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Annual Report of the Southern Ocean Research Partnership (IWC-SORP) 2018/19

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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

The Southern Ocean Research Partnership (IWC-SORP) was established in 2009 with the aim of developing a multi-lateral, non-lethal scientific research programme that would improve the coordinated and cooperative delivery of science to the IWC. There are now 13 member countries in the Partnership: Argentina, Australia, Belgium, Brazil, Chile, France, Germany, Italy, Luxembourg, New Zealand, Norway, South Africa, and the United States. This paper reports on the continued progress of IWC-SORP and its six ongoing research themes[1] since the Scientific Committee meeting in 2018. This progress includes the production of at least 18 peer-reviewed scientific papers in 2018/19, bringing the total number of peer-reviewed publications related to IWC-SORP produced since the start of the initiative to ca. 144. Moreover, 133 IWC-SORP related papers have been submitted to the Scientific Committee, 8 of them this year. Fieldtrips to the western Antarctic Peninsula, Marion Island, the Southern Ocean (between 60°S – 67°S and 138°E – 152°E), the Ross Sea and the Great Barrier Reef, Australia have taken place in the past year. Thousands of images for photo-identification have been collected, satellite tags have been deployed on killer whales, Antarctic minke whales and humpback whales. As well as video suction cup tags on Antarctic minke and humpback whales. Biopsy samples have been collected from killer whales, humpback and Antarctic minke whales; and hundreds of hours of cetacean acoustic recordings have been made and analysed.

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

INTRODUCTION

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

include Argentina, Australia, Belgium, Brazil, Chile, France, Germany, Italy, Luxembourg, New Zealand, Norway, South Africa, the United States of America.

The objectives, research plan, and procedural framework for the Partnership were developed through a workshop held in Sydney, Australia in March, 2009. Subsequently, a framework and set of objectives for IWC-SORP were endorsed by the IWC at its Annual Meeting in June 2009. Project plans (SC/63/O13) were presented to the IWC in 2011 and 2012 and reports summarising the activities of six IWC-SORP research projects have been presented annually to the Scientific Committee (SC/63/O12; SC/64/O13; SC/65a/O11; SC/65b/SH12; SC/66a/SH8Rev2; SC/66b/SH10Rev2; SC/67a/SH04Rev1; this paper). One of the endorsed IWC-SORP projects, the Living Whales Symposium, held in Chile, was completed in March 2012 and reported to the Scientific Committee in 2012 (SC/64/O14). With the endorsement of the IWC Scientific Committee (IWC/SC/67b) and the Commission (IWC67) a new IWC-SORP research Theme was established in 2018: *The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale*.

This paper reports on the progress and results of the six ongoing research Themes[1] since the last meeting of the Scientific Committee in 2018. Further details of this work can be found at https://iwc.int/sorp.

BRIEF SUMMARY OF PROGRESS

Overall, IWC-SORP projects have produced ca. 144 peer-reviewed publications to date and 133 IWC-SORP related papers have been submitted to the Scientific Committee, 8 of which will be considered by the IWC Scientific Committee this year.

IWC-SORP Research Fund

In 2018, £493,544 GBP were allocated to 15 of the 19 proposals submitted during an open, competitive grants round. An independent assessment process as detailed in Annex V, endorsed by both the Scientific Committee and the Commission, was undertaken. The Commission endorsed allocation of funds to the successful projects at IWC67. Details of the allocations and project progress reports are presented in Bell (2019) SC/68a/SHXY.

A further £15,000 GBP were allocated intersessionally by the IWC-SORP Scientific Steering Committee (SSC), toward the IWC-SORP *ENRICH* voyage to the Southern Ocean (Annex 1).

A financial report of the IWC-SORP Research Fund as of January 2019 is detailed in the Secretariat financial report, SC/68a/0X. Approximately **£135,497 GBP** remain unallocated and unspent.

IWC-SORP sincerely thanks the Governments of Australia, the Netherlands, WWF-Australia and the International Fund Animal Welfare for financial contributions to the IWC-SORP Research Fund that have facilitated IWC-SORP research in 2018/19. We also thank WWF-Australia for an additional contribution of $10,000 AUD toward participation of Paula Olson on the IWC-SORP ENRICH voyage to the Southern Ocean (see Annex 1 for more details).

Funding and vessel time

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

- Argentinean *ARA Almirante Irizar* voyage along Western Antarctic Peninsula - 2019 (Iniguez et al.)
- Brazilian *Almirante Maximiano* voyage along Western Antarctic Peninsula – 2019 (Dalla Rosa et al.)
- NSF-funded voyages to the Antarctic Peninsula – 2019 (Friedlaender et al.)
- Argentinean *ARA Almirante Irizar* voyage along Western Antarctic Peninsula - 2020 (Iniguez et al.)
- Brazilian *Almirante Maximiano* voyage along Western Antarctic Peninsula – 2020 (Dalla Rosa et al.)
- *RV Polarstern* to Scotia Sea - 2019 (Herr et al.)

[1]There are currently six IWC-SORP Themes (formerly referred to as Projects) covering 1) blue whales, 2) killer whales, 3) baleen whale foraging, 4) humpback connectivity, 5) blue and fin whale acoustics and 6) southern right whales.

- *RV Investigator voyage* to Ross Sea- 2019 (Nicol, Double, Bell et al.)
- New Zealand MBIE funded voyage to Ross Sea Region MPA – 2019 (Constantine et al.)
- *RV Maria S. Merian* to Western Antarctic Peninsula- 2020 (Herr 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 six ongoing IWC-SORP research Themes in 2018/19 are given below. Full project reports are included in Annexes 1 to 6.

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

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

In 2018/19 work on the Antarctic Blue Whale Project has focused on the collection of data on voyages to the Southern Ocean, analysis of data collected during previous voyages, analysis of movements of Antarctic blue whales from recent and historic data, photo-identification of Antarctic blue whales, and the planning of upcoming research voyages.

2019 IWC-SORP *ENRICH* Voyage

The 2019 IWC-SORP *ENRICH* Voyage (**E**uphausiids and **N**utrient **R**ecycling in **C**etacean **H**otspots), was conducted from 19 January – 05 March 2019, aboard the CSIRO Marine National Facility research vessel *Investigator*. The voyage departed from and returned to Hobart, Tasmania, Australia, and conducted most marine science operations in the area between 60°S – 67°S and 138°E – 152°E, covering 13,000 kilometres. The voyage was led by the Australian Antarctic Program and involved 28 international scientists.

The voyage represented the first time that a survey of Antarctic blue whales has been conducted together with a structured survey of their prey, Antarctic krill. Throughout the voyage 41 krill trawls were carried out, total of over 100,000 krill individuals were collected, 20 Instantaneous Growth Rate experiments were conducted and approximately 200 live adults krill and more than 10,000 thousand live larvae were returned to the Australian Antarctic Division for further research. A number of krill swarms were observed using a multi-beam echosounder and a sonar, including a small scale 'mapping' of swarm, where we followed around the edge of swarm.

A passive acoustic survey for marine mammals was undertaken throughout the duration of the voyage, the main goal being to monitor for and locate aggregations and groups of calling Antarctic blue whales (*Balaenoptera musculus intermedia*). Directional sonobuoys were used to conduct 295 listening stations, which resulted in 806 hours of acoustic recordings. Calls from blue and fin whales were detected in real time and calibrated measurements of the bearing and intensity of these calls were obtained for the majority of detections. 33,435 calls from Antarctic blue whales were detected at 238 listening stations throughout the voyage. Calling blue whales were tracked and located on multiple occasions to enable closer study of their calling behaviour as well as collection of photo ID, behavioural and photogrammetry data.

Over 300 hours of sightings effort, led to 36 encounters with blue whales and identification of 25 individuals. There were no within-season re-sights of the 25 individuals. All identification photographs are being compared to the Antarctic Blue Whale Catalogue (see below).

Hundreds of experiments were conducted on water samples collected using both a CTD and trace metal rosette, to test the theory that whale faeces is an important source of iron in the Southern Ocean and determine the impact of Antarctic blue whales and krill on local biogeochemical recycling. Investigations spanned the entire food chain from viruses to bacteria to phytoplankton to krill to Antarctic blue whales. The data collected on the voyage will be analysed over the coming year and detailed reports will be presented at SC/68b.

IWC-SORP sincerely thanks WWF-Australia for a contribution of $10,000 AUD toward participation of Paula Olson on the IWC-SORP ENRICH voyage (see Annex 1 for more details). £15,000 GBP were also allocated from the IWC-SORP Research Fund intersessionally by the IWC-SORP Scientific Steering Committee (SSC) toward voyage. We also acknowledge the CSIRO Marine National Facility staff and vessel crew for their incredible support before and during the voyage.

ARA Almirante Irizar voyage 2019

Visual and acoustic surveys of cetaceans were conducted aboard the Argentinean Navy icebreaker, *ARA Almirante Irizar*, February 22rd and March 22nd, 2019, navigating along the North-Eastern Antarctic Peninsula in the Weddell Sea, and through the Scotia Sea reaching Islas Orcadas del Sur/ South Orkney Islands (60°38.42'S 45°14.52'W). Visual surveys were conducted over a total of 48.5 h and 850 nm. On-effort cetacean sightings included four odontocete and three mysticete species, encompassing a total of 146 encounters. A total of 103 h of acoustic recordings were collected with a four-element towed hydrophone array. Recordings are being analysed in search for presence of odontocete acoustic signals. Additionally, photographs were taken of humpback, minke, fin and killer whales which are currently being reviewed. Those suitable for photo-identification will be classified and shared with other catalogues. A preliminary photo-identification catalogue of Antarctic fin whales was compiled using photographs taken from 2013 to 2019, and nine individual whales were catalogued.

Antarctic blue whale photo-identification

Identification photographs of 25 individual Antarctic blue whales were collected during the ENRICH voyage, January-March 2019. There were no within-season re-sights of the 25 individuals. All identification photographs are being compared to the Antarctic Blue Whale Catalogue, which in 2018 reached a total of 458 whales, represented by 342 left sides and 332 right sides. To date, a relatively small number of whales have been re-sighted inter-annually: 3% (14/458). There is evidence that the Antarctic blue whale population has indeed been increasing (Branch 2007) which would explain the low re-sighting rate.

In 2018 and 2019, opportunistically collected photographs were contributed to the Catalogue from citizen scientists and from research scientists working on other projects in the Antarctic. These opportunistic photographs will be compared to the Catalogue during 2019.

The addition of identification photos and sighting histories to the Catalogue improves the data that can be used in abundance model (e.g. Olson et al. 2018).

Platforms of opportunity

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

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

13 peer-reviewed publications have been generated by the Antarctic Blue Whale project to date. A full IWC-SORP Antarctic Blue Whale Project report is included in Annex 1, pp. 16-28.

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

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

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 2018/19 austral summer but funding is being sought to continue the project in the future. Two peer-reviewed publications have been prepared and submitted in 2018/19.

Dalla Rosa

No fieldwork was conducted during the 2018/19 austral summer. Funding is being sought to continue this fieldwork in 2019/20.

De Bruyn and Reisinger

At the time of writing, fieldwork is being carried out on Marion Island for the 2019 field season, partially funded by a grant awarded from the IWC-SORP Research Fund (SC/68a/SHXX). 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.

Killer whales are globally distributed apex predators, but 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. 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 ~105,000 images and 69 individuals have been identified. 34 satellite tags have been deployed and these have revealed seasonal site fidelity as well as rapid, long-distance movements and deep diving over seamounts. 70 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. However, 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. Preliminary analyses of killer whale tracking data and fishing vessel movements show that killer whales and fishing vessels use the same areas and show a number of instances where killer whales actively follow fishing vessels.

Overall, 36 peer-reviewed publications have been generated by the IWC-SORP killer whale project to date. A full project report is included in Annex 2, pp. 29-46.

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

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.

In 2018-2019 fieldwork was continued around the Western Antarctic Peninsula. The team focused on deploying suction cup tags on both humpback and minke whales, measuring prey and sea ice, and using UAS to generate estimates of body condition and animal size. This incredibly successfully effort resulted in 10 deployments on minke whales and 10 deployments on humpback whales. Additionally, 13 LIMPET tags were deployed on humpback whales and 1 on a minke whale through funding provided from the Antarctic and Southern Ocean Coalition and the Hogwarts Running Club. These data are part of a current NSF award to Dr Friedlaender.

Several articles were published that specifically show the dynamic nature of humpback whale foraging behaviour throughout the feeding season, and the spatio-temporal overlap between humpback whale foraging areas and the krill fishery around the Antarctic Peninsula.

49 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. 47-68.

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

Friedlaender et al. also received funding from the IWC-SORP Research Fund in 2016/17 and 2018/19. The details of these projects can be found in SC/67b/SH18 and SC/68a/SHXX.

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

There were two research components focused on humpback whale distribution and connectivity throughout the Oceania – east Australia region during the 2018/19 period: 1. Oceania feeding ground behaviour and, 2. Genetic connectivity of whales on the Great Barrier Reef (GBR) breeding grounds (Ei). The aim being to advance our understanding of the linkages between the breeding grounds and feeding grounds of the whales from these regions.

1. Oceania feeding ground behaviour

Between September and October 2015, 25 SPOT 5 PTT satellite tags were deployed on humpback whales migrating south past the Kermadec Islands, New Zealand (see Riekkola et al. 2018 for details). Final analysis of the tag data have been completed using state-space models to estimate whale locations and infer underlying behavioural states on their Southern Ocean feeding grounds. Potential environmental drivers of whale behaviour were examined using linear mixed-effect models and maximum likelihood models (Riekkola et al. accepted).

Our work has identified the Kermadec Islands as a diverse region for mixing of whales from Oceania breeding grounds as they migrate to a wide expanse of Southern Ocean (Riekkola et al. 2018). The islands are a significant migratory corridor for humpback whales throughout Oceania and for at least some individuals from east Australia. There are now resights of whales at the Kermadecs across multiple years, suggesting fidelity to this migratory corridor by some individuals. There are also different environmental variables influencing whale behaviour throughout the feeding grounds (Andrews-Goff et al. 2018, Riekkola et al. accepted).

Of the 25 tags, 14 transmitted data within the feeding grounds (south of 60°S) from November 2015 until June 2016 with a spatial range of 175°E to 80°W. Foraging behaviour increased as feeding season progressed, peaking in March. There were spatial differences between whales feeding in the Ross Sea region compared to those in the Amundsen-Bellingshausen Seas region. The Ross Sea whales were consistently farther away from the shelf break (>500 km) and ice edge (~370 km) than whales in the Amundsen-Bellingshausen Seas (within ~200 km of the shelf break and ~210 km on average to the ice edge). The most parsimonious model identified a 2-month lag in the distance to the ice edge, SSH and the interaction between region and month as important predictors of the behavioral state of humpback whales within their Southern Ocean feeding grounds.

2. Genetic connectivity of whales on the Great Barrier Reef (GBR) breeding grounds (Ei)

Fieldwork was carried out from 8th – 20th July and 26th August – 7th September 2018. During this period, 186 pods of humpback whales consisting of 377 (333 adults and 44 calves) individuals were sighted. A total of 21 genetic samples, and 9 h 51 mins of acoustic recordings targeting social sounds and singers were collected for analysis at the Cetacean Ecology and Acoustics Lab at the University of Queensland. Photo-identification images from 2016 and 2017 were matched to the Chesterfield-Bellona archipelago with no matches found (see Garrigue et al. 2018 for details).

A total of 113 genetic samples have now been collected from the E1 breeding stock within the Great Barrier Reef Marine Park. Preliminary analysis of the E1 samples have been undertaken at the Cetacean Conservation and Genomics Laboratory at Oregon State University and the results are detailed in Annex 3.

The GBR breeding ground surveys have provided important information about stock structure and connectivity to neighbouring breeding grounds although, despite the collection of 113 samples to date, the sample size remains low considering the number of whales in the Ei breeding grounds. This limits the conclusions that can be made when comparing to other more extensively sampled Oceania regions. There will be a 2019 field season in the GBR to collect samples from females with calves (not from the calves) which will help resolve the under-representation of females in the current GBR dataset. This cohort was not able to be sampled in 2016-2018 due to permit conditions that have now been removed.

20 peer-reviewed publications have been generated by the IWC-SORP Oceania humpback whale Theme to date. A full project report is included in Annex 4, pp. 69-74.

IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their substantial and collaborative contribution to this project. IWC-SORP gratefully acknowledges contributions from Pew Charitable Trusts, the New Zealand Ministry for Business, Innovation and Employment, the New Zealand Department of Conservation, the Australian Antarctic Division, the University of Auckland and the International Fund for Animal Welfare (IFAW). Constantine et al. and Paton et al. were both awarded grants from the IWC-SORP Research Fund in 2017 to support this Theme; see SC/67b/SH18 and SC/68a/SHXY for more details. Expedition MARACAS 3 is a component of the WHERE Project funded by the New Caledonian Government, the Ministère de la Transition Ecologique et Solidaire, the World Wildlife Fund for Nature, and Opération Cétacés.

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

Annotated library of acoustic detections

In late 2016 The SORP Acoustic Trends Steering Group was awarded a grant of £22,000 from the IWC-SORP Research Fund for the creation of an annotated library of acoustic detections. Several intercessional meetings of the steering group were held to discuss the implementation of this library, and annotation of acoustic data from four circumpolar sites is presently underway. Annotations of data is expected to continue through 2019. Details of planned and completed work can be found in the Annotated Library Progress Report (SC/68a/SHXX).

Postdoctoral researcher to develop framework for automated detection of calls

In 2018, the ATP was granted funds for a 14-month postdoctoral researcher to develop a standardized analytical framework for robustly detecting circumpolar call density trends in passive acoustic data for Antarctic blue and fin whales. The position will be based at the University of Concepción, Chile, and will include a research visit to the University of St Andrews, Scotland. During the meeting in Paris in June, the planning and requirements of the project were discussed in more detail. The position announcement has been finalised and will be advertised shortly (SC/68a/SHXX).

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

In 2017/18, members of the Acoustic Trends Project serviced 17 annual recording stations continuing multi-year records. The data volume from all instruments recovered in 2018 totaled approximately 230,000 hours of underwater recordings.

The Australian Antarctic Division recovered and replaced two moored acoustic recorders at its two long-term recording sites in East Antarctica (along resupply routes to Mawson and Casey stations; Fig 1, sites A & B). The instrument on the Casey resupply route recorded continuously from 23 December 2017 – 16 October 2018 (7126 h). The instrument from the Mawson resupply route was recovered, but at the time of writing this was still awaiting data retrieval.

ENSTA Bretagne, in collaboration with the Australian Antarctic Division, recovered and replaced one acoustic recorder at one long-term recording site along the resupply route to Dumont D'Urville Station. (65°30,6S 140°34.9E). The recovered instrument recorded continuously from 5 Feb 2018 to 5 October 2018 (5800 h).

The Alfred-Wegener Institute (AWI) recovered the 18 Sono.Vault recorders that were deployed in 14 moorings 2016/17 in the Atlantic section of the Southern Ocean (Weddell Sea, Fig 2 top map) during the 2018/19 Polarstern cruise. Nine of these contained over one year of data. Twelve Sono.Vault recorders were subsequently redeployed.

Low-latitude data collection (<60°S) 2018/19

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

• An AAD moored acoustic recorder was recovered from 53°00' S, and 076°09'E (off Heard Island) in cooperation with Austral Fisheries, FV Atlas Cove. It recorded from 16 Sep 2017 – 30 Mar 2018 (4670 h).
• ENSTA Bretagne recovered the AURAL deployed at 46°32'S, and 051°30E' (off Crozet Island). It recorded from Jan 2018 – Jan 2019.
• ENSTA Bretagne in collaboration with Institut Universitaire Européen de la Mer (IUEM) Géosciences Océan - UMR 6538 UBO-CNRS recovered and redeployed 9 long term autonomous hydrophones in the Indian Ocean between 24° to 56° South and from 52° to 83° East. This network of hydrophones has been in place since 2009/2010.

Participation in AAD-led ENRICH voyage to study blue whales and krill

In 2018, Širović and Stafford were awarded a grant of £30,107 GBP from the IWC-SORP Research Fund to join the AAD-led IWC-SORP ENRICH voyage as members of the passive acoustic team, while also providing an acoustic mooring for deployment in study area for the duration of the cruise. This voyage took place from 20 January to 6 March 2019. Details of the voyage will be provided at SC/68b.

The project has generated 30 peer-reviewed publications to date (two are also listed under the Antarctic Blue Whale Project). A full project report is included in Annex 5, pp. 75-84.

IWC-SORP Theme 6: The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale

IWC67 endorsed a new IWC-SORP research theme: *The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale.*

The specific objectives of the theme are be to:

1) Increase our understanding of southern right whale foraging habitats and ecology
2) Update our knowledge on southern right whale population dynamics in a comparative framework
3) Pursue integration of health assessment indicators with long-term monitoring data
4) Investigate the impact of climate variation at foraging grounds on population recovery

The Theme is led by Drs Emma Carroll and Els Vermeulen, in close collaboration with colleagues from Argentina, Australia, Brazil, New Zealand and South Africa. Work has already been undertaken against all four objectives including:

- Collation of available stable isotope data
- Analysis of seasonal distribution and abundance of SRW at major aggregation ground at Head of Bight using 26 years of annual sightings and photo-ID data (Charlton et al. 2019).
- A visual health assessment of southern right whales photographed along the South African coast between 2005 (start of digital photography) and 2018 (SC/68a/SH01).
- Commencement of a global comparative study of right whales by Christiansen et al. in collaboration with Murdoch University, Woods Hole, NOAA and others.
- Assessment of southern right whale body condition at major calving ground in South Australia during the 2016 season by Christiansen et al. (2018). Body condition data was also collected during 2016-2018 in South Australia.
- A South African study to assess the linkages between southern right whale reproductive success and Southern Ocean climate conditions and productivity (SC/68a/SH01).

A full theme report is included in Annex 6, pp. 85-87.

LIST OF IWC-SORP RELATED PAPERS SUBMITTED FOR CONSIDERATION TO SC/68a

SC/68a/SHXX	Bell E (2019) IWC-SORP Research Fund: progress reports (2016/17 & 2018/19).
SC/68a/SHXX	Bell E (2019) Annual Report of the Southern Ocean Research Partnership 2018/19.
SC/68a/SH04	Galletti Vernazzani B, Attard CRM, Barlow DR, Burton C, de Vos A, Double M, Gill P, Jenner C, Jenner M-N, Möller LM, Olson P, Salgado-Kent C, Torres LG (2019) Southern Hemisphere Blue Whale Catalogue: preliminary results of IWC comparisons between Australia, New Zealand and Sri Lanka regions.
SC/68a/SH09	Galletti Vernazzani B, Olson P, Salgado-Kent C (2019) Progress report on Southern Hemisphere Blue Whale Catalogue: Period May 2018-April 2019.
SC/68a/SH0X	Hörbst S, Vermeulen E, Moloney CL (2019) Visual health assessment of parous female southern right whales (*Eubalaena australis*) off the southern Cape coast, South Africa
SC/68a/SH03	Kershaw JL, Carroll EL, Torres L, Hall AJ (2019) Steroid hormone extraction and quantification validation in southern right whale (*Eubalaena australis*) blubber biopsy samples.
SC/68a/SH0X	van den Berg G, Vermeulen E, Hui C, Findlay K, von der Heyden S, Midgley G (2019) Linking climate and ocean productivity to the prevalence of southern right whales (*Eubalaena australis*) in South African waters
SC/68a/SH01	Vermeulen E, Wilkinson C, Thornton M (2019) Report on 2018 southern right whale aerial survey, South Africa

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.
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ANNEX 1 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

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

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Introduction

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

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

Overall objectives

The objectives of the Antarctic Blue Whale Project are to:

- Identify the most appropriate and efficient method to deliver a new circumpolar abundance estimate of Antarctic blue whales;
- Develop and refine methods to improve survey efficiency;
- Deliver a new circumpolar Antarctic blue whale abundance estimate;

- Improve understanding of Antarctic blue whale population structure;
- Improve understanding of linkages between Antarctic blue whale breeding and feeding grounds;
- Characterise the behaviour of Antarctic blue whale on the feeding grounds.

Project activities in 2018/19

Work on the Antarctic Blue Whale Project has focused on the planning and execution of IWC-SORP research voyages, the ongoing analysis of data collected during previous voyages, analysis of movements of Antarctic blue whales from recent and historic data, photo-identification of whales from research datasets and platforms of opportunity.

2019 ENRICH voyage to the Southern Ocean - Michael Double, Elanor Bell, Madelaine Brasier, Charlotte Boyd, Susannah Calderan, James Cox, David Donnelly, Thomas Holmes, Lynette Irvine, Olivia Johnson, Ailbhe Kavanagh, Natalie Kelly, Rob King, So Kawaguchi, Joshua Lawrence, Russell Leaper, Jessica Melvin, Brian Miller, Elanor Miller, Steve Nicol, James O'Brien, Paula Olson, Lavenia Ratnarajah, Vanesa Reyes Reyes, Clara Rodriguez Vives, Abigail Smith, Joshua Smith, Ana Širović, Kate Stafford, Alex Vail, Karen Westwood, Haiting Zhang

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

The 2019 IWC-SORP *ENRICH* Voyage (**E**uphausiids and **N**utrient **R**ecycling in **C**etacean **H**otspots), was conducted from 19 January – 05 March 2019, aboard the CSIRO Marine National Facility research vessel *Investigator*. The voyage departed from and returned to Hobart, Tasmania, Australia, and conducted most marine science operations in the area between 60°S – 67°S and 138°E – 152°E, covering 13,000 kilometres. The voyage was led by the Australian Antarctic Program and involved 28 international scientists.

Active acoustic survey and krill trawling

The voyage represented the first time that a survey of Antarctic blue whales has been conducted together with a structured survey of their prey, Antarctic krill. Throughout the voyage 41 krill trawls were carried out, total of over 100,000 krill individuals were collected, 20 Instantaneous Growth Rate experiments were conducted and approximately 200 live adults krill and more than 10,000 thousand live larvae were returned to the Australian Antarctic Division for further research.

A number of krill swarms were observed using a multi-beam echosounder and a sonar, including a small scale 'mapping' of swarm, where we followed around the edge of swarm. Several swarms extended over one kilometre in length and hundreds of metres across, containing many millions of krill.

Passive acoustic survey

As part of the multidisciplinary research, a passive acoustic survey for marine mammals was undertaken throughout the duration of the voyage, the main goal being to monitor for and locate aggregations and groups of calling Antarctic blue whales (*Balaenoptera musculus intermedia*). Directional sonobuoys were used to conduct 295 listening stations, which resulted in 806 hours of acoustic recordings. Calls from blue and fin whales were detected in real time and calibrated measurements of the bearing and intensity of these calls were obtained for the majority of detections. 33,435 calls from Antarctic blue whales were detected at 238 listening stations throughout the voyage.

Calling blue whales were tracked and located on multiple occasions to enable closer study of their calling behaviour as well as collection of photo ID, behavioural and photogrammetry data. Although not the main focus of the project, monitoring also took place for sperm whale, humpback whale, sei whale, Antarctic minke whale, leopard seal, crabeater seal, Ross seal, Weddell seal, and odontocete (low frequency whistle) vocalisations during each listening station. The passive acoustic data collected during this voyage will allow investigation of

the distribution of Antarctic blue whales in relation to their environmental correlates, especially prey. The data will also provide information on the properties of the sounds produced by Antarctic blue whales including their source levels and the relationship between movements and acoustic behaviour.

Cetacean sighting survey

Over 300 hours of sightings effort, led to 36 encounters with blue whales and identification of 25 individuals. There were no within-season re-sights of the 25 individuals. All identification photographs are being compared to the Antarctic Blue Whale Catalogue (see below).

Biogeochemical recycling

Hundreds of experiments were conducted on water samples collected using both a CTD and trace metal rosette, to test the theory that whale faeces is an important source of iron in the Southern Ocean and determine the impact of Antarctic blue whales and krill on local biogeochemical recycling. Investigations spanned the entire food chain from viruses to bacteria to phytoplankton to krill to Antarctic blue whales.

The voyage's multidisciplinary research will contribute to the improvement of ecosystem-based management of the Antarctic krill fishery and the conservation of endangered Antarctic blue whales. The data collected on the voyage will be analysed over the coming year and detailed reports will be presented at SC/68b.

IWC-SORP sincerely thanks WWF-Australia for a contribution of $10,000 AUD toward participation of Paula Olson on the IWC-SORP ENRICH voyage (see Annex 1 for more details). £15,000 GBP were also allocated from the IWC-SORP Research Fund intersessionally by the IWC-SORP Scientific Steering Committee (SSC) toward voyage. We also acknowledge the CSIRO Marine National Facility staff and vessel crew for their incredible support before and during the voyage.

2019* Rompehielos Almirante Irizar *voyage to North Antarctic Peninsula, Scotia Sea and South Orkney Islands" - Alexander Marino, Luis Bedriñana-Romano, A. Albalat, Marta Hevia, Vanesa Reyes Reyes, Mariana Melcón, Rodrigo Hucke-Gaete, 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, six summer season cruises to the Antarctic Peninsula have been conducted on board Argentinean vessels, five of them with Coast Guard vessels to the western part of the Peninsula, with the first one additionally including the Scotia Sea and Islas Orcadas del Sur/ South Orkney Islands, and the latest one with the Navy icebreaker *ARA Almirante Irizar* to the north-eastern part of the Peninsula in the Scotia Sea, Weddell Sea and Islas Orcadas del Sur/ South Orkney Islands. In this voyage dedicated researchers carried out line-transect visual observations of cetaceans and acoustic monitoring of odontocetes from a vessel used as a platform of opportunity.

Objectives

1. Conduct a visual and acoustic survey on cetacean species in the Scotia Sea and NW Antarctic Peninsula area.
2. Conduct skin biopsy sampling on cetacean species in the Scotia Sea and NW Antarctic Peninsula area.
3. Conduct photo-identification on cetacean species in the Scotia Sea and NW Antarctic Peninsula area.
4. Acoustically monitor the presence of cetacean species in the Scotia Sea and NW Antarctic Peninsula area year-round through an autonomous recorder.

Results

Visual and acoustic surveys of cetaceans were conducted aboard the Argentinean Navy icebreaker, *ARA Almirante Irizar*, travelling through the Southern Ocean between February 22rd and March 22nd, 2019, navigating along the North-Eastern Antarctic Peninsula in the Weddell Sea, and through the Scotia Sea reaching Islas Orcadas del Sur/ South Orkney Islands (60°38.42'S 45°14.52'W) as the easternmost location in the track, finally arriving to the port of Ushuaia (54° 48.52'S 68° 18.17'W) (Figure 1).

Visual surveys were conducted over a total of 48.5 h and 850 nm (Figure 1). On-effort cetacean sightings included four odontocete and three mysticete species, encompassing a total of 146 encounters (Table 1; Figure 2).

A total of 103 h of acoustic recordings were collected with a four-element towed hydrophone array. Recordings are being analysed in search for presence of odontocete acoustic signals.

Photographs were taken of humpback, minke, fin and killer whales which are currently being reviewed. Those suitable for photo-identification will be classified and shared with other catalogues. A preliminary photo-identification catalogue of Antarctic fin whales was compiled using photographs taken from 2013 to 2019, and nine individual whales were catalogued (Figure 1).

Figure 1 Two individuals of Antarctic fin whales included in the catalogue. Photo: M. Iñíguez/Fundación Cethus (top) and M. Hevia/Fundación Cethus (bottom).

On February 26th a small boat was deployed at the surroundings of Argentinean base, Petrel (63° 28'S 56° 17' W), with the objective of taking biopsy samples and collecting photo-ID data. After 15 minutes of effort no whales were found, therefore no samples were collected. Logistic activities of the vessel interrupted the sampling effort.

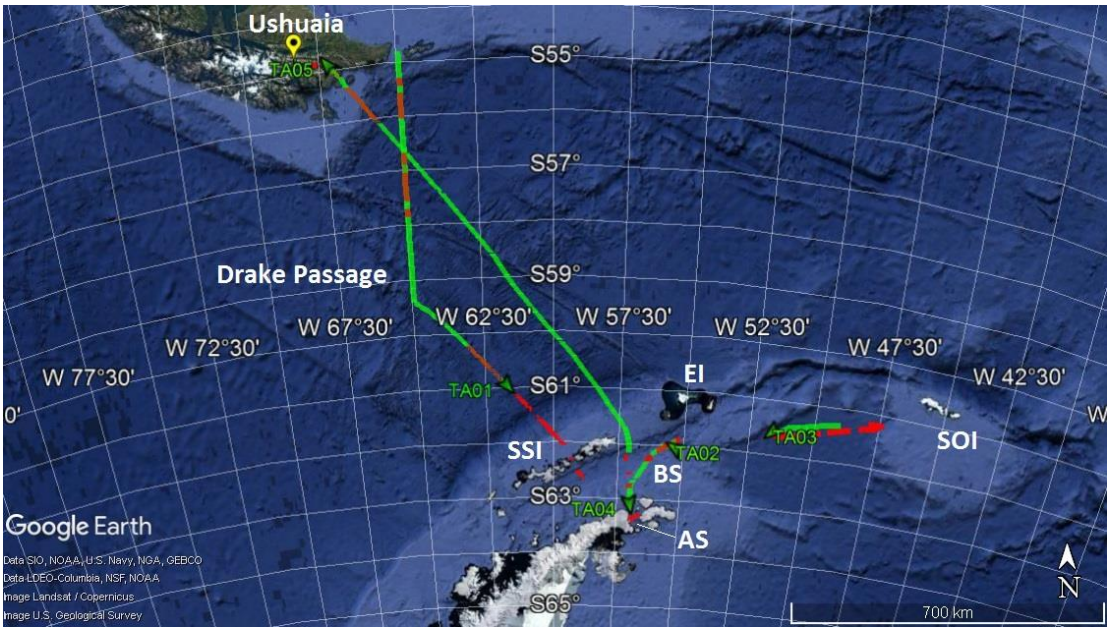


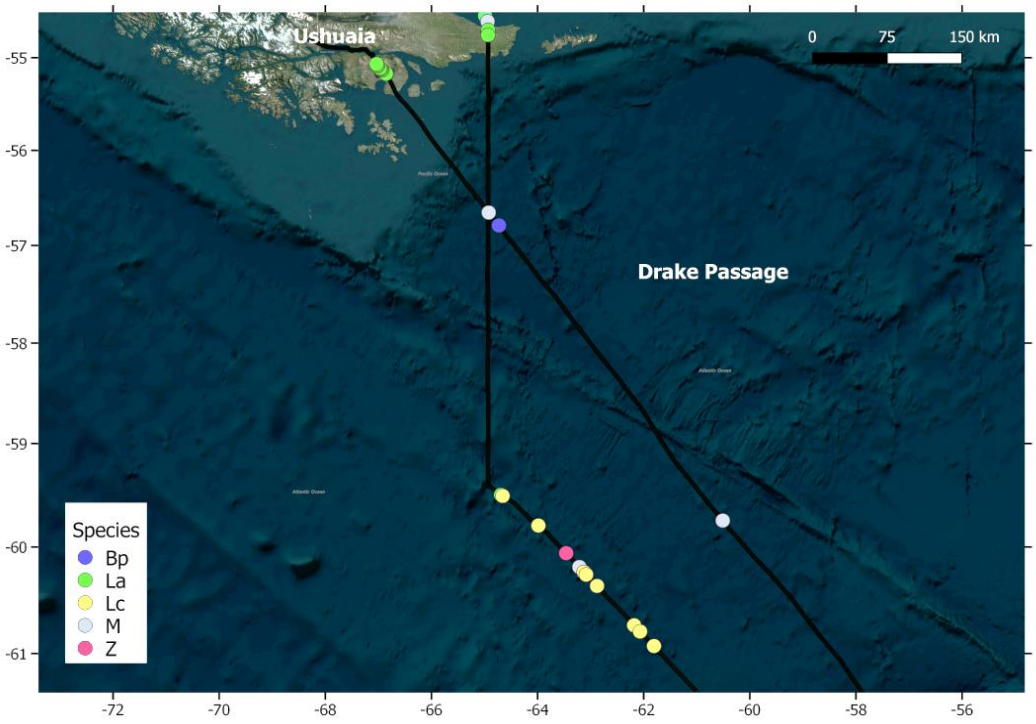
Figure 2 On-effort visual (red lines) and acoustic (green lines) tracks using a towed hydrophone array (TA: Towed Array). SSI: Islas Shetland del Sur/ South Shetland Islands/; EI: Isla Elefante/ Elephant Island; BS: Mar de la Flota/ Bransfield Strait; SOI: Islas Orcadas del Sur/South Orkney Islands; AS: Estrecho Antarctic/Antarctic Sound.

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	51	104	1-5	2.0 ± 1.1
*Balaenoptera acutorostrata**	Minke whale	4	4	--	--
Megaptera novaeangliae	Humpback whale	37	71	1-5	1.9 ± 1.1
Orcinus orca	Killer whale	3	20	4-8	6.6 ± 2.3
Lagenorhynchus cruciger	Hourglass dolphin	8	30	1-8	3.8 ± 2.1
Lagenorhynchus australis	Peale's dolphin	3	14	3-8	4.7 ± 2.9
Hyperoodon planifrons	Southern bottlenose whale	1	1	--	--
Unidentified cetacean	Unidentified cetacean	3	3	--	--

Unidentified delphinidae	Unidentified delphinidae	1	7	--	--
Unidentified mysticete	Unidentified mysticete	34	60	1-4	1.8 ± 1.0
Unidentified ziphiidae	Unidentified ziphiidae	1	1	--	--

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



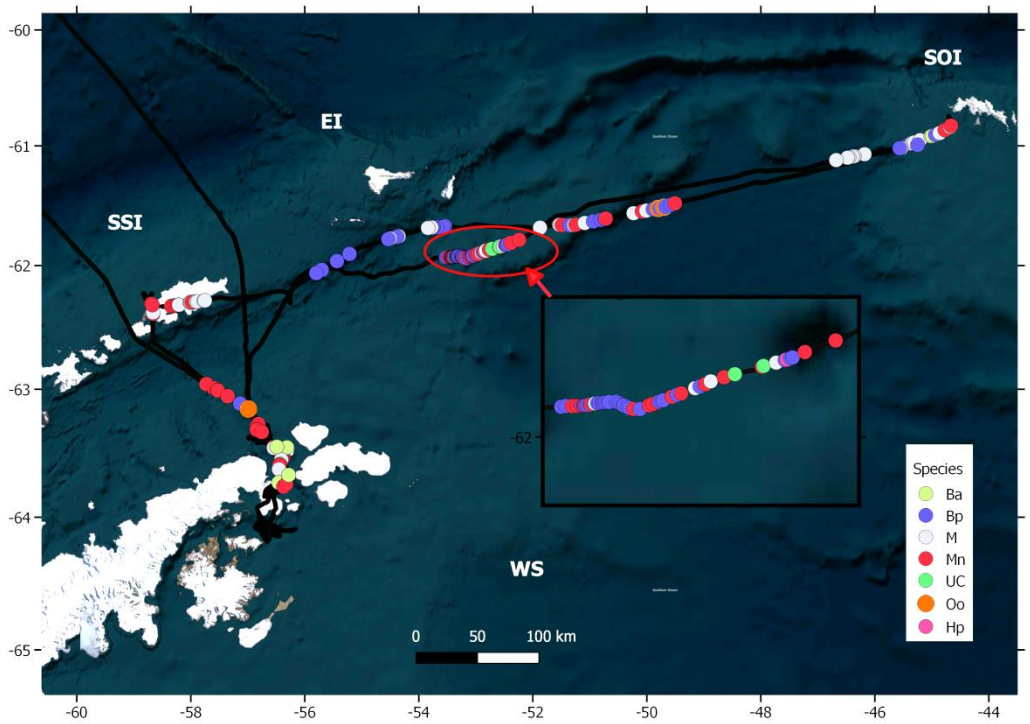


Figure 3 Cetacean sightings between February 22nd and March 22nd, 2019. (A) Drake Passage (B) North-eastern Antarctic Peninsula, Mar de Scotia/ Scotia Sea and Islas Orcadas del Sur/ South Orkney Islands. SSI: Islas Shetland del Sur/ South Shetland Islands; EI: Isla Elefante/ Elephant Island; WS: Mar de Weddell/ Weddell Sea; SOI: Islas Orcadas del Sur/ South Orkney Islands.

The largest concentration of fin whales was detected in Scotia sea between Islas Shetland del Sur/ South Shetland Islands and Islas Orcadas del Sur/ South Orkney Islands, result coincident with that was previously described in 2014 (Reyes Reyes et al. 2014). Mean encounter rates (number of sighted individuals per nautical mile surveyed) and standard deviation were calculated for fin whales in this particular area, considering segments of 10 nm as sampling units, giving 0.52 ± 1.08 whales/nm. Only whales sighted during visual effort were considered. Further analysis of visual and acoustic data will be done to increase information in the effort of assessing distribution of fin whales along north and northeast SSI during austral summer.

Acoustic recordings obtained with an autonomous acoustic recorded HARP from 2014 to 2016 are being analysed in order to detect presence of cetacean sounds and correlate them with environmental characteristics.

Challenges

The main challenge has been securing vessel time and funds for ongoing research, and the purchase, development, and/or refurbishment of equipment. This year, adapting the route pre-established by the vessel to the proposed study areas was not possible, hence a part of the originally planned areas was not surveyed. In turn, areas previously unreached within the Weddell Sea were surveyed in this occasion. In addition to logistic priorities of the vessel, climatic factors also affected small boat operations and consequently biopsy sampling efforts. Time delays in funding made the process of transporting a new HARP to Antarctica an impossible task.

Outlook for the future

Assemble and deploy a new HARP to replace the lost one in order to continue monitoring the seasonal distribution of blue whales, fin whales, killer whales, sperm whales, beaked whales, and possibly other cetaceans. Complete the analysis of visual data to assess the distribution of fin whales along north and northeast SSI during the austral summer. Increase the number of individuals in the Antarctic fin whale photo-ID catalogue and continue work on photo-ID of other species as mentioned above.

Photo-identification of Antarctic blue whales – Paula Olson

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, 2017). The use of photo-identification data in a capture-recapture analysis for the production of a contemporary (new) estimate of abundance of Antarctic blue whales is a component of the Antarctic Blue Whale Project (Bell, 2017).

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

Recently, photographs of Antarctic blue whales became available (recovered from storage) from the IWC IDCR and SOWER cruises conducted in 1989/1990, 1993/1994, and 1997/1998, as well as opportunistic photographs collected by collegial scientists, naturalists, and tourists in 2015-2018. This project identified and compared

individual identification photographs of Antarctic blue whales from the new photo collections with the Antarctic Blue Whale Catalogue. The addition of newly identified individuals will increase the sample size needed to conduct a capture-recapture analysis and to reveal movement patterns.

Objectives

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

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

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

Results

Identification photographs of 25 individual Antarctic blue whales were collected during the ENRICH voyage, January-March 2019. There were no within-season re-sights of the 25 individuals. All identification photographs are being compared to the Antarctic Blue Whale Catalogue, which in 2018 reached a total of 458 whales, represented by 342 left sides and 332 right sides. To date, a relatively small number of whales have been re-sighted inter-annually: 3% (14/458). There is evidence that the Antarctic blue whale population has indeed been increasing (Branch 2007) which would explain the low re-sighting rate.

In 2018 and 2019, opportunistically collected photographs were contributed to the Catalogue from citizen scientists and from research scientists working on other projects in the Antarctic. These opportunistic photographs will be compared to the Catalogue during 2019.

The addition of identification photos and sighting histories to the Catalogue improves the data that can be used in abundance model (e.g. Olson et al. 2018).

Platforms of opportunity

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

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

Project outputs

Peer-reviewed papers

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

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

Book chapters

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

Reports

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

Marino A, Albalat A, Bedriñana-Romano L. Informe de actividades realizadas en el marco del Consorcio para la Investigación del Océano Austral perteneciente a la Comisión Ballenera Internacional (IWC-SORP). Report presented to Dirección Nacional del Antártico in Argentina.

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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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Reyes Reyes MV, Baumann-Pickering S, Simonis AE, Trickey JS, Hildebrand JA, Melcón ML, Iñíguez MA

(2016) High-frequency modulated whistles of killer whales (*Orcinus orca*) in Antarctica. Oral presentation at the 1st Listening for Aquatic Mammals in Latin America Workshop. Natal, Brazil. 21-23 June 2016.

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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

Argentinean Navy's newspaper:
http://gacetamarinera.com.ar/el-trabajo-de-los-investigadores-a-bordo-del-irizar/

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):
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ANNEX 2 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

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

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Introduction

We have described five different ecotypes of killer whales from Antarctic waters, any or all of which could eventually be recognized as separate species. Killer whales are large apex predators that are commonly found in Antarctic waters; although relatively little is known about the distribution, abundance, habitat and prey preferences of each of the different ecotypes, cumulatively they are expected to play a key role in the Antarctic marine ecosystem. This project is investigating the ecosystem impact the different ecotypes of killer whales that occur in Antarctic and adjacent waters, by focusing on their systematic relationships, abundance, demographics, distribution, movement patterns, health, and prey preferences.

Progress and results for 2017/18

Luciano Dalla Rosa, West Antarctic Peninsula and Powell Basin.

Introduction

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

Objectives

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

Results

No fieldwork was conducted in 2018/19.

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 2019/20 and future seasons.

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

Introduction

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

Objectives

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

Results

Table 2 Summary of sightings, Satellite tagging and biopsy sampling

	2008-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	***All (2008-2019)**
Observation sessions										
Number	481	210	273	231	216	170	196	165	170	**2112**
Hours	2,511 h	1,145 h	1,846 h	1,380 h	1,247 h	916h	951h	921 h	933 h	**11850**
Sightings										
Dedicated	406	413	466	399	402	217	149	216	225	**2893**
Opportunistic	670	270	265	153	273	123	108	215	140	**2217**
Images										
Dedicated	9,160	5,354	7,833	6,288	8,313	6453	6224	9413	10835	**69873**
Opportunistic	6,420	5,803	2,346	876	4,639	1918	1177	7575	4245	**34999**
Tagging										
Attempts	-	25	7	10	6	0	2	6	2	**58**
Successful	-	10	6	6	2	0	2	6	2	**34**
Tags lost (without transmitting)	-	6	1	4	0	0	0	0	0	**11**

Duration (average)	-	7.5 d	26.6 d	8.2 d	5.9 d	0	30 d	12.7 d	20 d	**110,9**
Biopsy										
Attempts	-	63	9	18	15	9	14	14	8	**150**
Samples	-	24	5	6	6	7	8	10	4	**70**

*To 2019/03/15

Photo-identification

- ~105,000 images to date
- 69 unique individuals identified

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. Multi-event 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.

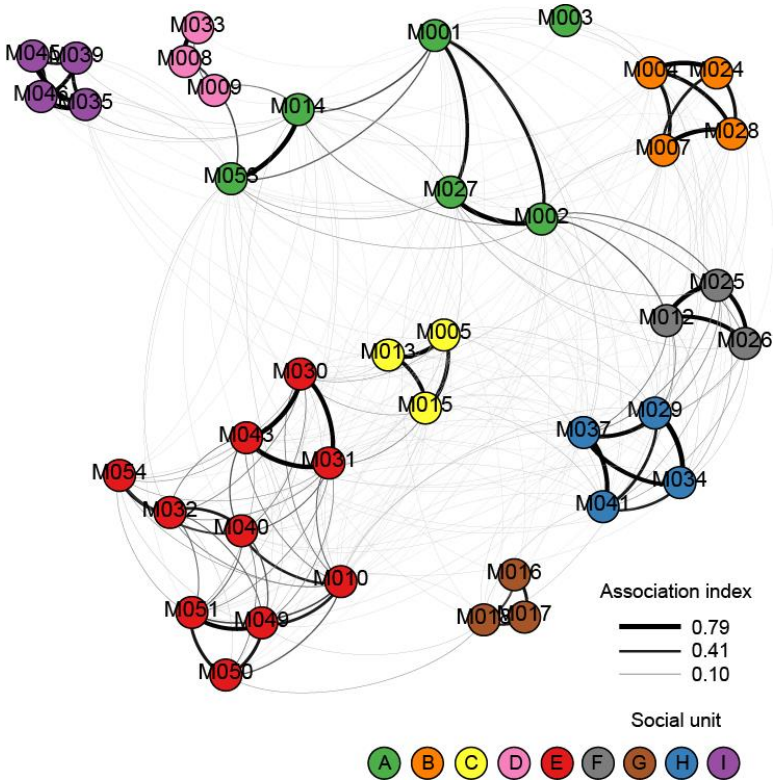


Figure 4 Network graph showing the associations between killer whales at Marion Island. Individuals are represented by nodes (coloured circles) and associations by edges (lines) between nodes. Colours represent social units and edges are weighted by the half-weight association index (Reisinger et al. 2017).

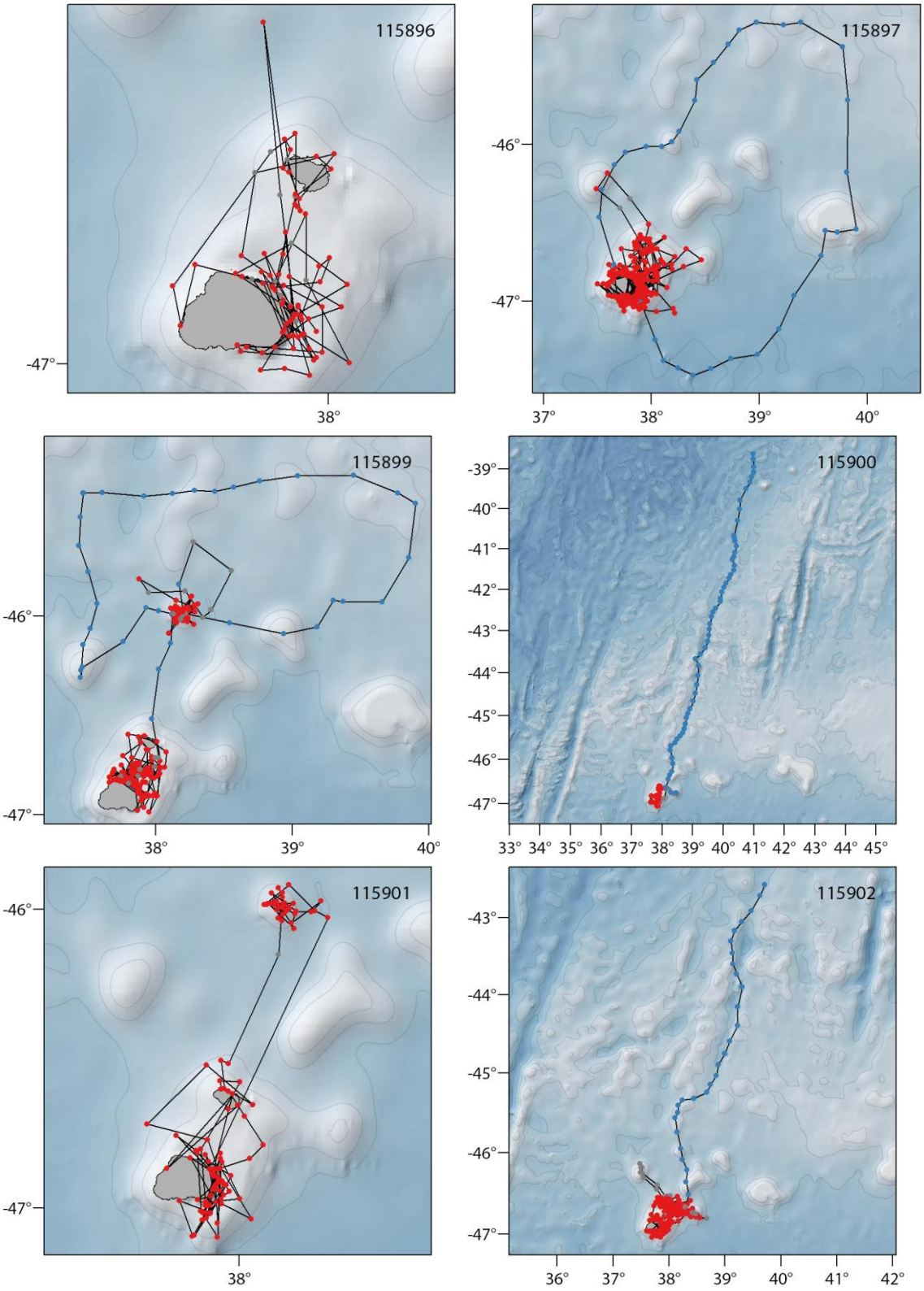
Movement and diving

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

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

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

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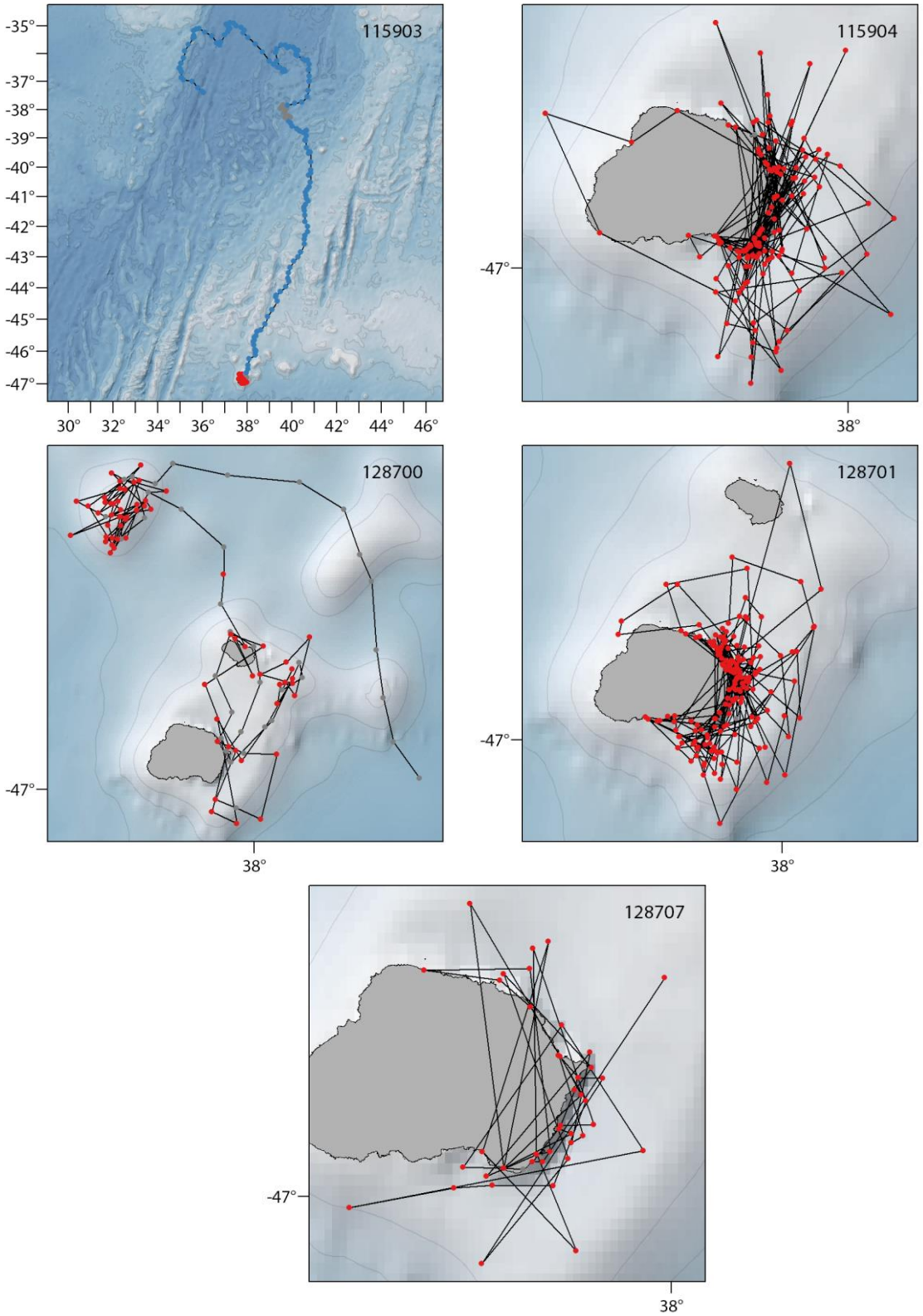

Figure 5 Individual tracks of satellite-tagged killer whales at Marion Island. Points represent state-space switching model position estimates based on ARGOS position estimates, and are coloured by behavioural mode (red – restricted; blue – transit; grey – uncertain). Solid lines represent straight lines 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.

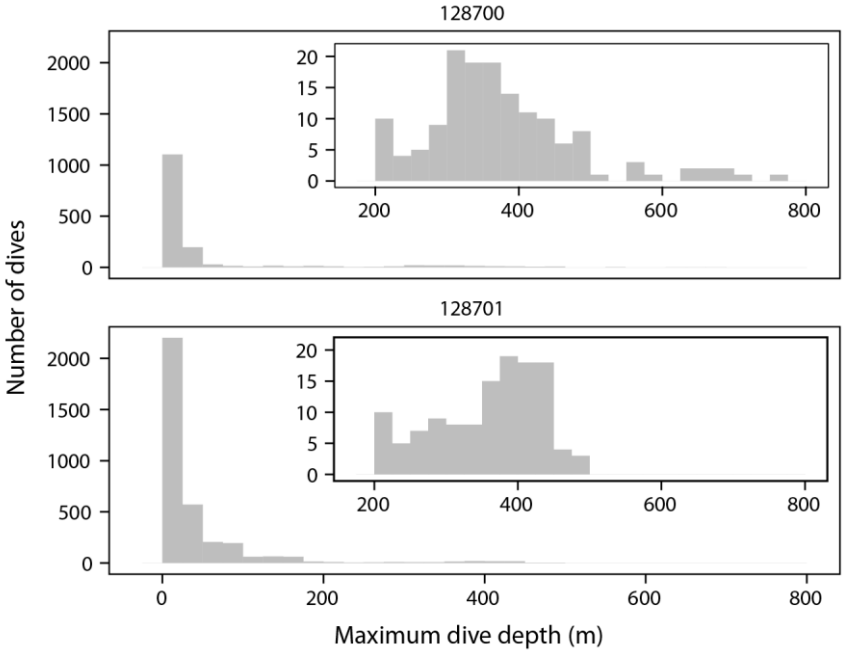

Figure 6 Histogram showing the distribution of maximum dive depths of two killer whales around Marion Island. The 200–800 m depth range is enlarged in the insets.

Killer whale movements in relation to fishing vessels

We used data from 22 satellite tag deployments on killer whales (2011-11-08 - 2017-05-02) and Vessel Monitoring System (VMS) data for the two licenced Patagonian toothfish vessels operating around the Prince Edward Islands (data obtained from the South African Department of Forestry and Fisheries) over the same period. Preliminary analyses show areas of high spatial overlap between killer whales and vishing vessels on seamounts north of Marion and Prince Edward Island, and on Galieni Bank to the north-west of the islands (Figure 4). We identified at least two instances where killer whales actively followed fishing vessels. In collaboration with Dr Paul Tixier (Deakin University) et al., we will analyse these data with data from the French EEZ around the Crozet Islands to determine the distance at which killer whales detect fishing vessels and begin to follow them (see, for example, Towers et al. 2019).

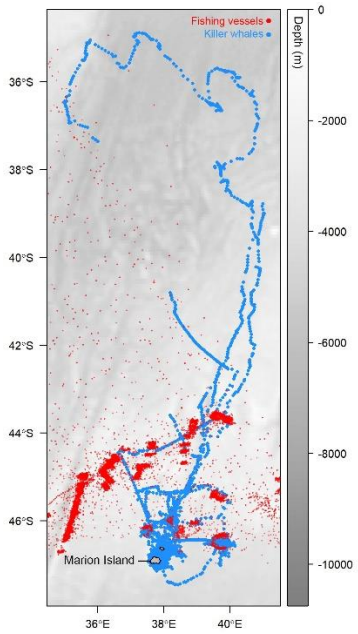

Figure 7 Map showing location estimates (blue points) from 22 satellite tag deployments on killer whales at Marion Island (2011-11-08 - 2017-05-02), with VMS locations of longline fishing vessels (red points) over the same period. For killer whales, hourly locations were estimated from Argos data using a first difference correlated random walk model.

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.

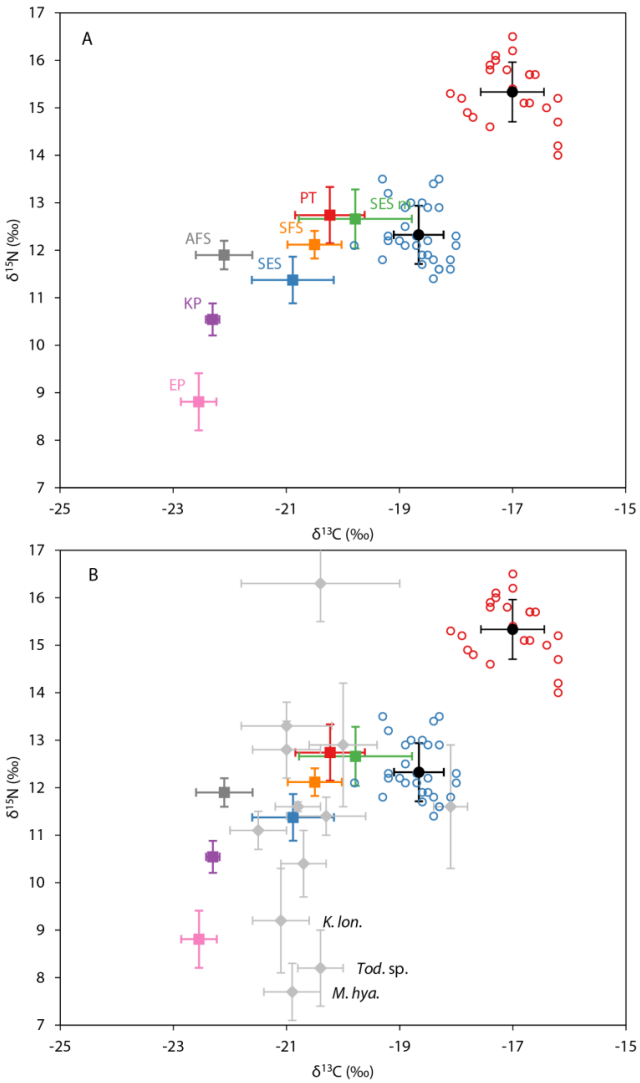

Figure 8 Biplot of δ13C against δ15N showing mean values ± SD for killer whales (filled circles) and their prey (squares). Individual values for killer whale blubber (red) and skin (blue) are shown with open circles. PT – Patagonian toothfish; AFS – Antarctic fur seal; SFS – Subantarctic fur seal; SES – 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 (~2years) effects on individual occurrence at Marion Island have been detectable.

Marion Island killer whales form small social units which are mostly stable over years. Genetic relatedness is higher within than between social units, but association is not correlated with genetic relatedness. Membership of social units is dynamic: some long-term associations are among non-kin, and kinship levels within pods is

highly variable. While social units are stable, associations between them are flexible, which may allow for the adjustment of group sized suited to different contexts.

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

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

Our tracking data show a high degree of overlap between killer whales and the fishery for Patagonian toothfish, including several instances of killer whales following fishing vessels.

Challenges

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

Outlook for the future

- Photo-ID and behavioural observations will continue, and this will facilitate the calculation of demographic parameters in this population and further investigations of social structure (PhD student, Rowan Jordaan).
- Satellite tagging should continue, to identify the reasons for rapid, long-distance movements. Continued tagging with time depth recorders will shed more light on deep diving behaviour over seamounts. Simultaneous biopsy sampling of tagged animals, although difficult to achieve logistically, may allow the detection of any dietary shifts associated with this behaviour.
- Quantitative fatty acid analyses of skin and blubber samples have yielded some preliminary data. We will continue this work in collaboration with Dr Erin McClymont (Durham University).
- We have initiated a collaboration with French (Dr Christophe Guinet et al.) and Australian (Dr Paul Tixier et al.) researchers to more broadly investigate the spatial dynamics of killer whale interactions with the fishery for Patagonian toothfish.

The funds for the purchase of SPLASH10-292B tags and to assist with travel and fieldwork expenses were awarded from the IWC-SORP Research Fund (SC/67b/SH18 and SC/68a/SHXX).

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, research 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 2018/19 austral summer. However, analysis of data from previous seasons continues, peer-reviewed papers have been produced and further funding is being sought to continue this work.

Outlook for the future

A new research proposal was submitted to the Italian Ministry of Research and Universities in July 2018; the proposal regards both Type C killer whales and Adélie and Emperor penguins in relation to the conservation objectives of the Ross Sea Region MPA (abstract below).

> ***Orca and PEnguins ReseArch (OPERA): core foraging areas, movements and dietary overlap of meso and top-predators in the Ross Sea MPA***
> *In October 2016 the CCAMLR members reached consensus to establish the Ross Sea Region Marine Protected Area that came into force in December 2017. According to protection objectives and priorities (ref. SC-CAMLR-XXXIII/BG/23 Rev. 1, i-Vii). , the need to shed light on some aspects of the ecology and the biology of key top predators (including specifically the piscivorous ecotype of the orca C Type and the Adélie and Emperor penguins) strongly stands out. These species occur in the area off Terra Nova Bay where some activities are already underway (Adélie penguins) and others have been conducted sporadically (Orca and Emperor penguin) in the past years. This proposal, therefore, builds up on these necessities as expressed by the CCAMLR and according to the strategic activities identified by Italy (WS-RMP-17/10) based on current knowledge. In this context, for the first time, OPERA is proposing a combined study towards the identification of core foraging areas, movements within and outside the Ross Sea Region MPA as well as the main prey species of the C-type Orca and the Adélie and Emperor penguins. Through standard approaches recognized by the CCAMLR, different methods of research and data analysis are proposed to carry out a detailed investigation on the importance that some areas of the Ross Sea may have for key role species of the MPA ecosystem. This approach will allow for the understanding of a) the species' biological functions, b) the relationships between key predators positioned at different trophic levels and c) possible overlapping with areas outside the MPA affected by fishing activities. The proposal fulfills international requirements related to research and management and results can inform dedicated management measures in both RSR MPA as well as in the ASPAs*

Project outputs

Papers

Busson M, Authier M, Barbraud C, Tixier P, Reisinger RR, Janc A, Guinet C (*In revision*) The role of sociality in the response of killer whales to an over-mortality event. Proceedings of the National Academy of Sciences of the USA.

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ANNEX 3 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

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

Dr. Ari S. Friedlaender[1]

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Executive summary

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

Introduction

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

understanding the ecological role of cetaceans and how these are being affected by climate-driven changes to their environment.

Objectives

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

Results

In 2018-9 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 OneOcean Expeditions and conducted research on 6 expedition trips. We also deployed a field team as part of an NSF award to Dr Friedlaender to study the ecological role of Antarctic minke whales. Below is the scientific report presented to the NSF Office of Polar Programs Program Manager at the conclusion of our field work and selected abstracts and figures from published work that were part of our final report to the AWR for a research grant.

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

Proposal OPP-1643877

Event # B-206-L

Chris Fritsen, NSF/OPP Program Officer

Timothy McGovern, NSF/OPP Ocean Projects Manager

Weekly Science Report 10 March February 2019

Prepared by: Dr. Ari FriedlaenderAdditional field team members: Dave Johnston, Chris Taylor, Dave Cade, Jake Linsky, Shirel Kahane-Rappaport, Julian Dale, and Patrick Gray

Award Abstract

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

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

Part 2. To understand how climatic changes will manifest in the demography of predators that rely on sea ice habitat requires knowledge of their behaviour and ecology. The largest ice-dependent krill predator and most abundant cetacean in the Southern Ocean is the Antarctic minke whale yet virtually nothing is known of the

their foraging behaviour or ecological role. Thus, we lack the knowledge to understand how climate-driven changes will affect these animals and therefore the dynamics of the ecosystem as a whole. We will use multi-sensor and video recording tags, fisheries acoustics, and unmanned aerial systems to study the foraging behaviour and ecological role of minke whales in the waters of the Antarctic Peninsula. We pose the following research questions:

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

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

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

Figure 9 Two Antarctic minke whales carrying motion-sensing and video-recording tags in Andvord Bay.

Weekly Science Synopsis

We completed our allotted science time and are organizing our final data and summaries from what has been an extraordinary expedition. We exceeded our expectations for the number of whales we tagged, the amount of sea ice data we collected, the amount of UAS imagery we generated, the amount of prey mapping that was accomplished, and the number of samples we collected. This was due in large part to the fantastic efforts of the

ASC and ECO crew who provided a safe, fun, and ideal working environment. We are grateful for all of the support we received. Below are summaries for the major components of our science team from the first week of our allocated time as well as a brief synopsis of the Simms field camp that was deployed on Livingstone Island.

G-412 Dr. Alex Simms
Field team: Cameron Gernant, Brittney Theilen, Cara Farrier, Robin Carroccia

The purpose of our field work on Livingston Island was to survey raised beaches using GPS and GPR and sample for optically stimulated luminescence dating to better constrain the late Holocene relative sea-level history of the region. We setup camp on February 22, 2019 and were picked up on March 8, 2019. We were picked up a day early as we had accomplished everything we could within a 3-4 mile radius of the camp and a storm was predicted to move in on our original pickup date (March 9th). The 14 day camp was marked by relatively good weather with snow-free beaches for most of our time ashore. As a result we were very productive and were able to accomplish all of our science goals.

During the field campaign we collected a total of 59 samples for OSL analysis. This included 30 cobbles and 29 sand samples. Four distinct prominent beaches were identified with an additional 4-5 weaker developed beaches/strand plains also identified. The prominent beaches had prevalent ice-rafted debris cobbles suitable for OSL analysis, while the poorly-developed and smaller beaches were largely composed of sands and gravels too small for our cobble technique. However, we managed to sample every beach we identified with at least 2 sand OSL samples.

In addition to sampling for OSL, we also collected more than 8 km of ground-penetrating radar (exact numbers will be tallied once we are able to process all our GPS data). From the lines we viewed in the field the data looks to be of high quality with several interesting features.

We also measured grain size on over 2320 cobbles and gravels from 8 of the beach ridges identified. Each of these grains was also classified according to the Powers Roundness index and a further 96 photographs of beach gravels were taken for further roundness observations in the lab. We also quantified the density of granodiorite ice-rafted debris cobbles >10 cm (#/m^2) on 9 of the raised beaches. In addition, the IRD was noted in the squares used for grain-size measurements but we are doubtful the small number of IRD samples within those squares will provide any statistically meaningful data (and hence the IRD density approach adopted while in the field).

We also deployed a portable tide gauge. However on the 4th day in the field the sensor was encased by kelp and ripped out during a storm. Despite this we are optimistic that we still recorded 3 days of tide data for the island.

Suction-cup tagging summary

Our final efforts from tagging operations in Andvord and Paradise Bays included 36 tags deployed and all were successfully recovered. Twelve tags were deployed on humpbacks and wired to release after 1 day. 24 tags were deployed without on minke whales, the last two with a 24 hour releases. The last tag was deployed in Paradise Bay, all others were in Andvord. The density of animals in Andvord declined over the course of the period coincident with declines in prey abundance. Deployment times ranged from 7 minutes to 106 hours, though data collection stopped after 24 to 44 hours. Group sizes of tagged whales ranged from 1 to 5. Tags were deployed throughout Andvord Bay (see map below), and all were recovered in Andvord or directly outside of the mouth of Andvord except for one 48 hour tag that was recovered in Paradise Bay, the 106 hour tag that was recovered in the Neumayer Channel approximately 25 miles from the tagged location, one tag in Flanders bay and one humpback tag in Wilhelmina Bay. Feeding behaviour ranged from shallow, 30-50 m feeding during deployments 2.24-2.26 to deeper feeding around 200 m since then. Strong diurnal patterns existed in all tags, which differs from last year's deployments (see dive profile from week 2 report). All minke tags were deployed with forward-facing or upward-facing cameras. 7 out of 12 humpback tags were data only. Cameras captured feeding, other conspecifics feeding, social behaviour, ice cover and even self-reflections that allowed for individual identifiable marks to be matched to UAV images.

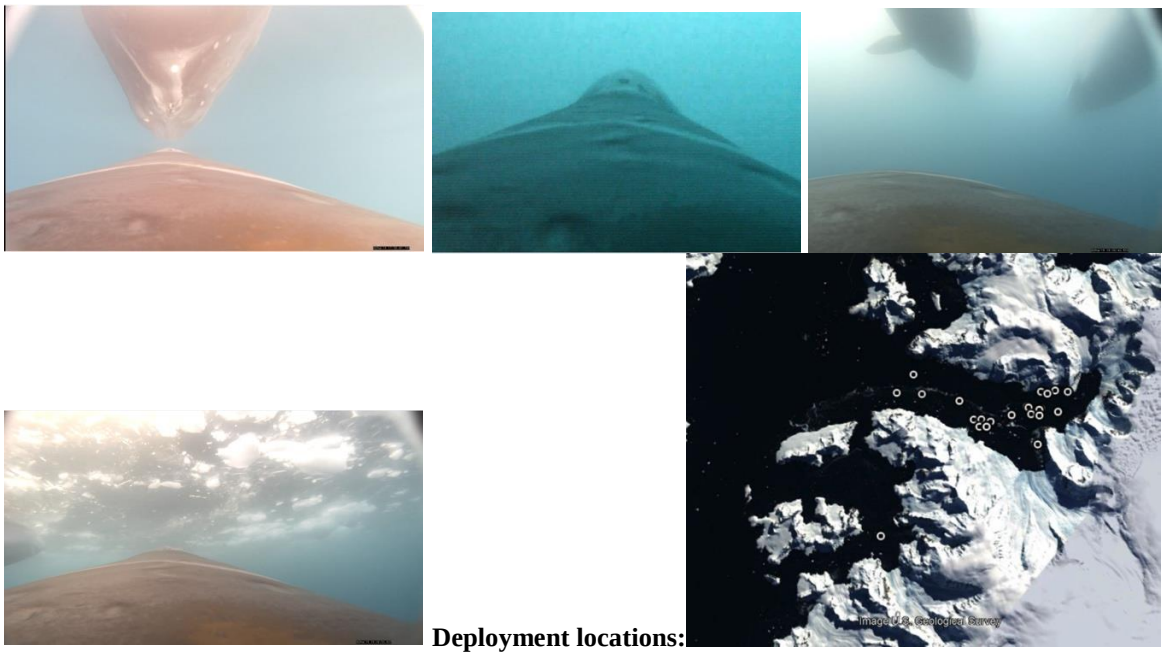

Figure 10 Cameras captured feeding, other conspecifics feeding, social behaviour, ice cover and even self-reflections that allowed for individual identifiable marks to be matched to UAV images

Duke Drone Team Summary

The Duke Marine UAS team has continued flying all three aircraft platforms: 1) a customized FreeFly Alta 6 hexacopter equipped with a high resolution RGB camera, a GoPro, a GoPro 360, and a laser altimeter for cetacean photogrammetry 2) a standard DJI Phantom quadcopter with a 4K RGB camera for contextual video and ice mapping 3) a Disco Ag fixed wing with a multispectral camera and wide angle RGB camera for ice mapping.

Flight counts as of March 11th, 2019 are 38 Alta flights, 31 Phantom flights, and 16 Disco flights for an estimated total of 32 minkes and ~27 humpbacks photogrammetrically measured, over 30 hours of contextual video, and 11500 hectares of ice mapping coverage.

Total UAS data count is:

- Alta Images: 8293
- Alta Videos: 390
- Phantom Images: 3144
- Phantom Videos: 204
- Disco Images: 2691 footprints and 13455 images

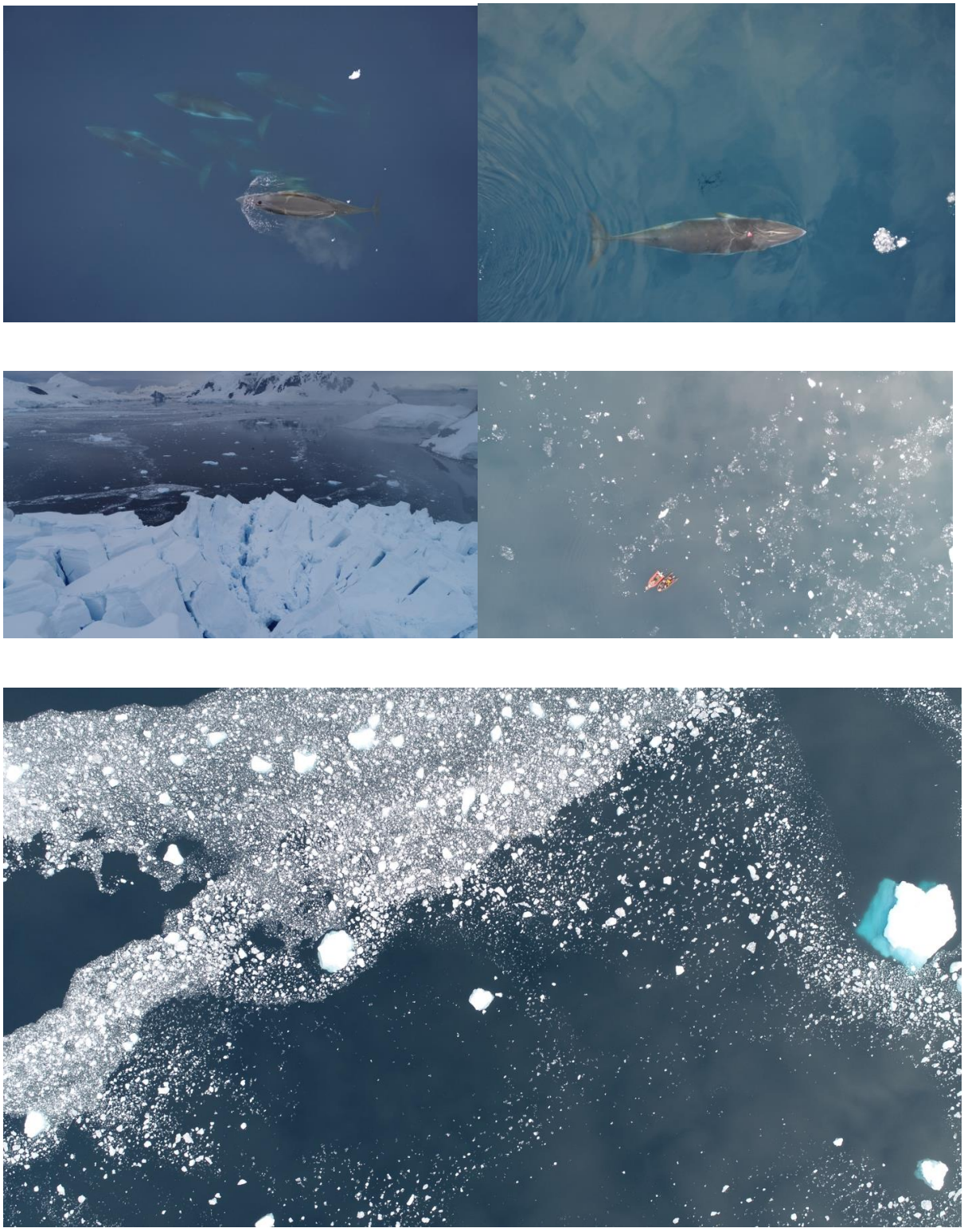

Figure 11 Examples of captured UAV images

Initial results from photogrammetry indicate the size-frequency ranges for both Antarctic minke whales and humpback whales measured during our first week.

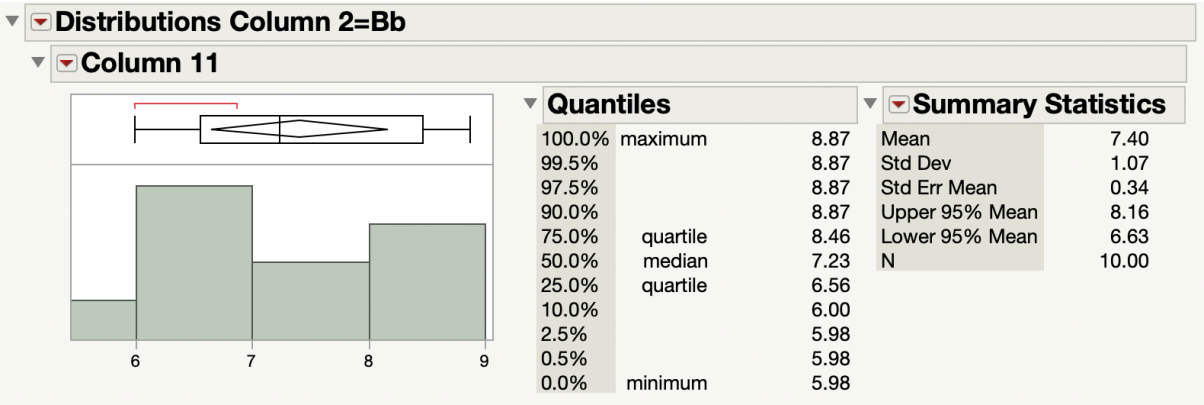

Figure 12 Length-frequency graphs of 10 UAS-measured Antarctic minke whales ranging from 5.98-8.87 meters, with an average of 7.40 metres.

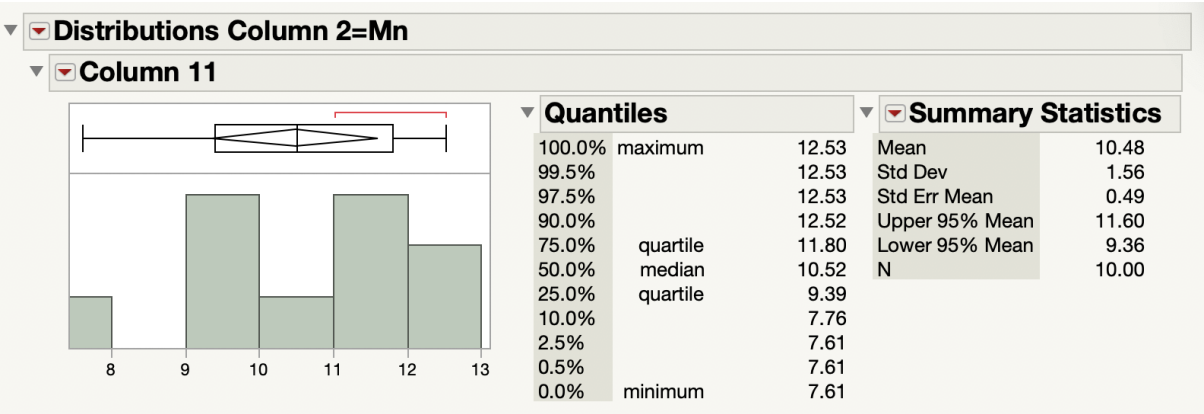

Figure 13 Ten Humpback whale measured lengths ranging from 7.61 to 12.53 meters with an average of 10.48 meters.

Prey Mapping

Prey mapping on board the LM Gould concluded this week. The majority of survey effort was focused in Andvord Bay, with additional opportunistic prey mapping surveys conducted in Paradise Harbor, Wilhelmina Bay, Flanders Bay. Over 250 line kilometers have been surveyed, nearly doubling the amount of prey mapping conducted over the mission last year. Significant improvements have been made to the towfish system that has allowed both longer tow times, towing through thicker ice and fewer instances of sudden towfish recovery.

Distribution of krill patches were generally deep, at about 200m in the latter week of the research.
Whale tags appeared to show preferences in dive/feeding depths between day and night. On 4 March, we conducted an overnight prey mapping survey to document the changes in vertical distribution in krill layers during the crepuscular and overnight hours. A race track design was established in the head of Andvord Bay (with some minor alterations required throughout the night to avoid icebergs). The krill rose from about 200m depths to within 50m of the surface at a rate of 2 m/s immediately at sunset. The layer became more diffuse at night, related to either dispersion of individual krill or possibly a change in their orientation altering their acoustic backscatter. Upon sunrise, the layer fell at a rate of about 2 m/s and resumed position of about 200m depths.

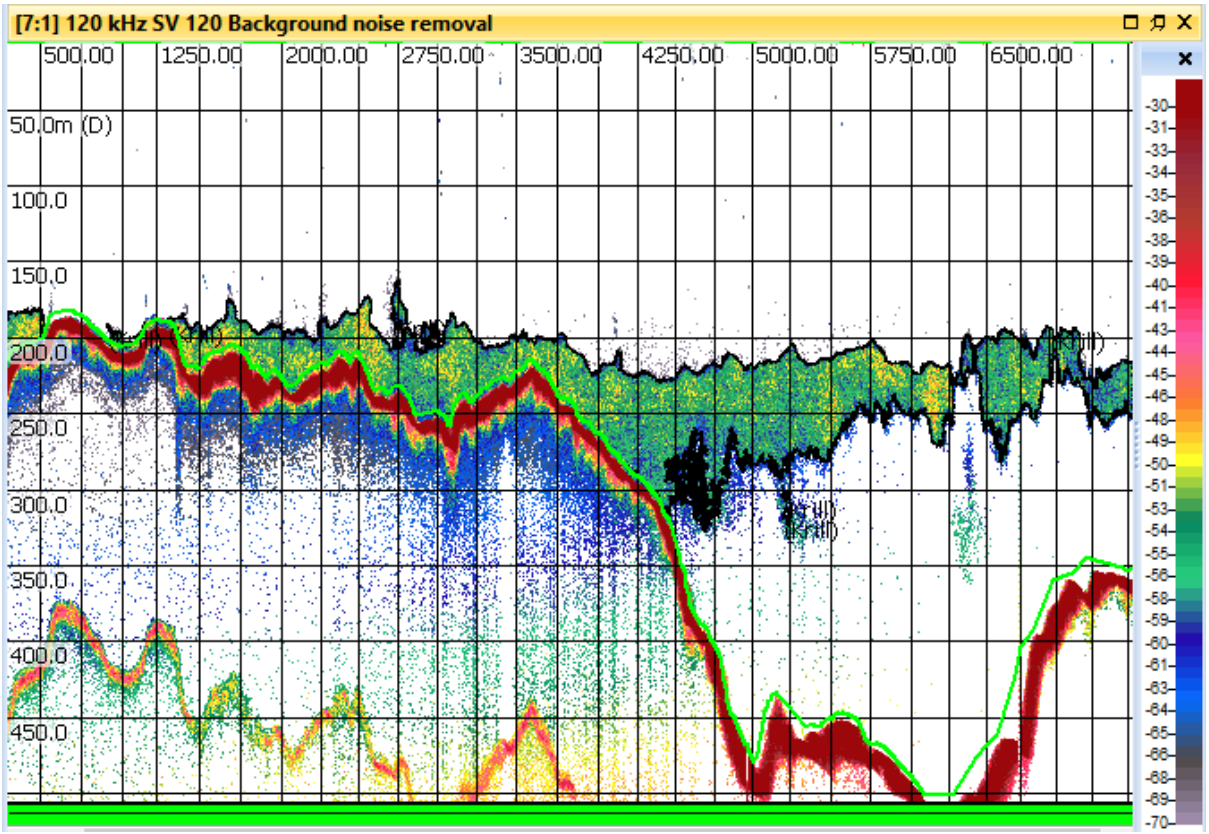

Figure 3 Krill layers at 200m depths in Andvord Bay,

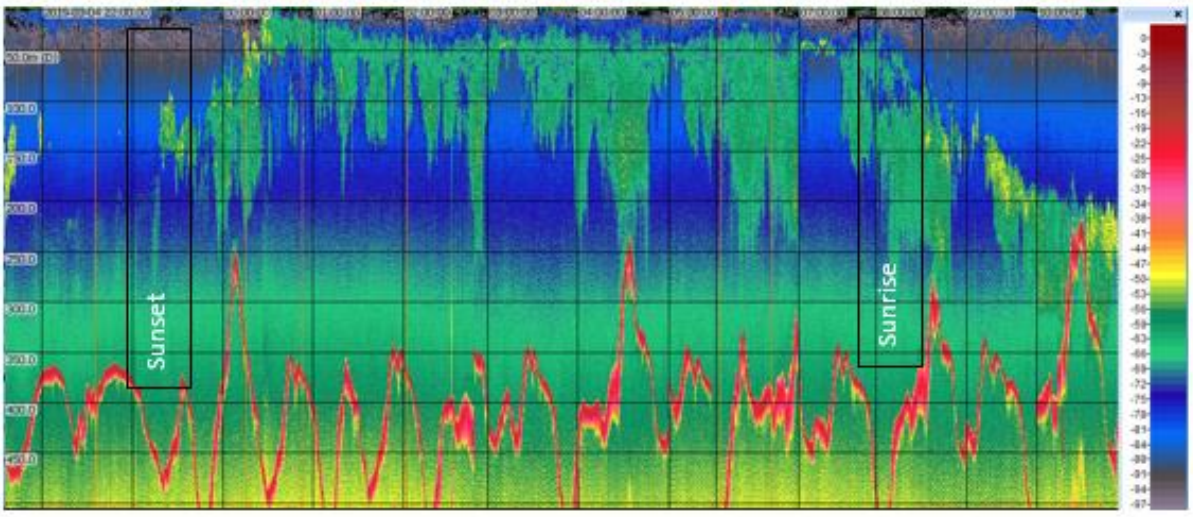

Figure 14 Overnight prey mapping documented vertical movement of krill layers (green blotches), rising at a rate of 2 m/s during sunset and falling 1 m/s at sunrise.

Performance of LMG EK80 and Evaluation of new tow cable system.

The data quality has improved significantly on the LMG towfish. We credit the MTs and ETs and bridge for input, discussions, experimentation and final changes to operations. Below are towfish operation changes that have make the greatest difference. More detailed notes will be shared with ET and MPC to include/update the towfish standard operating procedures.

1. Zero pitch on starboard drive has made the most significant improvement in data quality, especially on the 38 kHz channel. Clutching out the starboard drive does not improve data further in operating depths <600m, but may in deeper depths.
2. Bring towfish much closer to the ship, in the slipstream of ice reamer. Most/all of the ice and is deflected and kept outboard of the towfish. Only during port turns is there concern of ice colliding with cables and clear communication between bridge and deck will avoid those icy times.
3. Adding tigon tubing at water line for both tow line and safety line and transducer cables deflects the remaining ice. We have towed through many thick lines of brash ice and bergy bits that previously would have called for all-stop!
4. Remote Desktop connection from E-lab to Bridge, provides closer comms with bridge command and rapid comms to deck for securing the pinging and recovering the towfish.
5. We have eliminated the "Emergency Stop" button and the flashing light. Cutting power on the system rather than Stop Recording and Stop Pinging in EK80 tends to corrupt data files. There may be a better design for an indicator light to show when the system is transmitting or not pinging to confirm reports from the EK80 station watch. But the tow position and improved manning and comms described above should eliminate this need in most cases. **Power MUST be turned off when connecting and disconnecting transducer cables.

We successfully calibrated the EK80 for our mission parameters. The LMG's EK80 "Science" laptop has been updated with new calibration parameters and ET will have the final XML file in case the EK80 computer is replaced. The LTER data were collected with slightly different parameters (even after the updated config that removed the old transducers) and the calibration done near the end of LMG1901 LTER was not acceptable - the sphere was not far enough from the transducer, water was not deep enough, too much other scattering in the watercolumn. The final parameters were too far out of range for an acceptable calibration. Unfortunately, water depth is not sufficient at Palmer dock for a towfish calibration. Yet another calibration was performed using LTER parameters. The new calibration was well within acceptable parameters. The calibration parameter set is available to the ET and will be shared with the LMG1901 chief scientist.

Lastly, a new cable bundle will be evaluated on 11 March to assess noise and towing stability. The new bundle is a combined pair of transducer cables and two strength members in a single length. The new cable will wind around a tugger winch on the 01 deck, with the tail connected on deck using amphenol plugs to the deck box (also on 01 deck). Using amphenols in a patch cable is not advised. This is a fail point that caused damage to both the 38kHz transducer and transceiver in 2018. The amphenol plugs are not weatherproof and are not suitable for multiple connect/disconnect required for winch operations. Final installation using this winch should replace the amphenol dry end with a slip ring at the winch and patch cable run to upper Baltic room. Alternatively, the amphenol plugs should be replaced with water tight and weatherproof SubConn or SeaConn type connectors to a patch cable run to the upper Baltic Room. The new cable will require a thorough calibration and noise evaluation during each mission.

Broad-scale foraging ecology of humpback whales (*Megaptera novaeangliae*) in relation to krill catches around the Antarctic Peninsula from summer to winter
Ari S. Friedlaender, PhD (PI), Ben G. Weinstein, PhD (Post-doctoral researcher)

The following is taken largely from a final report to the AWR for a grant awarded to help fill SORP objectives for the ecology of baleen whales research program led by Dr Friedlaender.

Project Scope
The stated aims of the Antarctic Wildlife Research Fund (AWR) include development of a management system for the Antarctic krill fishery, monitoring reference areas for indications of long-term change, and designing field and analytical methods to provide indicators of ecological change and their causes. We believe that a long-term program aimed at studying the movement patterns and foraging behaviour of the largest krill predators in the Antarctic (baleen whales) can satisfy all of these objectives. Our research group has in-place the logistical support to conduct a long-term ecological study on the foraging behaviour of humpback whales around the Antarctic Peninsula, and specifically how critical foraging areas relate to historic catches of krill in the region. In this proposal, we outline an initial study that used a combination of robust ecological analyses to define the foraging range of humpback whales around the Antarctic Peninsula across broad spatio-temporal scales, and modelled the amount of overlap between these areas and those where the krill fishery has historically operated.

Using resources provided by an existing award from the National Science Foundation's Office of Polar Programs as part of the Palmer Long-Term Ecological Research program, and a collaboration with OneOcean Expeditions, we have secured the platforms to deploy satellite-linked time depth recording tags on whales throughout the Antarctic feeding season in 2016. Combined with deployments we have made from 2012-2015, we have a unique opportunity to test specific ecological hypotheses and add to a high value data set while contributing to the goals of the AWR. To this end, we requested support to purchase satellite tags that we can deploy in 2016, and support for a post-doctoral scholar dedicated to the analyses described herein under the guidance of the project PIs.

Objectives

The objectives of our proposed research are to: (1) leverage an existing data set of satellite tracks to define the spatial and temporal use patterns of humpback whales around the Antarctic Peninsula, (2) add significant data to test ecological hypotheses using state-space modelling techniques about specific areas where whales forage throughout the feeding season, and (3) generate spatial overlap estimates between whale foraging regions and locations of historic commercial krill catches. In combination, these analyses will provide a quantitative perspective on the foraging ecology of the largest krill predator (and most abundant whale species) in the nearshore waters around the Antarctic Peninsula. With respect to the research goals of the AWR, we are confident that our proposed research represents a unique opportunity to study the potential overlap between whales and the krill fishery.

We used new modelling techniques to quantify the movement patterns and habitat use of humpback whales around the Antarctic Peninsula. The use of state-space models allow us to determine not only the movement paths of whales, but also to define portions of these paths where whales are foraging versus simply transiting. This fundamental step forward provides us with a far more robust means for characterizing the physical environmental features that promote increased whale feeding. However, with the addition of historic krill catches from the region, we can specifically quantify if, when, where, and to what extent commercial fishing effort and humpback whale feeding co-occur. This information is critical for managing both the amount and location of fishing effort while also providing useful information on the biology and ecology of these top predators in a changing environment.

Below are synopses of the findings from our work that were published in peer-reviewed scientific journals. Together, these manuscripts provide a compelling foundation for understanding the movement patterns of humpback whales throughout the foraging season and how the distribution and behaviour of these krill predators overlaps with the commercial krill fishery. In the summary, we will provide insights as to how this information is currently being used to help mitigate the impact of the krill fishery on these whales and other krill predators in the region in the form of a newly-proposed marine protected area by the Antarctic scientific community.

Findings and Peer-reviewed Publications

Weinstein, B.G.; Friedlaender, A.S. Dynamic foraging of a top predator in a seasonal polar marine environment. Oecologia 2017, 185, 427–435.

By combining high-resolution satellite-tagged data with hierarchical Bayesian movement models, we associated spatial patterns of movement with Antarctic Humpback behaviour. We used a multi-state mixture model to describe humpback whale traveling and area-restricted search states as they forage along the West Antarctic Peninsula. We estimated the change in the geography, composition and characteristics of these behavioural states through time. We show that whales later in the austral fall spent more time in movements associated with foraging, travelled at lower speeds between foraging areas, and shifted their distribution northward and inshore. Seasonal changes in movement are likely due to a combination of sea ice advance and regional shifts in the primary prey source.

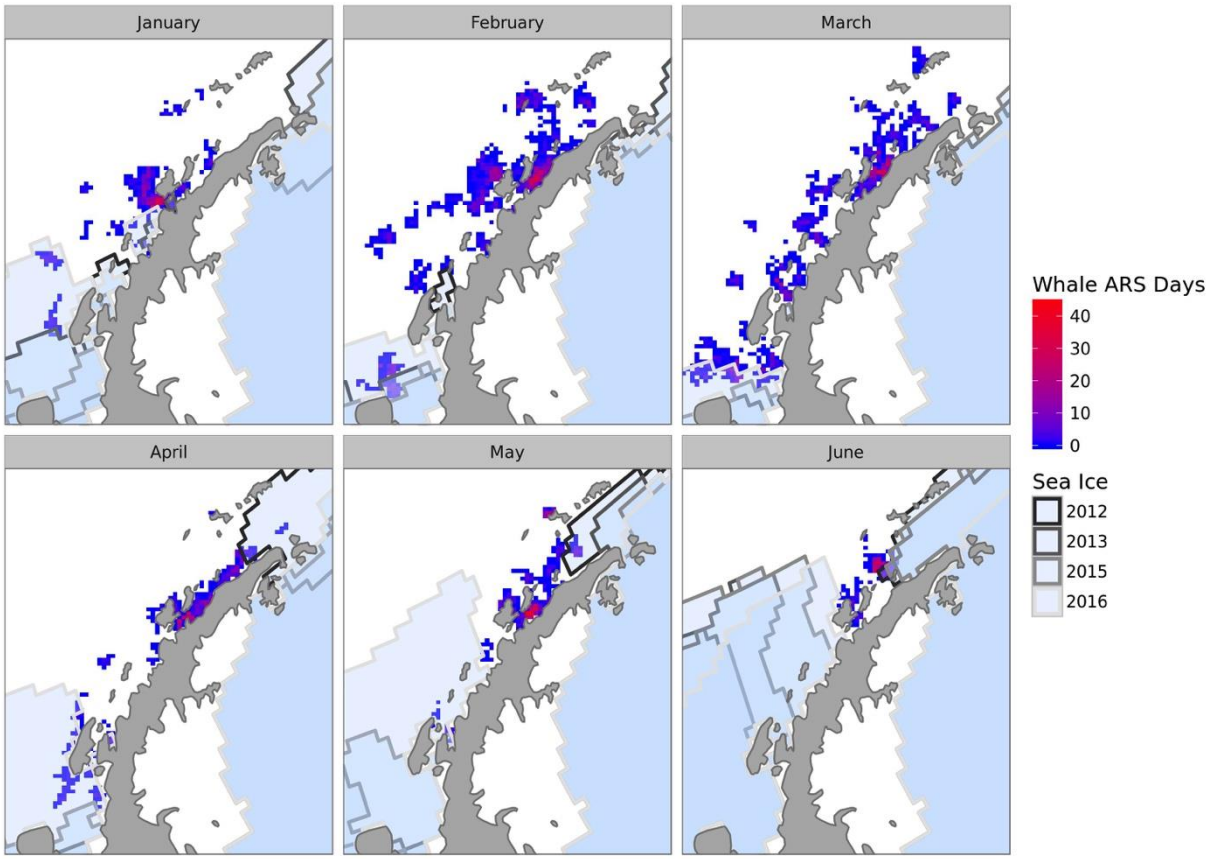

Figure 15 Seasonal change in the geography of whale movement (n=40). Filled cells show the geography of area-restricted search (ARS) for humpback whales off the coast of the West Antarctic Peninsula. The total duration of area-restricted search time in each cell was calculated based on a 100 by 100 grid (~20km/cell). The maximum monthly extent of sea ice is shown in light blue. The borders of the sea ice polygon indicate the extent by year.

Weinstein, B.G.; Double, M.; Gales, N.; Johnston, D.W.; Friedlaender, A.S. Identifying overlap between humpback whale foraging grounds and the Antarctic krill fishery. Biol. Conserv. 2017, 210, 184–191.
The Antarctic krill fishery is the largest in the southern ocean, but currently operates without fine-scale information on whale movement and behaviour. Using a multi-year dataset of satellite-tagged whales, as well as information on krill catch levels, we analysed the spatial distribution of whales and fisheries effort within the small-scale management units defined by the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Using a Bayesian movement model to partition whale movement into traveling and area-restricted search states, we found that both whale behaviour and krill catch effort were spatially clustered, with distinct hotspots of the whale activity in the Gerlache and southern Branfield Straits. These areas align with increases in krill fishing effort, and present potential areas of current and future conflict. We recommend that the Antarctic West and Bransfield Strait West management units merit particular attention when setting fine-scale catch limits and, more broadly, consideration as critical areas for krill predator foraging.

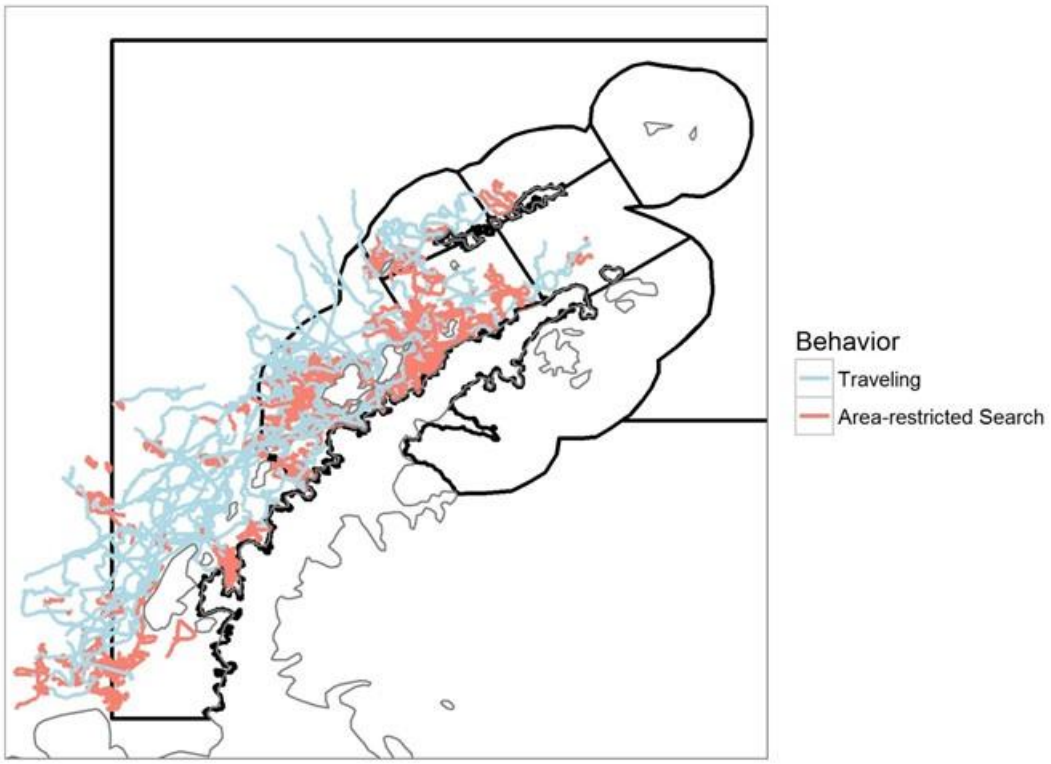

Figure 16 Predicted behaviours for each filtered whale track based on the state-space model. If the mean probability of switching to the area-restricted state (ϕ_ARS) was greater than 0.5, the observation was labelled as area-restricted search. The eight CCAMLR small-scale management units for region 48.1 are shown in black lines.

Weinstein, B.G.; Irvine, L.; Friedlaender, A.S. Capturing foraging and resting behaviour using nested multivariate Markov models in an air-breathing marine vertebrate. Mov. Ecol. 2018, 6, 1–10.
As animal-borne dataloggers capture a greater diversity and frequency of three dimensional movements, we can increase the complexity of movement models describing animal behaviour. One challenge in combining data streams is the different spatial and temporal frequency of observations. Nested movement models provide a flexible framework for gleaning data from long duration, but temporally sparse, data sources. Using a two-layer nested model, we combined geographic and vertical movement to infer traveling, foraging and resting behaviours of Humpback whales off the West Antarctic Peninsula. Our results showed increased intensity in foraging activity in late season animals as the whales prepared to migrate north to tropical calving grounds. Our model also suggests strong diel variation in movement states, likely linked to daily changes in prey distribution. Using a combination of two-dimensional and three-dimensional movement data, we highlight the connection between whale movement and krill availability, as well as the complex spatial pattern of whale foraging in productive polar waters.

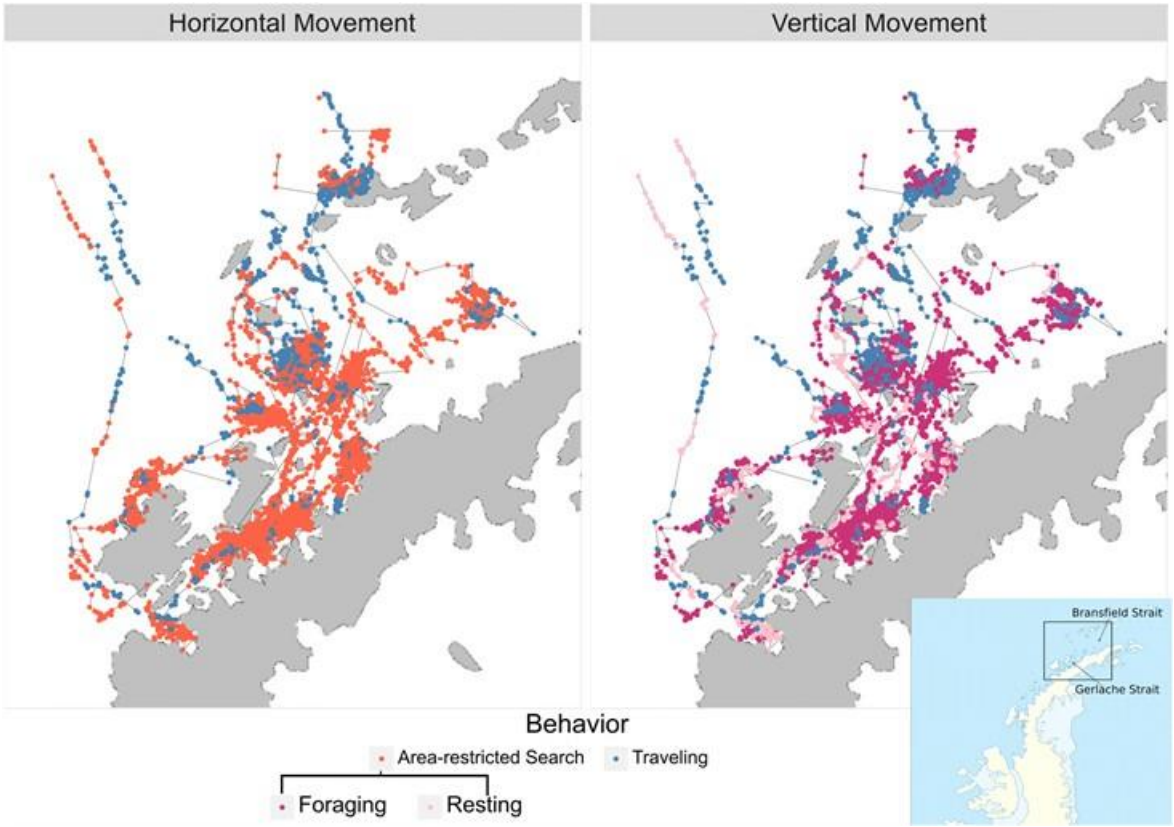

Figure 17 Spatial prediction of the behavioural states for 11 satellite tagged humpback whales off the West Antarctic Peninsula from Feb-May 2016. The observed locations are first partitioned into traveling and area-restricted search states based on the two-dimensional pattern of horizontal movement. The area-restricted search states are then subdivided into foraging and resting sub-states based on vertical dive depths. We did not subdivide the traveling state based on dive depths, therefore the traveling state appears in both maps.

Conclusions and Impact

The set of peer-reviewed publications resulting from the AWR funding provides the foundation necessary to bring baleen whales to the forefront of Antarctic strategic conservation planning. The results from our work have also been utilized by organizations such as World Wildlife Fund with whom we partnered to produce a report entitled 'Whales of the Antarctic Peninsula: science and conservation for the 21st century. A copy of that report is attached to this report. Prior to this award, cetaceans were not considered as part of how CCAMLR managed the commercial krill fishery. Rather, other krill predators including pinnipeds and penguins were considered when developing management areas and guidelines for minimizing risk of the consequences of harvesting krill. Our thorough and compelling results have been welcomed by the scientific, conservation, and management communities as filling a critical gap in our ability to determine the risks of the current commercial krill fishery. We have been invited to participate in several workshops sponsored in part by the Pew Charitable Trust, including an upcoming meeting in June 2019 entitled 'Workshop on krill fishery management for Subsareas 48.1 and 48.2', that will be coordinated with the 2019 meeting of CCAMLR WG-EMM. The information contained in our publications resulting from AWR funding are also being used by the international community to help define and submit for review a new marine protected area around the Antarctic Peninsula that considers the ecological roles and needs of baleen whales among other krill predators. This is a benchmark step in the development of a more holistic conservation/management strategy because our findings show very clearly that the spatio-temporal distribution of humpback whales is specifically linked to that of Antarctic krill and elucidates a number of key areas and times that currently do not overlap with where other krill predator 'hot-spots' occur but are coincident with increasing fishing effort by the commercial krill fishery. We hope that this grant and our products represent a first step in establishing a more long-term evaluation and monitoring program of baleen whales around that Antarctic Peninsula that can yield dynamic and inter-annual information on the needs of baleen whales as they relate to prey distribution and abundance.

We are grateful for the support from AWR and believe that we have successfully achieved all of our proposed objectives and now have a unique opportunity to continue working in this capacity with Antarctic baleen whales. We look forward to the opportunity to work with the AWR and similar groups focused on using science to help produce effective conservation and management strategies for the Antarctic marine ecosystem.
This project represents the value of maintaining the long-term SORP project on baleen whale foraging ecology. By aggregating findings and building on the intellectual development of this project, we have a unique opportunity to bolster our ability to study and protect baleen whales and the Antarctic marine ecosystem.

Overall conclusions

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

Challenges

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

Outlook for the future

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

current collaborators hail from over 10 countries and there are at least 12 graduate students and 4 post-docs utilizing data from this research program.

Friedlaender et al. also received funding from the IWC-SORP Research Fund in 2016/17 and 2018/19. These projects are detailed in SC/67b/SH18 and SC/68a/SHXX.

IWC-SORP sincerely thanks One Ocean Expeditions for their ongoing and invaluable support of this IWC-SORP Theme, as well as WWF-Australia, the Antarctic and Southern Ocean Coalition (ASOC) and the Hogwarts Running Club for their contributions to fieldwork and financial support of tagging and analyses during the 2018/19 season.

Project outputs

Papers

Alberston GR, Friedlaender AS (2017) Temporal stability and mixed-stock analyses of humpback whales (*Megaptera novaeangliae*) in the nearshore waters of the Western Antarctic Peninsula. Polar Biology. doi:10.1007/s00300-017-2193-1

Costa D, Huckstadt L, Schwarz L, Friedlaender AS, Mate B, Zerbini AN, Gales N (2016) Assessing the potential exposure of animals to acoustic disturbance: towards an understanding of the population consequences of disturbance. Proceedings of Meetings on Acoustics, Fourth International Conference on the Effects of Noise on Aquatic Life, Dublin, Ireland.

Curtice C, Johnston D, Gales N, Friedlaender AS (*In press*) Spatially and temporally dynamic humpback whale feeding areas in the Antarctic. Movement Ecology.

de la Mare W, Friedlaender AS, Goldbogen JA (*In review*) Developing a functional response using an individual-based energetics model for rorqual foraging dives. Functional Ecology.

Espinase B, Zhou M, Zhu Y, Hazen E, Friedlaender AS, Nowacek DP, Chu D, Carlotti F (2012) Austral fall transition of mesozooplankton assemblages and krill aggregations in an embayment west of the Antarctic Peninsula. Marine Ecology Progress Series. doi:10.3354/meps/09626

Friedlaender AS, Goldbogen JA, Nowacek DP, Read AJ, Johnston A, Gales N (2014) Feeding rates and under-ice foraging strategies of the smallest lunge-filter feeder, the Antarctic minke whale. Journal of Experimental Biology 217: 2851-2854. doi: 10.1242/jeb.106682

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Social Media

Blog Stats

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

Twitter

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

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

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

Instagram

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

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

Media

Documentary films

National Geographic Channel Documentary Series: *Continent 7*

Antarctic Edge: 70° South

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

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

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http://news.stanford.edu/news/2014/august/minke-whales-feeding-081414.html?view=print
http://www.themercury.com.au/news/tasmania/minkes-tracked-going-for-the-krill/story-fnj4f7k1-1227026146584
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Antarctic minke whale acoustics

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http://www.independent.co.uk/news/science/50year-mystery-of-the-ocean-quack-finally-solved-by-scientists-9277824.html
http://www.zeit.de/wissen/umwelt/2014-04/antarktis-zwergwal-geraeusch-walfang
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ANNEX 4 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

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

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7. UMR ENTROPIE (IRD, Université de La Reunion, CNRS), Laboratoire d'excellence-CORAIL, 101 promenade Roger Laroque, BPA5, 98848 Noumea Cedex, New Caledonia
8. Opération Cétacés BP12827, 98802 Nouméa, Nouvelle-Calédonie
9. Blue Planet Marine, P.O. Box 919, Jamison Centre, ACT, 2614, Australia
10. Marine Mammal Laboratory, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA. & Cascadia Research Collective, 218 1/2 W 4th Ave., Olympia, WA 98501, USA.
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Introduction

There were two research components focused on humpback whale distribution and connectivity throughout the Oceania – east Australia region during the 2018/19 period; Oceania feeding ground behaviour and genetic connectivity of whales on the Great Barrier Reef (GBR) breeding grounds (Ei). This advances our understanding of the linkages between the breeding grounds and feeding grounds of the whales from these regions. Our work has identified the Kermadec Islands as a diverse region for mixing of whales from Oceania breeding grounds as they migrate to a wide expanse of Southern Ocean (Riekkola et al. 2018). There are different environmental variables influencing whale behaviour throughout the feeding grounds (Andrews-Goff et al. 2018, Riekkola et al. accepted).

Oceania humpback whales are listed as endangered but different sub-populations within the region are showing differing rates of recovery leading to considerable complexity in modelling population status, understanding interchange between sub-populations and migratory pathways. With the east Australian Ei breeding stock close to pre-whaling abundance (IWC 2015), the linkages of these whales to migratory corridors and breeding grounds is being revealed (Gales et al. 2009 SC/61/SH17, Garrigue et al. 2011, Steel et al. 2014 SC/65b/SH07, Steel et al. 2018). The GBR breeding ground biopsy surveys are beginning to reveal connections to other Oceania regions, in particular the Chesterfield-Bellona archipelago, New Caledonia and New Zealand. These findings will aid in the development of improved mixed stock models for whole of Oceania and their Southern Ocean feeding grounds.

Objectives

The focus of the 2018/19 research was:

1) Analysis of the 2015 Raoul Island expedition data to the Oceania humpback whale feeding grounds, led by Rochelle Constantine, Alex Zerbini, Virginia Andrews-Goff, Ari Friedlaender and Leena Riekkola.

2) Surveys from 8th – 20th July and 26th August – 7th September 2018 to the Great Barrier Reef breeding ground complex to genetically profile this breeding stock and determine genetic linkages to Oceania, led by Dave Paton and Simon Childerhouse.

Results

Kermadec Islands to Southern Ocean Feeding Grounds

Between September and October 2015, 25 SPOT 5 PTT satellite tags were deployed on humpback whales migrating south past the Kermadec Islands, New Zealand (see Riekkola et al. 2018 for details). Final analysis of the tag data have been completed using state-space models to estimate whale locations and infer underlying behavioural states on their Southern Ocean feeding grounds. Potential environmental drivers of whale behaviour were examined using linear mixed-effect models and maximum likelihood models (see Riekkola et al. accepted for details).

Of the 25 tags, 14 transmitted data within the feeding grounds (south of 60°S) from November 2015 until June 2016 with a spatial range of 175°E to 80°W. Foraging behaviour increased as feeding season progressed, peaking in March. There were spatial differences between whales feeding in the Ross Sea region compared to those in the Amundsen-Bellingshausen Seas region. The Ross Sea whales were consistently farther away from the shelf break (>500 km) and ice edge (~370 km) than whales in the Amundsen-Bellingshausen Seas (within ~200 km of the shelf break and ~210 km on average to the ice edge). The most parsimonious model identified month, 2-month lag in the distance to the ice edge, SSH and the interaction between region and month as important predictors of the behavioral state of humpback whales within their Southern Ocean feeding grounds (Table 3).

Table 3 Results of the best Linear Mixed Effect model, with logit transformed behavioural state (*b*) as a response variable and individual whales as a random effect. Higher b-values indicate an increasing likelihood of whales exhibiting ARS-foraging behaviour.

Parameter	Estimate	SE	DF	t-value	p-value
Intercept	-9.49	1.10	3796	-8.61	**<0.001**
Region_Ross Sea	-0.55	0.58	3796	-0.96	0.34
Month	1.91	0.38	3796	4.99	**<0.001**
Month^2	-0.35	0.06	3796	-5.40	**<0.001**
dist ice lag 2	0.00	0.00	3796	0.26	0.80
dist ice lag 2^2	-0.00	0.00	3796	-3.55	**<0.001**
SSH	-4.92	1.08	3796	-4.57	**<0.001**
Region_Ross Sea*Month	-0.93	0.48	3796	-1.95	0.05
Region_Ross Sea*Month^2	0.24	0.08	3796	3.16	**<0.01**

Estimates are in log-odds scale. During model selection all models were fitted using maximum likelihood for comparing models with different fixed effects. The best model was then fitted with restricted maximum likelihood to obtain final parameter estimates. Variables with a significant parameter estimate (<0.05) are in bold.

Great Barrier Reef genetic sampling (refer to IWC-SORP Project 9, Paton et al in SC/68a/SHXX)

Standard biopsy sampling techniques were applied using both sloughed skin and Paxarm biopsy systems to collect tissue samples from whales on their GBR (Ei) breeding grounds. The sampling location was in and around the Mackay Region and Whitsunday Islands (20.2°N 148.9°E) including areas further offshore but all inside the GBR. This location is well documented as part of the core range of Ei breeding group and as confirmed by habitat modelling by Smith et al. (2012).

Fieldwork was carried out from 8th – 20th July and 26th August – 7th September 2018. During this period, 186 pods of humpback whales consisting of 377 (333 adults and 44 calves) individuals were sighted. A total of 21 genetic samples, and 9 h 51 mins of acoustic recordings targeting social sounds and singers were collected for analysis at the Cetacean Ecology and Acoustics Lab at the University of Queensland. Photo-identification images from 2016 and 2017 were matched to the Chesterfield-Bellona archipelago with no matches found (see Garrigue et al. 2018 for details).

A total of 113 genetic samples have now been collected from the E1 breeding stock within the Great Barrier Reef Marine Park. Preliminary analysis of the E1 samples have been undertaken at the Cetacean Conservation and Genomics Laboratory at Oregon State University. Samples from 2011 – 2017 have been DNA profiled, including 16 microsatellite loci, sex identification and sequences of mitochondrial control region (Steel et al. 2018). Of the 78 individuals identified (52 males, 25 females and 1 unknown), preliminary matching revealed five recaptures; New Caledonia (n = 2), Chesterfield-Bellona Reef (n = 0), and east coast Australia migratory corridor (n = 3). Comparison of mtDNA frequencies to other breeding grounds and migration corridors in the Oceania and Pacific regions revealed significant differences to all regions except the Chesterfield-Bellona archipelago (Table 4). It is significantly different to New Caledonia but the signal is weaker. The GBR is not significantly different to samples from the migratory corridor of east Australia and mainland New Zealand but is significantly different to the Kermadec Islands, New Zealand (Table 4).

Table 4 Tests of differentiation and F_{ST} for pairwise comparison of GBR (n = 77) to other breeding grounds and migratory corridors for humpback whales.

Breeding grounds and migratory corridors	N	F_{ST}	P value
Colombia	95	0.0665	< 0.0001
French Polynesia	194	0.0250	< 0.0001
American Samoa	144	0.0172	0.0002
Cook Islands	92	0.0203	0.0003
Tonga	337	0.0101	0.0004
New Caledonia	952	0.0034	0.0298
Chesterfield (NC)	35	0.0064	0.1213
West Australia	174	0.0113	0.0003
East Australia (Byron, Ballina, Hervey Bay)	316	0.0000	0.4880
East Australia (Eden, Tasmania)	104	0.0008	0.3485
Kermadec Islands (NZ)	111	0.0100	0.0015
New Zealand	158	0.0000	0.7238

Conclusions

The Oceania humpback whale connectivity work has revealed important migratory stopover regions (Gales et al. 2009 SC/61/SH17, Riekkola et al. 2018) and critical feeding ground habitat for the east Australia and Oceania E and F breeding stocks (Andrews-Goff et al. 2018, Riekkola et al. Accepted). The Kermadec Islands are a significant migratory corridor for humpback whales throughout Oceania and for at least some individuals from east Australia. There are now resights of whales at the Kermadecs across multiple years, suggesting fidelity to this migratory corridor by some individuals. These whales migrate to different feeding grounds; the Ross Sea region and the Amundsen and Bellingshausen Sea regions spanning ~4,100 km of Southern Ocean (Riekkola et al. 2018).There are differences in feeding ground habitat use and travelling behaviour presumably when whales are searching for prey patches.

The GBR breeding ground surveys have provided important information about stock structure and connectivity to neighbouring breeding grounds although, despite the collection of 113 samples to date, the sample size remains low considering the number of whales in the Ei breeding grounds. This limits the conclusions that can be made when comparing to other more extensively sampled Oceania regions. There will be a 2019 field season in the GBR to collect samples from females with calves. This cohort was not able to be sampled in 2016-2018 due to permit conditions that have now been removed so samples can be taken from mothers (not the calves). This will help resolve the under-representation of females in the current GBR dataset.

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

Outlook for the future

The humpback connectivity research has moved into plans for a collaborative circum-polar analysis of whale telemetry data to ascertain broad patterns of movements on the feeding grounds. With a number of multi-year

and opportunistic tag deployments, this approach will advance this project beyond the Oceania region. Future research should find innovative ways to study the environmental parameters of importance to these whales on their feeding grounds (Andrews-Goff in prep) and how changes in Southern Ocean productivity might influence these whales in the future. The large genetic and photo-identification databases are valuable, even for small datasets and these must continue to be open access.

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

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ANNEX 5 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

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

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Executive summary

The Blue and Fin Whale Acoustic Trends Project (ATP) 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 2018, members of the Acoustic Trends Project deployed 16 autonomous recording devices in the Southern Ocean at 16 different recording sites, and the group recovered 21 previously deployed autonomous recorders from 17 recording sites around Antarctica. The data volume from all instruments totalled approximately 230,000 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. (SOHN)
In 2018, the group produced six peer reviewed papers, four conference presentations, one scientific report and presently has 1 manuscript that has been submitted and is under peer review. Additionally, one PhD project is ongoing and one Master's project was completed by students from France and Germany, respectively, using the ATP data. In 2018, two IWC grants were received from IWC-SORP: one for a postdoctoral researcher to develop a standard analytical framework for robustly detecting trends in passive acoustic data for Antarctic blue and fin whales and another for participation by US researchers in a cruise undertaken by the Australian Antarctic Division to study krill and whale dynamics in the Southern Ocean. A short project meeting took place at the DCLDE Workshop in Paris in June 2018.
In 2018, three further contracts for analysts were issued from the IWC grant received in 2016 to create an annotated library of acoustic recordings that can be used to train and test automated detection methods. The annotated dataset now comprises (multi-year) data from four sites: Ross Sea, Kerguelen plateau, Elephant Island and Maud Rise.

Introduction

Passive acoustic monitoring is a robust means of monitoring Antarctic blue (*Balaenoptera musculus intermedia*) and fin whales (*Balaenoptera physalus*) in remote areas, such as the Southern Ocean, over long time periods. The analysis of data sets that are available to date (including those collected specifically for this project) has revealed insights into the geographic and seasonal occurrence of blue and fin whales around the Antarctic and throughout the Southern Ocean e.g. (Širović et al., 2004, 2009; Samaran et al., 2013, 2018; Leroy et al., 2016, 2018; Thomisch et al., 2016; Buchan et al., 2017; Shabangu et al., 2017). 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 successful undertaking of this program requires a coordinated multinational effort to collect long-term passive 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 2018/19 were continued data collection at long-term SOHN sites; increased spatial coverage and number of recording stations for the hydrophone network; continued development and implementation of an annotated library of underwater recordings.

Results

Annotated library of acoustic detections

In late 2016 the SORP Acoustic Trends Steering Group was awarded a grant of £22,000 from the IWC-SORP Research Fund for the creation of an annotated library of acoustic detections. Details of planned and completed work can be found in the Annotated Library Progress Report (SC/68a/SHXY).

Postdoctoral researcher to develop framework for automated detection of calls

In 2018, the ATP was granted funds for a 14-month postdoctoral researcher to develop a standardized analytical framework for robustly detecting circumpolar call density trends in passive acoustic data for Antarctic blue and fin whales. The position will be based at the University of Concepción, Chile, and will include a research visit to the University of St Andrews, Scotland. During the meeting in Paris in June, the planning and requirements of the project were discussed in more detail. The position announcement has been finalised and will be advertised shortly.

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

In 2017/18, members of the Acoustic Trends Project serviced 17 annual recording stations continuing multi-year records. The data volume from all instruments recovered in 2018 totaled approximately 230,000 hours of underwater recordings.

The Australian Antarctic Division recovered and replaced two moored acoustic recorders at its two long-term recording sites in East Antarctica (along resupply routes to Mawson and Casey stations; Figure 18, sites A & B). The instrument on the Casey resupply route recorded continuously from 23 December 2017 – 16 October 2018 (7126 h). The instrument from the Mawson resupply route was recovered, but at the time of writing this was still awaiting data retrieval.

ENSTA Bretagne, in collaboration with the Australian Antarctic Division, recovered and replaced one acoustic recorder at one long-term recording site along the resupply route to Dumont D'Urville Station. (65°30,6S 140°34.9E, Figure 18, site C). The recovered instrument recorded continuously from 5 Feb 2018 to 5 October 2018 (5800 h).

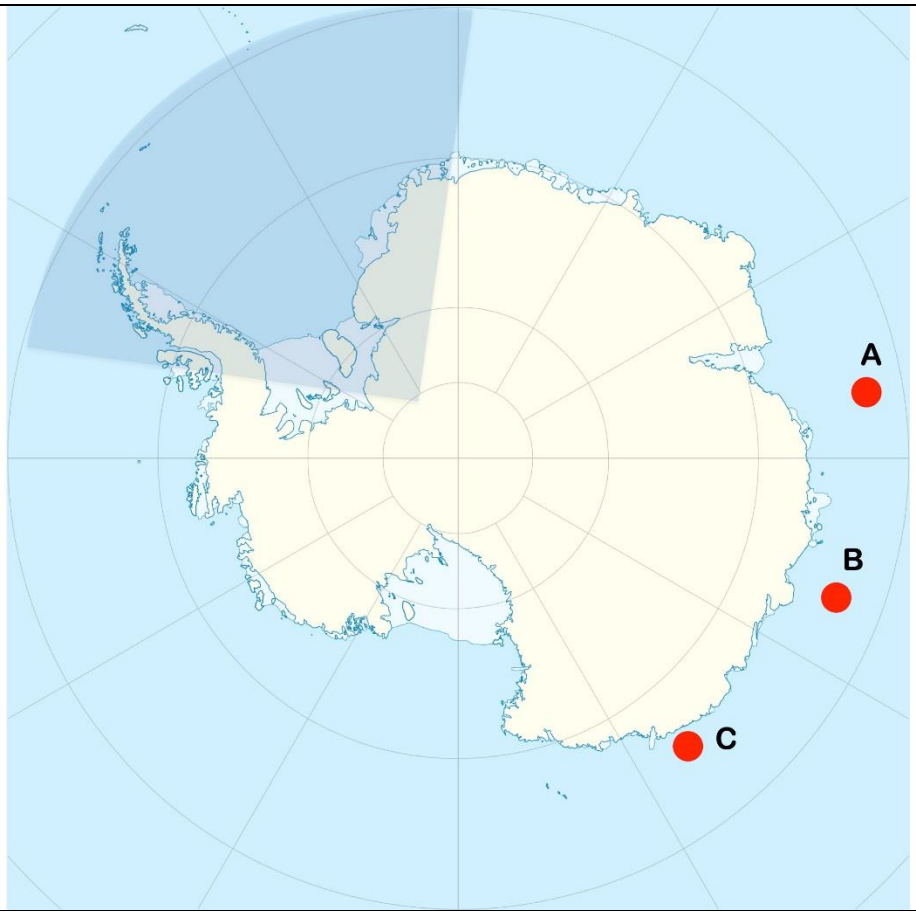
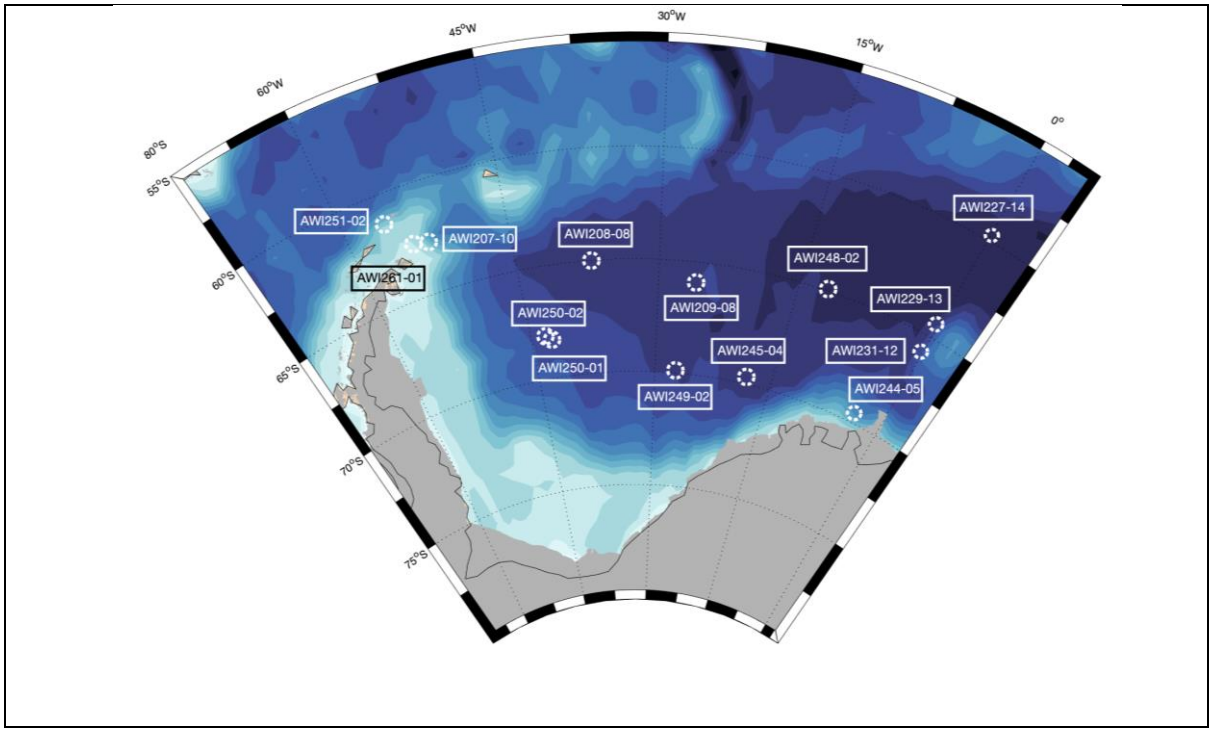


Figure 18 Map showing the approximate locations of project instruments that were retrieved and redeployed in 2018. See figure 2 for detail maps of instrument retrievals and deployments for the Weddell Sea area (shaded section).



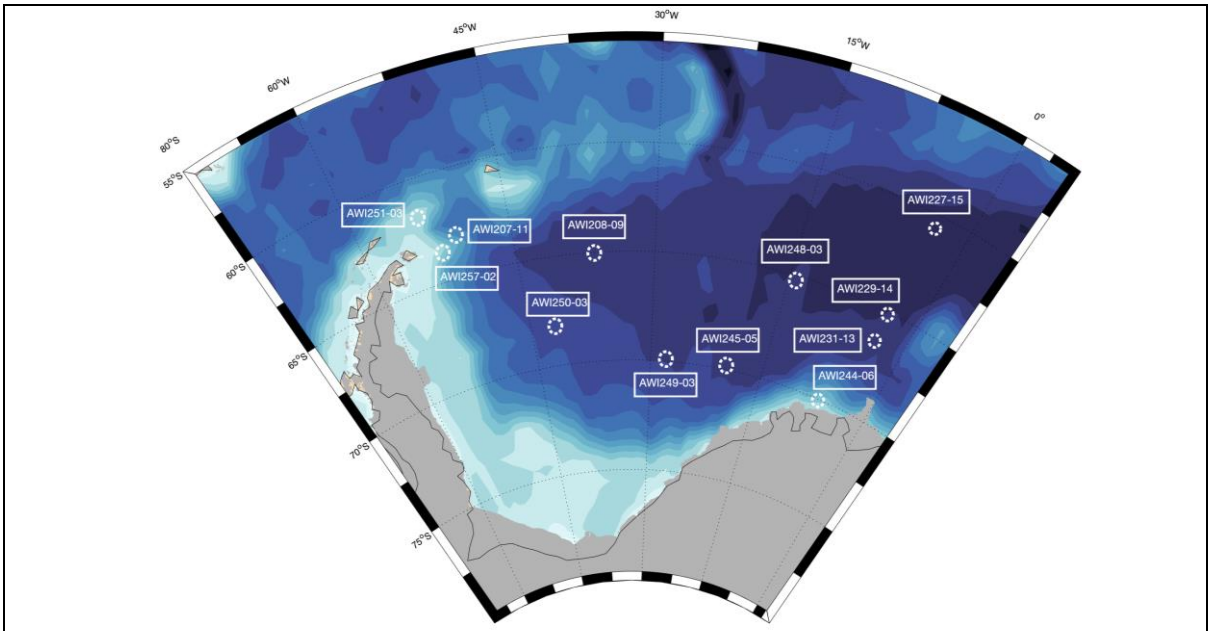


Figure 19 Detailed map of the Weddell Sea area showing the locations of project instruments that were retrieved (top) and redeployed (bottom) in 2018/2019.

The Alfred-Wegener Institute recovered the 18 Sono.Vault recorders that were deployed in 14 moorings 2016/17 in the Atlantic section of the Southern Ocean (Weddell Sea, Figure 19, top map) during the 2018/19 Polarstern cruise. Nine of these contained over one year of data. Twelve Sono.Vault recorders were subsequently redeployed (Figure 19, bottom map).

Low-latitude data collection (<60°S) 2018/19

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

- An AAD moored acoustic recorder was recovered from 53°00' S, and 076°09'E (off Heard Island) in cooperation with Austral Fisheries, FV Atlas Cove. It recorded from 16 Sep 2017 – 30 Mar 2018 (4670 h).

- ENSTA Bretagne recovered the AURAL deployed at 46°32'S, and 051°30E' (off Crozet Island). It recorded from Jan 2018 – Jan 2019.

- ENSTA Bretagne in collaboration with Institut Universitaire Européen de la Mer (IUEM) Géosciences Océan - UMR 6538 UBO-CNRS recovered and redeployed 9 long term autonomous hydrophones in the Indian Ocean between 24° to 56° South and from 52° to 83° East. This network of hydrophones has been in place since 2009/2010.

Participation in AAD-led ENRICH voyage to study blue whales and krill

In 2018, Širović and Stafford were awarded a grant of £30,107 GBP from the IWC-SORP Research Fund to join the AAD-led IWC-SORP ENRICH voyage as members of the passive acoustic team, while also providing an acoustic mooring for deployment in study area for the duration of the cruise. This voyage took place from 20 January to 6 March 2019. Details of the voyage will be presented at SC/68b.

Conclusions

Through the many varied contributions of the steering group members, the project has made further progress. Data collection has continued via the SOHN, and the spatial coverage and number of sampling sites for which multi-year data is collected is increasing.

Method development, such as the published evaluation of the performance of manual and automated detectors for Antarctic blue whale calls, has also continued. Data annotation is continued and will provide a valuable basis for the postdoctoral researcher to evaluate the performance of automated detection for different environmental noise conditions and acoustic recorder types. Several inter-sessional (in-person and Skype) 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 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 further remain as high-priority for expansion of the SOHN.

Furthermore, 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. Ongoing work has made progress on automating D-call detection using an adapted version of the generalized power law detector (Helble et al., 2012). For fin whales, standardized methods for call abundance estimation e.g., based on automatically extracted frequency-band specific energies are needed, as single call counts are often prone to analyst bias.

Group meetings are challenging to coordinate as the ATP comprises members from different continents, hemispheres and time zones. However, in-person group meetings have been highly effective in developing the project's long-term strategy plan and identifying project priorities. For 2019, the world marine mammal conference in Barcelona offers a promising prospect for an ATP group meeting.

Outlook for the future

Data annotation is still ongoing and is planned to consume the remaining IWC-SORP funds allocated for this purpose in 2016. This first annotated data set will provide the required basis for the postdoc starting in the course of this year 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. Expansion of the SOHN will require further effort to alert members from different communities to our project.

The group is anticipating undertaking a large effort to analyse passive acoustic and other ancillary data collected during ENRICH voyage, along with similar data collected during previous AAD blue whale voyages to provide baseline information on acoustic behaviour of Antarctic blue whales. During the most recent voyage, a substantial data set has also been collected on fin whale calling behaviour and we expect it may be a good start to start to answer some similar questions for that species. The ultimate goal for these data sets would be their application for density estimation for these species from passive acoustic recordings, which will continue to be one of the goals of the group.

Project outputs

Papers

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ANNEX 6 - PROGRESS REPORTS ON THE IWC-SORP RESEARCH THEMES FOR 2018/19

IWC-SORP Theme 6. The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale

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Introduction

The Southern Right Whale Theme was established at the 2018 following endorsement at IWC67. It aims to provide an over-arching research programme linking southern right whale population dynamics and health with foraging ecology, and assessing these linkages on a global scale. Its main goal is to leverage the existing long-term datasets from the primary wintering grounds with new knowledge on the species' foraging ecology and linkages between migratory habitats, with the ultimate goal of investigating the impact of past and future climate variation on right whale recovery.

Objectives

1. Increase our understanding of southern right whale foraging ecology
2. Update our knowledge on southern right whale population dynamics in a comparative framework
3. Pursue integration of health assessment indicators with long-term monitoring data
4. Investigate the impact of past and future climate variation at foraging grounds on population recovery

Progress to date

Objective 1

During the 2018 IWC-SORP Call from Proposals, the first research project was funded under the auspices of IWC-SORP Theme 6, entitled, *Circumpolar foraging ecology of southern right whales: past and present* (see SC/68a/SHXY for details). This project involves 16 researchers from 9 countries.

To date, the PIs of this project have had two meetings and have collated all the available stable isotope data, primarily coming from four independent research projects. A set of calibration samples have been run for two of the four projects and have been shared with another ongoing research project on South Georgia right whales (See Jackson et al., in prep). Calibration samples will be run for the other projects in the near future, to ensure the ability to account for factors such as variation in lipid extraction method. At the same time, the PIs of the project are working towards understanding the requirements for sharing these calibration samples to additional laboratories, given CITES and other permitting frameworks.

An additional 50 samples from the South African right whales have been contributed by Els Vermeulen and colleagues and will be analysed for inclusion in this work. All these analysis work towards the first objective of the IWC-SORP Theme: Increase our understanding of southern right whale foraging ecology, related to an improved understanding of right whale foraging habitats and ecology. Additional funding was obtained for a further in-depth assessment of South African population dynamics in relation to foraging ecology based on stable isotope data and habitat modelling, forming an integral part of theme Objective 1.

A substantial dataset of stable isotopes from New Zealand right whales (Auckland Islands n = 424, mainland New Zealand n = 36) has been contributed by Glenn Dunshea, Simon Childerhouse, Seth Newsome and Scott Baker. This will contribute all the project objectives, including the pilot study to investigate whether there is heterogeneity in foraging ecology linked with demographic class.

Objective 2

Funding is being sought for proposed IWC project to develop a common model for estimating SRW demographic parameters, which will contribute to Objective 2: update our knowledge on southern right whale population dynamics in a comparative framework. The Australian Government Department of the Environment and Energy's National Marine Science Program (NESP) funded a collaborative research program to assess the abundance and connectivity of southern right whales off Australia, which contributes to Objective 2 of IWC-SORP Theme 6. Progress includes collation of major Australian sighting and photo identification datasets into the Australasian Right Whale Photo Identification Catalogue (ARWPIC). A revised population estimate of SRW in the south-east of Australia was completed by Stamation et al. (2019, see SC/68a/SHXX) along with an assessment of calving intervals, site fidelity and long range movements of SRW in eastern Australia (Watson et al. 2019 in prep). Charlton et al. (2019) published results on seasonal distribution and abundance of SRW at major aggregation ground at Head of Bight using 26 years of annual sightings and photo-ID data.

Objective 3

Substantial progress was also made toward Objective 3 of IWC-SORP Theme 6, related to the integration of health assessment indicators with long-term monitoring data. As such, a visual health assessment (based on Pettis et al. 2004) was conducted for southern right whales photographed along the South African coast between 2005 (start of digital photography) and 2018. Preliminary data from this assessment revealed a significant decrease in female physical health condition in 2008 and 2014. So far, no direct linkages could be found between observed health and calving interval, possibly due to the ability to only assess calving females or due to the lack of data post 2014, when the numbers of calves along the South African coast plummeted. However, preliminary results indicated a link between female visual health and Southern Ocean climate conditions and productivity in at least one of the proposed feeding grounds. More in-depth analyses are ongoing. Subsequently, these data will be used for a similar assessment of the Australian right whale population. For more detail, please see document SC/68a/SHX01

A global comparative study of right whales is being undertaken by Christiansen et al. in collaboration with Murdoch University, Woods Hole, NOAA and others. This data will provide comparative assessment of body condition as an indicator for health for southern right whales off Australia, Argentina and New Zealand. Funding has been sourced to ensure a quantitative health assessment of right whales along the coast of South Africa based on photogrammetry and the methods of Christiansen et al. (2018). These data will be used in the global comparison of similar data obtained from the other primary wintering grounds.

Body condition of southern right whales was assessed at major calving ground in South Australia during the 2016 season by Christiansen et al. (2018). Body condition data was also collected during 2016-2018 in South Australia, with funds secured for annual research until 2020. Planned studies include: assessment of links between body condition and reproductive status; visual health assessment of SRW comparing qualitative health scores (aligned with Pettis et al. 2004 and Hörbst 2019) and quantitative body condition measurements using photogrammetry.

Objective 4

In regard to progress toward Objective 4, a South African study was conducted to assess the linkages between southern right whale reproductive success and Southern Ocean climate conditions and productivity. Results of this study indicate strong links between a de-trended number of right whale calves observed along the South African shore and various Southern Ocean climate conditions (ONI, AAO and Antarctic Sea Ice) at various time lags, as well as chlorophyll *a* concentrations in 2 of the 3 proposed feeding grounds. See SC/68a/SHXX for more detailed information. These data build on the existing knowledge of similar linkages found for the populations off Argentina and Brazil (Leaper et al. 2006 and Seyboth et al. 2016) and, as stipulated by Objective 4, it is aimed that they are integrated into global models of population dynamics.