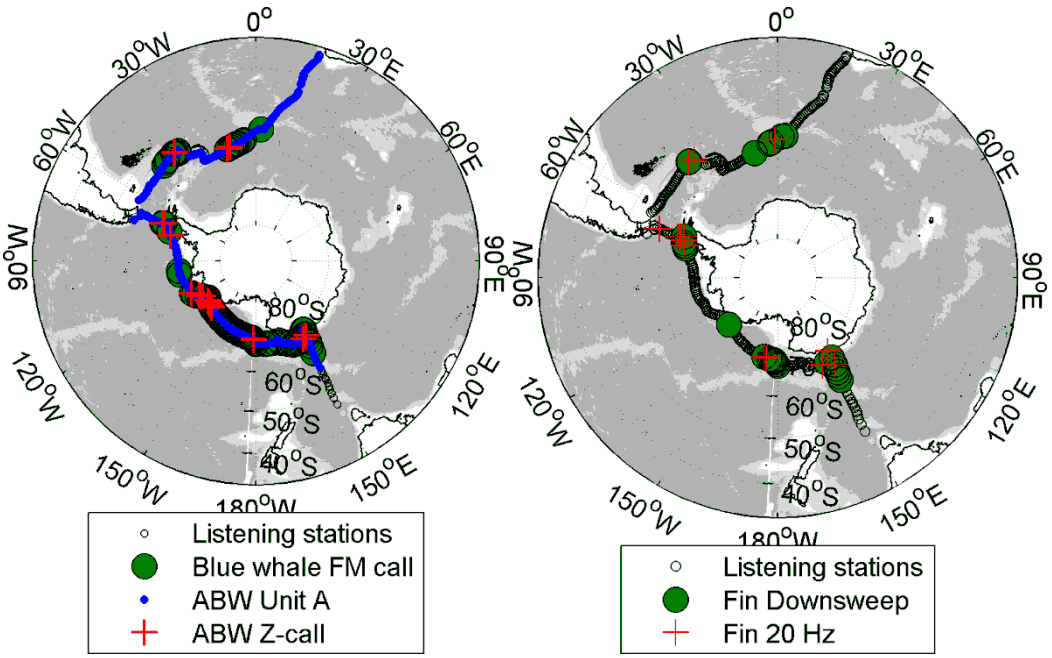


**Figure 3** Maps showing listening stations during the Antarctic Circumnavigation Expedition. Left map: stations with detections of calls from Antarctic blue whales, including song unit A (blue circle), z-calls (red cross), and FM calls (green circle). Right map: stations with detections of calls from fin whales including 20 Hz pulses (red cross), and downsweeps (green circle).

*IWC-SORP sincerely thanks the International Fund for Animal Welfare (IFAW) for its generous contribution of 7,519 GBP to facilitate the research conducted during the ACE voyage.*

**Analysis of existing data for 2016/17 and related outputs**

***IWC SOWER***

Shabangu et al. (2017) published an analysis of the effects of environmental conditions on the acoustic occurrence and behaviour of Antarctic blue whales (both Z and D calls) using Random Forest models applied to acoustic data collected on the IWC SOWER cruises in the austral summers of 1997 through 2009. Rates of D-calls were strongly predicted by the location of the southern boundary of the Antarctic Circumpolar Current (SBACC), latitude and visually detected number of whales in an area while call rates of Z-calls were predicted by the SBACC, latitude and longitude. A further four papers authored by Shabangu, Findlay and others are currently under review.

***Evaluation of automated detectors for Antarctic blue whale Z-calls***

In a pilot study for the Southern Ocean Hydrophone Network project, two automated Antarctic blue whale Z-call detection methods were evaluated based on their performance under varying acoustic conditions and call densities. One detector based on spectrogram correlation, and the other used a subspace-detection strategy. Analyses were conducted on two test datasets reflecting the acoustic conditions of two ocean basins: the Southern and Indian Oceans. Furthermore, the effect of different sound sources that potentially interfered with detection based on their acoustic characteristics was tested using further data subsets. Two analysts then conducted manual analyses of the same data to create ground truth data sets. The variability between the two human analysts in the detection of Antarctic blue whale Z-calls, as well as the intra-analyst variability was investigated to understand how this impacts the creation of a ground-truth and the assessment of automated detector performance. Using a ground-truth based on combined results of both analysts, the performances of two automated detectors were evaluated. Results show that the presence of the Antarctic blue whale chorus poses a significant reliability problem in distinguishing single call events from the continuous 26 Hz (frequency of unit A) band for both automated methods, but also is the cause of significant intra- and inter-analyst variability in ground truth data sets. A manuscript describing this work is in preparation.

***The P calls, a new whale call which could be easily mistaken for incomplete Antarctic blue whale Z-calls***

Leroy et al. (in review) reported two previously unidentified signals found in acoustic records from the southern Indian Ocean and spanning seven years (2007, 2010 to 2015). The first reported signal (M-call) consists of a single tonal unit near 22 Hz and lasts about 10 s. The second signal (P-call) is also a tonal unit lasting about 10 s, but at a frequency near 27 Hz. The latter closely resembles the unit A of Z-calls, and thus can be easily mistaken for incomplete Antarctic blue whale Z-calls. From a systematic analysis of the acoustic database, results show that both signals have similar characteristics as blue whale vocalizations, but with spatial and seasonal patterns that do not resemble any of the known populations dwelling in the southern Indian Ocean. M-calls were recorded only in 2007, while P-calls were present every recording year, with an increasing abundance over time. P-calls may co-occur with, but are clearly distinct from, Z-calls. The sources of the two new calls have yet to be visually identified.

***New estimate of source level of Antarctic blue whales***

With the amount of acoustic data in the Southern Indian Ocean, Meillour et al. (to be submitted) have described a new method for estimating the source level (SL) of Antarctic blue whales using passive acoustic data. This method considers a propagation model based on ray theory, and the estimated SLs depend on the depth of the calling whale. Such depth cannot be estimated from the data, but is known to be about a few dozen meters based on data from vocal whales instrumented with depth-of-dive archival tags. The proposed method is applied on a sequence of 42 Z-calls emitted by a single animal. For an assumed calling depth held constant at 35 m, the estimated SL found over the [25-29] Hz frequency band is 183 dB re 1 µPa @ 1 m. If the calling depth varies between 20 and 35 m, the SL is found to be between 183 and 187 dB re 1 µPa @ 1 m. These SL are estimated on 2 hydrophones separated by 10 km. The average SL is the same on the 2 hydrophones. The SL standard deviation is either 1 or 2 dB, depending on the hydrophone.

***ABW detections in lower latitudes***

Samaran et al. (SC/67a/SHXX) present the first evidence for an ABW presence in the Equatorial Atlantic Ocean from a passive acoustic experiment conducted from March to December 2013 with a hydrophone moored near the Equator (0°09.31N 027°47.25W). The analysis of the records shows the presence of ABW « chorus » (combined distant calls produced by whales in the area) every month with peak occurrence in July with individual Z-calls detected. These acoustic records of ABW represent the furthest north collection of calls ever documented for this species at such low latitude. This new observation further emphasizes the complex and wide distribution of ABW in the Southern Hemisphere.

***Large Scale Density Estimation of Blue and Fin Whales***

A collaborative project involving the University of St Andrews and the University of New Hampshire (led by Danielle Harris, Jennifer Miksis-Olds and Len Thomas), funded by the Office of Naval Research (grant numbers: N00014-14-1-0394 and N00014-14-1-0397) has developed a novel density estimation method that produces density maps of calling animals by incorporating measured bearings to detected animals. This method can be used when only bearings to animals are estimable (as opposed to locations or ranges), so may be suitable for use with sonobuoy data. A manuscript describing the methodology is currently in review. This project will provide another density estimation method that is relevant to IWC-SORP, possibly being used in future analyses and to inform future instrument deployments

**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. The steering group has expanded, and includes two new members. Additionally, the steering group has forged strong links with other IWC-SORP and international programs, including collaboration between the Acoustic Trends Project and: an acoustic survey of whales during the Antarctic Circumnavigation Expedition; the nascent IWC working group on southern ocean Fin whales around the West Antarctic Peninsula; the IWC working group investigating acoustics of Pygmy blue whales for population assessment; the SCAR/SCOR Southern Ocean Observing System; and the IWC-SORP Antarctic Blue Whale Project.

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 the evaluation of the performance of manual and automated detectors, 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.

**Challenges**

The steering group has overcome many challenges in 2016/17, however many still remain.
The demand for data from acoustic recorders and opportunity to deploy instruments has outstripped 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 around Antarctica. For example, 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**

The project has obtained funding from various sources including IWC-SORP for a much needed meeting of the steering group, and will be developing a new 5-year strategic plan for 2018-2023. Funding was also obtained via IWC-SORP to initiate an annotated library of acoustic recordings. Work on the 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. The annotated library aims to focus equally on all call types from both blue and fin whales, so should help to address the imbalance in effort that has resulted in a strong emphasis on stereotyped calls from blue whales over stereotyped calls from fin whales and FM calls of both species. Plans for expansion of the SOHN are expected to continue, as are plans for a standardised circumpolar analysis of SOHN and historical recordings (AKA the blueprint of analysis methods). Additionally, the group will continue efforts towards passive acoustic density estimation. However, the jump to density estimation requires independent observations of the number of whales in the area vs. the number of calls in the same area (i.e. a 'multiplier' to convert cue rate to animal density). Obtaining this 'multiplier' will likely require dedicated ship time to deploy acoustic recording tags on animals, and/or a combined visual and acoustic survey.

## Project outputs

*Papers*

Gavrilov AN, McCauley RD, Gedamke J (2012) Steady inter and intra-annual decrease in the vocalization frequency of Antarctic blue whales. Journal of the Acoustical Society of America 131: 4476-4480.

Harris D et al. (*In preparation*) Estimating the detection probability of long-ranging baleen whale song using a single sensor: towards density estimation.

Leroy E, Bonnel J, Samaran F, Royer J-Y (2016) Seasonal and diel vocalization patterns of Antarctic blue whale (*Balaenoptera musculus intermedia*) in the Southern Indian Ocean: a multi-year and multi-site study. Plos One 11 (11) DOI: 10.1371/journal.pone.0163587

Leroy EC, Thomisch K, Royer JY, Boebel O, Van Opzeeland IC (*In preparation*) On the variability in ground-

truth data and the performance of two automated detectors for Antarctic blue whale calls under different acoustic conditions.

Leroy E, Bonnel J, Samaran F, Royer J-Y (*In review*) Two new potential whale calls in the southern Indian Ocean, and their geographic, seasonal and diel distribution.

Meillour M, Bonnel J, Samaran F (*In review*) Source level estimation of Antarctic blue whale calls in the Southern Indian Ocean.

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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