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IWC-SORP Research Fund: progress reports (2016/17 and 2018/19)

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INTERNATIONAL
WHALING COMMISSION

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ABSTRACT

Following open, competitive Calls for Proposals in 2016/17 and 2018/19 a total of £144,058 GBP and £489,154 GBP, respectively, were allocated from the IWC-Southern Ocean Research Partnership (IWC-SORP) Research Fund to 25 research projects. This paper summarises the progress of these research projects.

KEYWORDS: SOUTHERN OCEAN RESEARCH PARTNERSHIP, IWC-SORP, RESEARCH FUND, PROJECT PROGRESS REPORTS

BACKGROUND ON THE IWC-SOUTHERN OCEAN RESEARCH PARTNERSHIP (IWC-SORP)

The IWC's Southern Ocean Research Partnership (IWC-SORP) was proposed to the International Whaling Commission (IWC) in 2008 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. Currently, there are 13 member countries in the Partnership: Argentina, Australia, Belgium, Brazil, Chile, France, Germany, Italy, Luxembourg, New Zealand, Norway, South Africa and the United States. IWC-SORP is an open Partnership that welcomes new members. Its ethos is one of open collaboration, communication and data sharing.

There are currently six endorsed and ongoing IWC-SORP themes: 1) 'The Antarctic Blue Whale Project'; 2) A project aimed at describing the 'Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean'; 3) The 'Foraging ecology and predator-prey interactions between baleen whales and krill' project; 4) A project to investigate the 'Distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica?' focused initially on east Australia and Oceania; 5) The 'Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean' project; and 6) The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale.

IWC-SORP CALL FOR PROPOSALS 2016/17 and 2018/19

Following voluntary contributions to the IWC-SORP Research Fund by the governments of Australia and The Netherlands, the International Fund for Animal Welfare, and WWF-Australia, the Fund held a balance of £781,833 GBP (2016). Since that time two Calls for Proposals have been completed: 2016/17 and 2018/19.

2016/17

The first IWC-SORP Call for Proposals opened on 26 July 2016 and closed on 17 August 2016. Eleven proposals were received by the IWC-SORP Secretariat and assessed for eligibility in accordance with criteria clearly stated in the guidelines associated with the Call. An interim proposal assessment procedure, developed by the Scientific Committee (Item 1.2 of Annex W (IWC/66/Rep01), was followed. The evaluation process was coordinated by Chair of the Scientific Committee of the IWC and the IWC-SORP Secretariat. Nine members of the IWC-SORP Scientific Steering Committee (SSC) reviewed the proposals. Conflicts of interests were reported by both proponents and assessors. The coordinators decided on a case-by-case basis if the assessor(s) should be excluded from the assessment of individual project(s).

A total of £144,058 GBP was allocated to 10 research projects, ahead of the 2016-2017 austral summer survey season. The majority of these projects submitted final reports to SC/67b (SC/67b/SH18). Updates from three projects still in progress in 2018/19 are included in this report.

2018/19

A second IWC-SORP Call for Proposals opened on 5 September 2017 and closed on 5 January 2018. An Assessment Panel (the Panel) composed of 15 members of the IWC Scientific Committee and chaired by the Chair of the Scientific Committee of the IWC, assessed 19 eligible proposals submitted during the Call. The composition of the Panel was agreed by the Scientific Committee at SC/67a (IWC/67/Rep01 (2017) Annex V, Appendix 1, pp 7-8).

The Panel proposed to the IWC-SORP SSC and subsequently the IWC/SC, the allocation of a total of £489,154 GBP from the IWC-SORP voluntary fund to 15 projects. This allocation was endorsed at IWC67.

FUNDING ALLOCATIONS

The Chair of the Scientific Committee in conjunction with the IWC-SORP SSC, sought endorsement from the F&A Committee and the Commission (IWC/66 and IWC/67) on the Call procedures and all aspects of their implementation, including the allocations of funding outlined in Tables 1 and 2. Full endorsement was received at both IWC/66 and IWC67. Disbursement of funds to successful applicants commenced in January 2017 and December 2018, respectively.

Table 1: List of the projects that received funding from the IWC-SORP Research Fund in 2016/17. Amounts are in GBP.

Project number	Chief Investigator	Co-Investigators	Title	Allocated funding (£)	Project status
1	Baker, C. Scott	Sremba, Angie; Jackson, Jen	Beached bones: assessing genomic diversity and population differentiation of historical blue whales	11,000	Completed final report received SC67b
2	Constantine, Rochelle	Zerbini, Alex; Riekkola, Leena; Friedlaender, Ari; Andrews-Goff, Virginia	Habitat use of humpback whales and their Antarctic feeding grounds: Areas V, VI & I	7,740	Completed final report received SC68a
3	de Bruyn, Nico	Reisinger, Ryan	Habitat use of killer whales at the Prince Edward Islands	10,000	Completed final report received SC67b
4	Friedlaender, Ari	Weinstein, Ben; Double, Michael	Foraging ecology and predator-prey interactions between baleen whales (humpback and minke) and krill: a novel analysis of long-term dive data to quantify feeding rates	20,883	Completed final report received SC67b
5	Harcourt, Robert	Miller, Elanor; Cox, Martin; Miller, Brian; Double, Michael	Antarctic blue whale-krill interactions: an analysis	18,804	Completed final report received SC67b
6	Miller, Brian	Samaran, Flore; Sirovic, Ana; van Opzeeland, Ilse;	An annotated library of underwater acoustic recordings for testing and training automated algorithms for detecting Southern Ocean baleen whales	22,000	Ongoing Interim report received SC68a
7	Moller, Luciana	Attard, Catherine; Beheregaray, Luciano	Population genomic structure of Antarctic blue whales in the Antarctic feeding grounds	19,381	Completed final report received SC67b
8	Olson, Paula		Photo-identification of Antarctic blue whales	2,250	Completed final report received SC67b
9	Paton, Dave	Baker, C. Scott; Dietrich-Steel, Debbie; Garrigue, Claire; Noad, Michael; Childerhouse, Simon	Who are the real East Australian (E1) breeding group of humpback whales? Genetic characterisation of E1 and the influence of E1 across Oceania	23,000	Completed final report received SC68a
10	Samaran, Flore	Stafford, Kate; Miller, Brian; van Opzeeland, Ilse; Harris, Danielle; Findlay, Ken; Sirovic, Ana; Buchan, Susannah; Gedamke, Jason	IWC-SORP Project 5. Acoustic trends in abundance, distribution and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean: 5-year strategic meeting	9,000	Completed final report received SC67b
			TOTAL	**144,058**	

Table 2: List of the projects that received funding from the IWC-SORP Research Fund in 2018/19. Amounts are in GBP.

Project number	Chief Investigator	Co-Investigators	Title	Recommended amount (£)	Project status
11	Baker, C. Scott; Steel, Debbie	Ari Friedlaender, Renee Albertson, Michael Poole, Susana Caballero, Logan Pallin, Jooke Robbins, Ana Lucia Cypriano-Souze, Rochelle Constantine	Is migratory connectivity of humpback whales in the Central and Eastern South Pacific changing? A decadal comparison by DNA profiling	**26,375**	Ongoing Interim report received SC68a
12	Charrassin, Jean-Benoit	Laurene Trudelle, Virginia Andrews-Goff	Application of satellite telemetry data to better understand the breeding strategies of humpback whales in the Southern Hemisphere	**21,200**	Ongoing Interim report received SC68a
13	Branch, Trevor		Modelling somatic growth and sex ratios to predict population-level impacts of whaling on Antarctic blue whales	**32,594**	Ongoing Interim report received SC68a
14	Friedlaender, Ari; Constantine, Rochelle	Jooke Robbins, Scott Baker, Claire Garrigue, Logan Pallin	Pregnancy rates in Southern Ocean humpback whales: implications for population recovery and health across multiple populations	**19,984**	Ongoing Interim report received SC68a
15	Herr, Helena	Sacha Viquerat, Simone Panigada, Bettina Meyer, Anna Panasiuk, Natalie Kelly, Jennifer Jackson, Paula Olson, Ursula Siebert	Recovery status and ecology of Southern Hemisphere fin whales (*Balaenoptera physalus*)	**81,900**	Ongoing Interim report received SC68a
16	Friedlaender, Ari; Constantine, Rochelle	Alex Zerbini, Ben Weinstein	A circumpolar analysis of foraging behaviour of baleen whales in Antarctica: Using state-space models to quantify the influence of oceanographic regimes on behaviour and movement patterns	**34,711**	Ongoing Update received SC68a
17	Buchan, Susannah; Miller, Brian	Flore Samaran, Danielle Harris, Kate Stafford, Ken Findlay, Ana Širović	A standardized analytical framework for robustly detecting trends in passive acoustic data: A long-term, circumpolar comparison of call-densities of Antarctic blue and fin whales	**41,369**	Ongoing Interim report received SC68a
18	Lang, Aimee; Archer, Frederik	Robert L Brownell, Kelly Robertson, Michael R McGowan	Inferring the demographic history of blue and fin whales in the Antarctic using mitogenomic sequences generated from historical baleen	**22,710**	Ongoing Interim report received SC68a
19	Zerbini, Alex; Clapham, Phillip	Yulia Ivashchenko, Mike Double, John Bannister, Els Vermuelen, Ken Findlay	Assessing blubber thickness to inform satellite tag development and deployment on Southern Ocean whales	**22,426**	Ongoing Interim report received SC68a

20	Širović Ana, Stafford Kate,		Acoustic ecology of foraging Antarctic blue whales in the vicinity of Antarctic krill studied during AAD interdisciplinary voyage aboard the *RV Investigator*	**30,107**	Completed Report received SC68a
21	Kelly, Natalie; Maire, Frederic	Amanda Hodgson, David Peel, Helena Herr, Phil Trathan, Jennifer Jackson; Guy Williams	Development of statistical and technical methods to support the use of long-range UAVs to assess and monitor cetacean populations in the Southern Ocean	**30,576**	Ongoing Interim report received SC68a
22	Reisinger, Ryan; de Bruyn, Nico	A. Rus Hoelzel, Christophe Guinet, Simon Elwen	An integrative assessment of the ecology and connectivity of killer whale populations in the southern Atlantic and Indian Oceans	**33,650**	Ongoing Interim report received SC68a
23	Bengston Nash, Susan	Ari Friedlaender, Frederik Christiansen, Juliana Castrillon, David Johnston	Implementation of humpback whales for Antarctic sea-ice ecosystem monitoring; Inter-program methodology transfer for effective circumpolar surveillance	**51,555**	Ongoing Interim report received SC68a
24	Carroll, Emma; Torres, Leigh; Graham, Brittany	Luciano O Valenzuela, Darren Gröcke, Scott Baker, Rochelle Constantine, Ken Findlay, Robert Harcourt, Pavel Hulva, Petra Neveceralova, Larissa Rosa de Oliveira, Paulo Henrique Ott, Per Palsbøll, Vicky Rowntree, Jon Seger	Circumpolar foraging ecology of southern right whales: past and present	**21,290**	Ongoing Interim report received SC68a
25	Iñíguez Bessega, Miguel	Simone Baumann-Pickering Marta Hevia John Hildebrand Alexander Marino Mariana Melcón Maria Vanesa Reyes Reyes Ana Širović Juan Pablo Torres Florez	Habitat use, seasonality and population structure of baleen and toothed whales in the Scotia Sea and the western Antarctic Peninsula using visual and passive acoustic methods and genetics	**23,097**	Ongoing Interim report received SC68a
			TOTAL	**493,544**	

PROJECT PROGRESS REPORTS

Progress reports for the IWC-SORP Research Fund funded projects follow. In some instances, only brief summaries are provided because projects have only recently commenced or the reader is guided toward separate, more detailed, primary papers submitted to the IWC Scientific Committee for consideration.

IWC-SORP FUNDED RESEARCH PROJECT 2 (2016/17). Habitat use of humpback whales and their Antarctic feeding grounds: Areas V, VI & I

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Objectives

1. Identify important Antarctic habitat for humpback whales and the environmental divers behind whale distribution by modelling humpback whale satellite tracks against environmental variables.
2. Consider how whale distribution might be affected by future changes in Antarctic ecosystems and potential prey availability by undertaking predictive habitat modelling.
3. Understand the factors behind different population recovery rates by comparing migration behaviour and Antarctic habitat use of distinct humpback whale populations.

Results

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).

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.

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.

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, SH21 and SC/68b/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 FUNDED RESEARCH PROJECT 9. Who are the real East Australian (E1) breeding group of humpback whales? Genetic characterisation of E1 and the influence of E1 across Oceania

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Executive summary

Phase 1 of the IWC-SORP Project Movements and mixing of humpback whales around Antarctica has focused on Oceania and this project is an extension of the existing work under that programme. Oceania humpback whales are listed as endangered but different sub-populations within the region are showing differing rates of recovery leading to considerable complexity in modelling population status, understanding interchange between sub-populations and migratory pathways. There is an identified gap in that there are no primary genetic samples from the East Australian (E1) breeding ground as almost all of the available samples were actually collected on the E1 migratory corridor rather than the breeding ground. There has been some speculation that the migratory corridor could include a mix of individuals from E1 and E2 breeding stocks. This has limited our ability to characterise this population and how it might be interacting with the other sub-populations of Oceania. The collection of genetic samples will allow an insight into the relationship between EA and the New Caledonia breeding stock (E2), which appear to be closely linked and also aid in the development of improved mixed stock models for whole of Oceania. Analysis has already been undertaken for samples from other sub-populations and those data are available so it is only necessary to add the true E1 to complete the picture. This project is multi-national and will be undertaken through the South Pacific Whale Research Consortium and includes collaborators from Australia, New Caledonia (France), New Zealand, and USA. The outcomes of the research will allow for an improved understanding of the structure and status and migratory paths and feeding grounds of the Oceania humpback whales and 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.

Sample collection was undertaken in 2016 and 2017 and has been reported on previously. The most recent fieldwork was undertaken over two periods during the 2018 breeding season: 8-20 July and 26 August to 7 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 hours and 51 minutes of hand-deployed acoustic recordings targeting social sounds and singers were collected during the 2018 survey. Individual photo-identification analysis is currently underway to confirm the number of individual whales identified by tail fluke identification photos.

The addition of the 21 genetic samples collected during 2018 brings the total number of genetic samples collected from the E1 breeding stock within the Great Barrier Reef Marine Park between 2011 and 2018 to 113. Preliminary analysis of the E1 samples has been undertaken at the Marine Mammal Institute with full analysis for samples collected. Sample size from the GBR breeding grounds for full population level comparison is still low (particularly for females). Further sampling is proposed during 2019 during the peak of humpback sighting in the GBR breeding grounds. Revisions to permit conditions for 2019 will allow sampling of mothers with calves (but not calves), which should significantly increase our sample numbers, especially of females. Following completion of this analysis a full report will be prepared to SORP/IWC and a manuscript developed for publication.

Introduction

An improved understanding of the movements and mixing of humpback whales (*Megaptera novaeangliae*) around Antarctica is a priority for the International Whaling Commission (IWC) because such information is integral to Stock Assessments - a prerequisite of which is the allocation of catches to particular breeding populations (e.g., Jackson et al. 2008; IWC 2015). An improved understanding of the migratory paths and feeding grounds of humpback whales 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 (Carroll et al. 2015; IWC 2015).

The IWC population assessment process would benefit from a greater understanding of the distribution and mixing of all Southern Hemisphere humpback whale populations. The Southern Ocean Research Partnership (IWC-SORP) Humpback Whale Connectivity Project has focused on the remote Antarctic Areas V, VI and I, which are nominal feeding grounds for Breeding Stocks E (broadly clustered as east Australia and western Oceania) and F (eastern Oceania). In 2010, an Antarctic survey of 5,800 nm south of 60° between 150°W and 150°E (incorporating parts of Areas V and VI) found that whales encountered feeding mainly in the Balleny Islands region were linked to east Australia, with a few matches to New Caledonia and New Zealand (Constantine et al. 2014). This is consistent with previously reported connections between east Australia, New Zealand and the eastern Oceania region (e.g., Constantine et al. 2007; Franklin et al. 2014; Garrigue et al. 2011; Steel et al. 2014). The absence of whales linked to the east Oceania breeding grounds meant that a robust understanding of connectivity in the region remained unresolved with the exception of a few individual movement records (Robbins et al. 2011; Steel et al. 2008).

Extensive commercial whaling during the 20th century drove humpback whales close to extinction. Since the cessation of whaling, humpback populations have been rebuilding but with differential recovery rates (e.g. fast recovery in east Australia (E1) (Noad et al. 2011) but significantly slower rates in New Celdonia (E2) and Tonga (E3)), has been slow to recover (IWC 2015; Orgeret et al.; 2014Constantine et al. 2012). Throughout Oceania there is clear sub-population genetic structuring as humpbacks typically return to their natal breeding grounds (Olavarría et al. 2007). Recent work in the region has shown that different age- and sex-class groups prefer different habitat when on their breeding grounds (Lindsay et al. 2016). It has been suggested that the population decline post-whaling meant social aggregations on breeding grounds were fragmented and whales moved to areas of higher density, ultimately leading to higher rates of population increase in some areas (e.g., east Australia) compared to others (e.g., Fiji) (Clapham and Zerbini 2015). The migration distance, feeding opportunities along the migration path (Owen et al. 2016) and quality of feeding grounds may also explain slower rates of recovery for some sub-populations.

Oceania humpback whales (comprising sub-populations E1, E2, E3, F) are listed as Endangered (IUCN). However, different sub-populations within the region are showing significantly different rates of recovery leading to considerable complexity in modelling population status, understanding interchange between sub-populations and migratory pathways. The IWC, as part of the Comprehensive Assessment of Southern Hemisphere Humpback Whales, identified a gap in that there are no primary genetic samples from the East Australian (E1) breeding ground which is limiting the ability to characterise this population and how it might be interacting with the other sub-populations of Oceania. Almost all of the existing samples for characterising the E1 breeding stock have been collected on the E1 migratory corridor rather than the actual breeding ground and there is speculation that there individuals using the corridor may be from a mix of breeding groups (i.e. E1 and E2). The collection of genetic samples will allow an insight into the relationship between EA and the New Caledonia breeding ground (E2) which appear to be closely linked and also aid in the development of improved mixed stock models for the whole of Oceania. Analysis has already been undertaken for samples from other sub-populations and those data are available so it is only necessary to add “true” E1 to complete the picture. The outcomes of this research will allow for an improved understanding of the structure and status of the Oceania humpback whales and will result in an improved assessment of status and lead to better conservation and management.

In 2011, Blue Planet Marine (BPM) commenced a long-term collaborative study in the Great Barrier Reef Marine Park to better identify the breeding grounds of humpback whales within the Great Barrier Reef. A component of this research involved the collection genetic samples and photo identification data to address the identified gap in characterising this population of whales and how it relates to other sub-populations within Oceania. BPM has conducted self-funded surveys in the Great Barrier Reef in 2011, 2014, 2016, 2017 and 2018. In 2016, BPM joined forces with the Cetacean Ecology Laboratory at the University of Queensland and further expanded the study to investigate other research questions including characterising the acoustics of the E1 sub-population.

In late 2016, BPM and Oregon State University (OSU) received a grant from the IWC-SORP Secretariat to assist with undertaking the assessment of stock structure within the East Australian (E1) Breeding grounds. This research represents a component of the existing SORP Project Movements and mixing of humpback whales around Antarctica which has so far had a focus on Oceania and understanding the complex relationships between humpbacks within the region. This project is multi-national and will be undertaken through the South Pacific Whale Research Consortium and includes collaborators from Australia, New Caledonia (France), New Zealand, and USA. The outcomes of the research will allow for an improved understanding of the structure and status and migratory paths and feeding grounds of the Oceania humpback whales and 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 is likely to improve the accuracy of recovery assessments and estimates of pre-whaling abundance.

This report is the final report to the IWC-SORP Secretariat and partly meets the final deliverable under the grant from the IWC for the project, *Who are the real East Australian (E1) breeding group of humpback whales?* Genetic characterisation of E1 and the influence of E1 across Oceania. The IWC-SORP Secretariat has contributed partial funding for this project but most of the funding has come from alternative sources. The report here meets the reporting requirements for the IWC-SORP component of the research but does not provide a detailed summary of the other components of the broader research.

Objectives

The specific objectives of the IWC-SORP component of the research are:

1. What does the genetic identity of the East Australian (E1) breeding group look like from samples collected on the breeding ground?
2. What does the genetic identity of the whales found at the Chesterfield reef system look like from samples collected on the breeding ground?
3. How does the new genetic identity of E1 from these samples compare with previous descriptions of the E1 breeding group based on samples collected from the migratory corridor?
4. What is the genetic relationship between East Australia (E1) breeding group, the nominal Chesterfield group, and other breeding groups in the Oceania population (i.e. E2, E3, F1, F2) and how does this vary from previous descriptions?
5. What do changes in the genetic relationship between E1 breeding group, the nominal Chesterfield group and other breeding groups in the Oceania population (i.e. E2, E3, F1, F2) from previous analyses mean for stock structure, historic catch allocation and our present understanding of status?

The specific outputs of the project for this Report are related to the following elements:

1. Completion of the field programme in E1 for 2018; and
2. A preliminary analysis of all genetic samples.

Methodology

Field methods

Standard biopsy sampling collection and storage techniques were applied using both sloughed skin and Paxarm biopsy systems to collect small pieces of tissues from whales on the 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 Great Barrier Reef. This location is well documented as part of the core range of E1 breeding group and as confirmed by habitat modelling by Smith et al. (2012). The research was based from a large mother-vessel with whales generally approached using a small rigid hulled inflatable. Details records of effort, sample location, sampled individuals, photo-identification and other environmental data were collected. Efforts were made to spread sampling effort throughout the Mackay/Whitsunday Islands and offshore but offshore sampling in particular was limited by prevailing weather. Further field work is proposed between August and September for the 2019 season with a proposed 4-week field season (funding permitting). All research has been led by experienced whale researchers working with experience vessel operators. Currently the number of females is under represented in a genetic samples (52 males, 25 females). This is as a result of not being permitted to sample mothers with calves. For the 2019 field season we have been able to revise our research permit conditions and are now permitted to sample mothers where calves are present.

Analytical methods

<u>Collection and genotyping of samples</u>
Total cellular DNA was isolated from skin tissue using an automated Promega Maxwell ® 16 System. Up to 15 microsatellite loci will be amplified for each sample using previously published primers (GT23, GT211, GT575 (Bérubé, et al. 2000), GATA28, GATA417 (Palsbøll, et al. 1997), EV1, EV14, EV21, EV37, EV94, EV96, EV104 (Valsecchi and Amos 1996) and rw31, rw48, rw4-10 (Waldick, et al. 1999)). Microsatellite loci were amplified individually following methods described in Steel et al (2018). Sex determination and sequencing of the mitochondrial (mt) DNA control region (700bp) followed methods described in detail by Olavarría, et al. (2007).

<u>Replicates and comparison with existing genotypic catalogues</u>
Replicates were identified and removed from within the dataset using GenAlex (Peakall and Smouse 2005). Genotypes of the remaining individuals were then compared to a total of over 2,766 previously typed individuals from datasets from the South Pacific Whale Research Consortium including samples from New Caledonia, Tonga, Samoa, Cook Island, French Polynesia, Niue, New Zealand, Australia and Antarctica. All datasets also include mtDNA control region sequence and sex information for the majority of samples.

<u>Standardisation of datasets</u>
Due to differences in microsatellite run conditions during original analysis, standardisation of allele size has already been undertaken using allele frequency calibration (i.e. aligning allele frequency histograms) and exchange of samples between laboratories. Initial genotype matching between all datasets was conducted using Cervus (Kalinowski, et al. 2007) using 'relaxed' conditions to avoid false exclusion of true matches due to genotyping or standardisation errors. The relaxed conditions required a minimum of 6 matching loci between any pair of samples. These 'likely matches' were then reviewed for errors at any mismatching loci to confirm identity (Waits and Leberg 2000, Waits, et al. 2001, Hoffman and Amos 2005, Morin, et al. 2010). Where available, variation in mtDNA control region sequences (i.e. haplotypes) and sex were used to confirm matches. This standardisation exercise now provides a standardised dataset of over 2,500 individuals from across Oceania.

Results and discussion

Field results

BPM, in conjunction with CEAL, undertook 4 weeks of dedicated humpback whale surveys in the Whitsundays and Mackay region of the Great Barrier Reef Marine Park during 2018. Surveys were undertaken during two periods during the breeding season 8th July to 20th July and 26th August through to the 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 hours and 51 minutes of hand deployed acoustic recordings targeting social sounds and singers were collected during the 2018 survey. The 2018 samples will be sent to OSU for analysis once CITES and other permits have been confirmed. Individual photo-identification analysis is currently underway to confirm the number of individual whales identified by tail fluke identification photos. Unfortunately, due to lack of funding and other work commitments during the anticipated peak of whales within the region (August) no field work was undertaken during this period. It is anticipated that the 2019 field season will target the peak of sightings for whales in the GBR breeding grounds.

The total number of samples collected during the 2018 field season was low in relation to the total number of whales observed. The primary reasons for this were:

1. No samples (sloughed or biopsy) are able to be collected within Green Zones (i.e., completely no take zones) within the GBRMP under our permit conditions (Figure 1);
2. No samples (sloughed or biopsy) are able to be collected in sight of any members of the public; and
3. No samples are able to be collected from either a mother or calf.

These restrictions considerably impacted on the team's ability to collect samples as while many whales were seen, most were in areas or were individuals which could not be sampled. See Table 4 for the number of genetic samples collected per year within the E1 breeding grounds since 2011. The collection of 21 additional samples in 2018 brings the total number of samples to 113 samples.

Table 4 Number of genetic samples collected in the E1 Breeding grounds 2011- 2018. *Samples collected in 2018 are awaiting genetic analysis.

Year	Number of genetic samples
2011	21
2014	15
2016	25
2017	31
2018*	21
Total	**113**

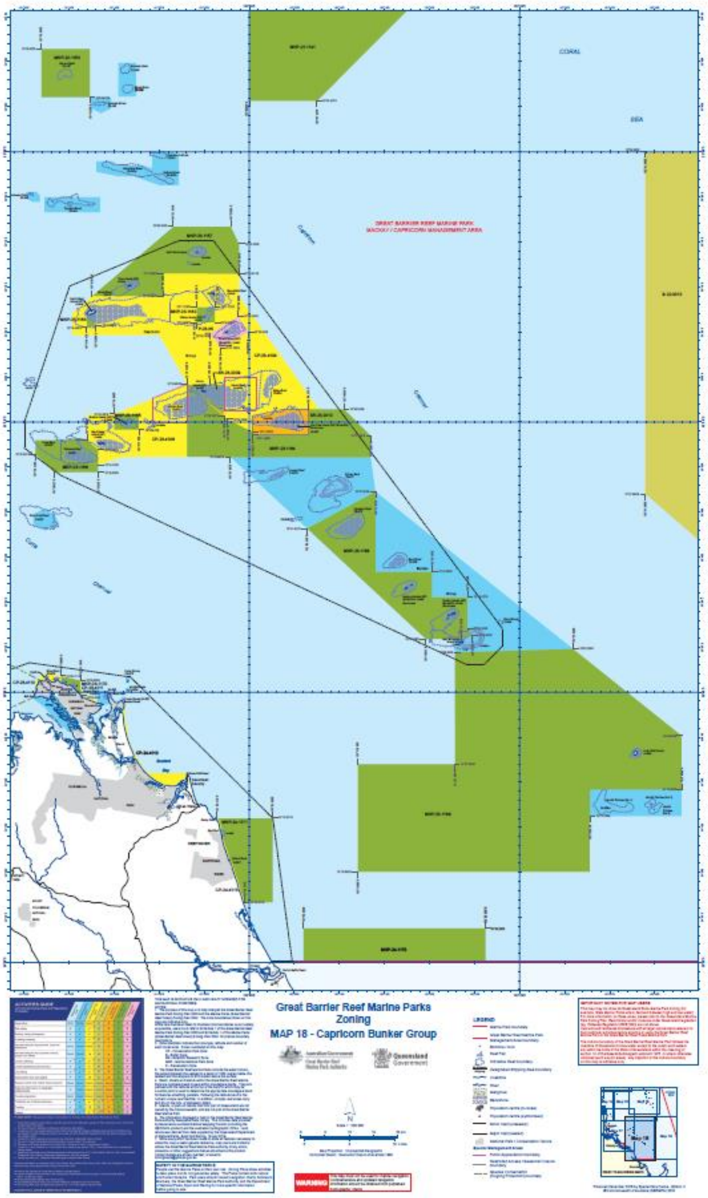

Figure 1 Great Barrier Reef Marine Park showing different zones for the Mackay/Capricorn Management Area. *Green zones are no take areas where sampling is not permitted*.

Data analysis

Photo-ID

A large number of photo identification images were also collected during the 2018 field season and have been sorted and archived. Further analysis is currently underway to confirm the total number of unique photo-identifications were obtained during the 2018 field season. All images will be entered into *Happywhale* (Happywhale.com) for matching. All photo identifications from 2011, 2014, 2016 and 2017 have been analysed and have been entered into *Happywhale* for matching. All images will be reviewed and matched with other datasets held by the authors and images will be made available to other researchers in the Oceania region for matching.

Individuals whales identified through photo-ID collected in 2016 and 2017 in the GBR area were compared with individual whales identified through photo-ID in Chesterfield-Bellona archipelago, but no match was found (For more details see Garrigue et al 2018).

DNA profiling

A total of 92 genetic samples were collected on the Great Barrier Reef (GBR) between 2011 and 2017 and transferred for analysis to the Cetacean Conservation and Genomics Laboratory at Oregon State University (OSU). Samples collected in 2018 are awaiting transfer to OSU for DNA profiling. Following standard methods developed for large-scale comparisons of humpback whales across the Southern Hemisphere, we used these samples for 'DNA profiling', including genotyping at 16 microsatellite loci, sex identification and sequences of the mitochondrial DNA control region (Steel et al, 2018). Comparison of these profiles identified 14 replicate samples from 11 individuals (eight sampled twice and three sampled three times). All replicate samples were within the same field season except one whale that was sampled twice in 2016 and then again in 2017, i.e., a between-year genotype recapture. After removing replicate samples there were 78 individuals (52 males, 25 females and one unknown) represented in the first 'DNA register' of humpback whales from the GBR. Preliminary matching of these DNA profiles to those from the migratory corridor of East Australia (Southern Queensland/Northern NSW n = 734; Eden and Tasmania n = 131); the nearby breeding ground of New Caledonia (n = 1,246); and the recently surveyed Chesterfield Reef region (n = 35) revealed 5 genotype recaptures, three to East Australia and two to New Caledonia (see Table 2).

The two individuals already observed within the New Caledonia waters were adult females. One was observed in a competitive group on La Torche bank in the off-shore waters located south of New Caledonia. The second one was a mother accompanied by a calf. Both of these whales have only been observed once in New Caledonia.

Table 2 Results of initial matching of DNA profiles from humpback whales sampled in the Great Barrier Reef (GBR) with those from other breeding grounds or migratory corridors of Breeding Stock E1.

Region (years)	n	Female recaptures with GBR (n =25)	Male recaptures with GBR (n = 52)
New Caledonia (1995-2017)	1,246	2	0
Chesterfield/Bellona Reef (2016-2017)	35	0	0
S Queensland/N NSW (2002-2004)	734	2	1
Eden, NSW/Tasmania (2006-2008)	131	0	0

Mitochondrial DNAhaplotype information was available for 77 of the 78 individual GBR humpback whales. This frequency information was compared to the mtDNA frequencies of all currently sampled breeding grounds and migratory corridors of the South Pacific. Result of this analysis are shown in Table 3.

While the sample size for the GBR breeding grounds is low (particularly for females) preliminary results indicated that the GBR is significantly different to the breeding grounds of Western Australia, Colombia, French Polynesia, American Samoa, Cook Islands and Tonga. It is also significantly different to New Caledonia but this difference is weaker. It is not significantly different from the Chesterfield which may be more due to the low number of samples collected in the Chesterfield-Bellona archipelago. When it comes to migratory corridors GBR is not significantly different to samples collected at locations on the east Australian migratory corridor or NZ, but it is different to samples from the Kermadec Islands (NZ).

Table 3 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

2019 field season

BPM, in conjunction with CEAL, is planning to run a 4-week field season with in period of peak humpback whale sighting (August) in the GBR in 2019. We also received a variation to our permit conditions to allow us to biopsy mothers with calves which should increase the proportion of encounters from which a biopsy can be collected.

Acknowledgements

Thanks for all our IWC-SORP and SPWRC collaborators including Professor. Scott Baker, Dr Debbie Dietrich-Steel, Dr Claire Garrigue, Associate Prof Mike Noad, Dr Rochelle Constantine, Dr Mike Double, Dr Simon Childerhouse and Claire Bonneville. We also thank the field assistants for their support of the work including Dana Casano, Damien Morales, Dr Rebecca Dunlop, Lesley Douglas. We would also like to thank the people involved in the issuing of the relevant permits for this work. Special thanks to IWC-SORP for providing partial funding for this work and IFAW for their ongoing support during the 2019 field season.

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IWC-SORP FUNDED RESEARCH PROJECT 6 (2016/17). An annotated library of underwater acoustic recordings for testing and training automated algorithms for detecting Southern Ocean baleen whales

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Introduction

In November 2016, the IWC-SORP Acoustic Trends Group was awarded a grant of £22,000 by IWC-SORP to create an annotated library of Antarctic underwater recordings. The initial purpose of the library was for characterising the performance of automatic detectors of animal sound. However, at the 2017 Acoustic Trends Working Group Meeting, it was determined that the annotated library would also form an integral part of the new standardised circumpolar acoustic analysis framework that is being implemented by the Working Group.

Objectives

The objectives and the work plan from the original proposal were as follows:

Activity to be undertaken	**Responsibility**	**Est. finish date (mm/yy)**	**Actual finish date (mm/yy)**
Objective 1: Define library scope, and initial data set (1-2 months)	Acoustic Trends Steering Group (Project PIs and CIs)	06/17	05/17
Objective 2: Annotate initial data sets (10-11 months)	PI and Technician	04/18	08/18 (est.)
Objective 3: Improvement of tools for annotation of data (ongoing throughout Task 2)	Acoustic Trends Steering Group (Project PIs and CIs)	04/18	05/17, but ongoing until project completion.

Results

From Nov. 2016 to April 2017 the Acoustic Trends Group held regular teleconferences to define the library and initial datasets (objective 1). During this time, the group decided that it would be beneficial to first conduct a smaller 'pilot' dataset before committing full funding towards the library.

Annotation of the pilot dataset (a 400 hour subset of data from two different sites) was subcontracted to consultant Dr Naysa Balcazar using an in-kind funding contribution from the Australian Antarctic Division. The results of this pilot dataset were presented at the 2017 Meeting of the IWC-SORP Acoustic Trends Working Group in Bled, Slovenia. The scope of the library and initial dataset were then finalised (Objective 1) by the Working Group at this meeting. The annotations from the pilot dataset will be included in the Annotated library, and are recognized as an important contribution to Objective 2. Dr Balcazar's final report also included feedback that contributed towards Objective 3: improvement of tools for annotating acoustic data.

Work on Objective 2 has continued from May 2017 to present. The initial scope of Objective 2 was annotations from four sites in the same year (2014), and one of those sites (S. Kerguelen Plateau) for multiple years. This was completed in May 2018 with 9,140 GBP of funds leftover for completing additional supplemental analysis. After discussion amongst group members, it was decided that the additional analysis should aim to include an additional year of annotation (2015) at each of the four sites plus an additional year of data at the Elephant Island site that includes two different models of instruments deployed on the same mooring (2013 Aural & Sonovault).

Outlook for the future

As of 29 April 2019, £17,040 of the £22,000 has been allocated, all to subcontractors who have undertaken the technical task of annotating every low-frequency sound for blue and fin whale calls (Table 7). At this point, the supplemental analysis is nearly halfway complete, and plans call for the remainder of the IWC-SORP funding to be spent on additional subcontracts to expand the datasets included in Objective 2 (Table 8).

Upon completion, the Annotated Library will contain a sample of approximately 2000 hours annotated sounds. The Annotated library will be the most representative collection of ground-truth sounds to date, and it will contain regularly sampled data throughout the year across different areas (Western Antarctic Peninsula, Atlantic, Pacific, and Indian sectors of the Southern Ocean), instruments (Scripps ARP, Aural, AAD Moored Acoustic Recorder, SonoVault), and years (2005, 2013, 2014, 2015). Once completed, the Annotated Library will be made publicly available.

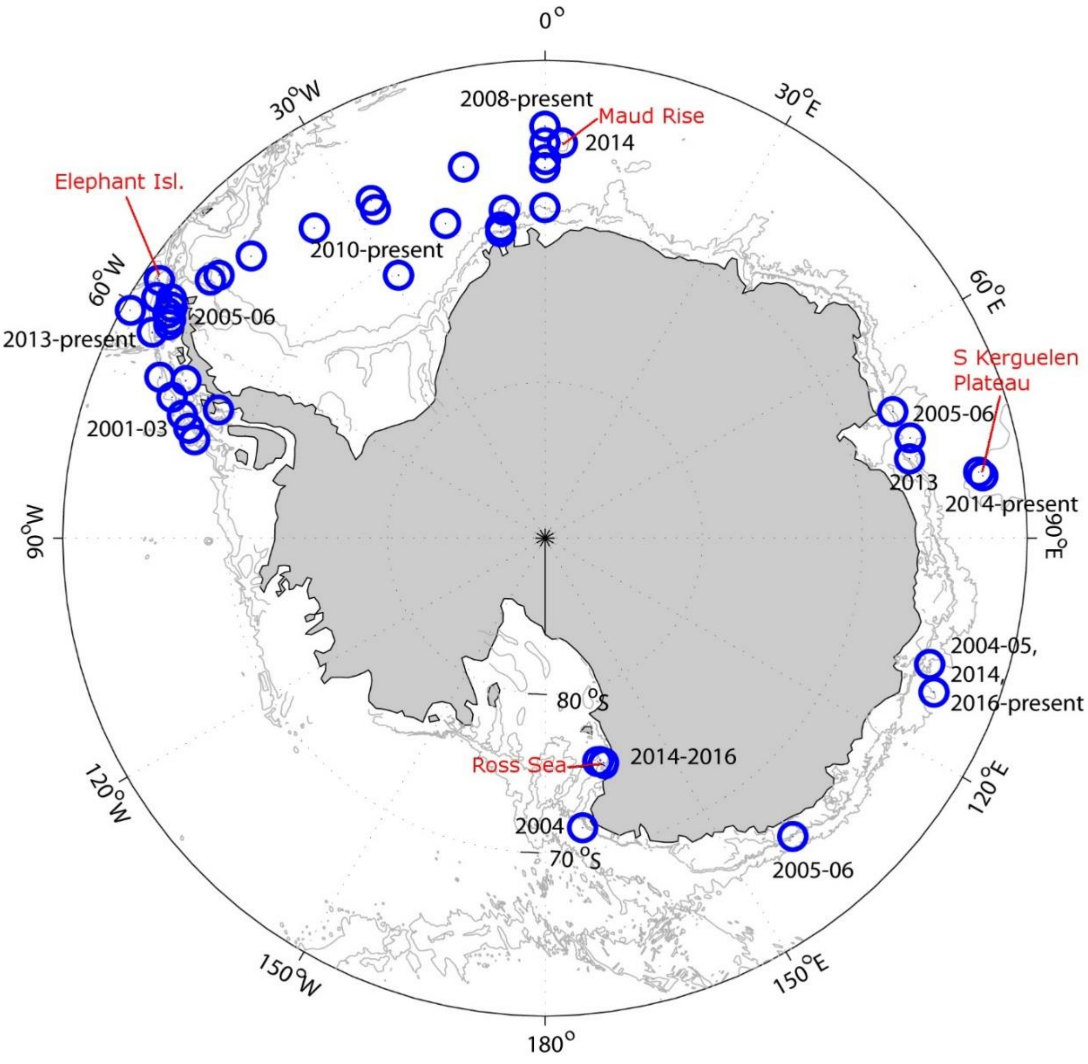

Figure 2 Map of previous and current locations of long-term acoustic recordings south of 60° S, along with years when acoustic data are available for each location.

Table 7 Funds as of 2019-04-29	GBP
Granted:	22,000
Spent:	12,860
Allocated (2019):	7,930
Remaining:	1,210

Table 8 Summary of data available and annotated

Dataset	Data Owner	SORP Funding	Analyst	Instrument	Acoustic Data Available	Start	Stop	Hours annotated
S. Kerguelen Plateau 2005	AAD	Yes	NB	AAD-MAR	Yes (BSM)	2005-01-31	2006-01-31	200
S. Kerguelen Plateau 2014	AAD	No	NB	AAD-MAR	Yes (BSM)	2014-02-22	2015-02-20	200
S. Kerguelen Plateau 2015	AAD	Yes	NB	AAD-MAR	Yes (BSM)	2015-02-10	2016-01-27	200
Casey 2014	AAD	No	NB	AAD-MAR	Yes (BSM)	2013-12-25	2014-12-12	194
Ross Sea 2014	NOAA/PMEL	Yes	SN	OBH	? (KS)	2014-02-08	2014-12-14	176
Ross Sea 2015 (Balleny Isl.)	NOAA/PMEL	Yes	SN	OBH?	? (KS)	2015	2015	TBC
Elephant Island 2013	AWI	Yes	NB	Aural	? (IVO)	2013	2013	TBC
Elephant Ilsand 2013	AWI	Yes	NB	Sonovault	? (IVO)	2013	2013	TBC
Elephant Island 2014	AWI	Yes	EL	Aural	? (IVO)	2014-01-01	2014-12-31	216
Elephant Island 2015	AWI	Yes	NB	Sonovault	? (IVO)	2015	2015	TBC
Maud Rise 2014	UoP?	No	FS	Aural	? (KF)	2014-01	2014-09	2499
Maud Rise 2015	AWI	Yes	NB	Sono.vault	? (IVO)	2015-01-02	2015-12-31	190

	Blue whale annotations				Fin whale annotations			
Dataset	**A**	**B**	**Z**	**D**	**20 Hz**	**dsweep**	**higher**	**Unidentified/other**
S. Kerguelen Plateau 2005	335	237	166	435	788	444	78	3062+335minke.ds
S. Kerguelen Plateau 2014	1505	741	394	357	1150	240	1099	3825
S. Kerguelen Plateau 2015	1970	542	236	1180	552	525	718	1244+773minke.ds
Casey 2014	3682	1398	1091	679	660	0	0	5005
Ross Sea 2014	104	0	0	0	0	0	0	255 including low and quick downsweeps
Elephant Ilsand 2014	6935	967	100	1034	4940	4078	3010	474+230 backbeat
Maud rise 2014	TBC?	TBC?	TBC?	TBC?	TBC?	TBC?	TBC?	TBC?
Maud rise 2015	841	161	29	84	2	46	1	342

IWC-SORP FUNDED RESEARCH PROJECT 11 (2018/19). Is migratory connectivity of humpback whales in the Central and Eastern South Pacific changing? A decadal comparison by DNA profiling

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Executive summary

We have now integrated existing DNA profiles of humpback whales from the South Pacific and Southern Ocean into a single, curated DNA register, representing more than 4,000 individuals. A further 571 samples are pending importation and analysis. Since the initial proposal to SORP, there have been collaborative contributions of samples collected in Panama and in the Pitcairn Islands as well as an additional year of sampling in Colombia. Initial matching has revealed new records of migratory interchange between Oceania, the Antarctic Peninsula and the eastern South Pacific.

Introduction

Humpback whales wintering along the Pacific coast of South America, referred to as Breeding Stock G (BSG) are unusual in having well-defined migratory destinations near the western Antarctic Peninsula (AP) and in their degree of genetic differentiation from other breeding stocks in Oceania and the South Atlantic. However, the extent of this isolation might be changing as populations are increasing at variable rates, perhaps encouraging individual whales to explore alternate migratory destinations. Here we report initial progress on the investigation of decadal changes in connectivity between BSG and the 'adjacent stocks' of Oceania using DNA profiling, including sex and 10-15 microsatellites for individual identification and sequencing of the mtDNA haplotype for maternal lineages. For this, we are building on efforts of the South Pacific Whale Research Consortium and collaborators in assembling a 'DNA register' of profiles representing 2,104 individual humpback whales sampled on wintering grounds and in the Antarctic from 1991 to 2005.

Objectives

1. Update the existing DNA register of humpback whales in the South Pacific with recently available DNA profiles and complete analysis of existing samples, for an anticipated grand total of more than 4,500 individual DNA profiles;
2. Reconcile matching DNA profiles (capture-recapture) from the updated register, to document migratory interchange, with an emphasis on Oceania and BSG, including the Antarctic Peninsula;
3. Update mixed-stock analysis of humpback whales from the Antarctic Peninsula, to estimate the allocation of whales from Oceania (BSE and BSF) and those from BSG, using Brazil (BSA) as an outgroup;
4. Compare rates of interchange and mixed-stock allocation for two approximately decadal periods, 1991-2005 and 2006-2016, to look for changes in connectivity; and,
5. Provide information on individual identification and sex to regional collaborators and contribute to related IWC-SORP programs, including the previously funded 'The Great Humpback Whale Trail' and the proposed 'Rates of pregnancy in humpback whales in the Southern Ocean'.

Results

- The DNA register has been updated with an additional 2,081 individuals (Table 9). Since the initial proposal to SORP, there have been further collaborative contributions of samples collected in Panama (courtesy K. Rasmussen) and in the Pitcairn Islands (courtesy T. Dawson) as well as an additional year of sampling in Colombia (courtesy S. Caballero). These samples will increase the geographic coverage and improve the genetic resolution of Breeding Stock G.
- With the inclusion of an additional 2,081 individuals to the DNA register, a total of 13 records of migratory interchange have been documented (Figure 3).
- Analysis is pending completion of remaining 571 samples (awaiting CITES permits).
- Analysis is pending completion of remaining 571 samples (awaiting CITES permits).
- Information on individual identification and sex has been provided to regional collaborators and to Principal Investigators of related SORP programs, including the ‘The Great Humpback Whale Trail’ (R. Constantine); ‘Rates of pregnancy in humpback whales in the Southern Ocean’ (A. Friedlaender, L. Pallin) and ‘Who are the real East Australian (E1) breeding group of humpback whales’ (D. Paton and C. Garrigue). Further coordination with collaborators was facilitated by presentation and discussion at the 2019 meeting of the South Pacific Whale Research Consortium (Auckland, New Zealand, 4 - 6 February, 2019).

Table 9 Additional DNA profiles now integrated into the existing DNA register of humpback whales for the South Pacific and Southern Ocean (Steel et al. 2018), with samples still pending profiling and analysis. Regions in bold are the focus of the proposed comparison.

	Profiled individuals now integrated into DNA register		Samples still to be added transferred to OSU,		Total
Region	years	individuals	years	samples	
French Polynesia	**--**	**--**	**2008-16**	**469**	**469**
Panama	**2016**	**3**	**2018**	**100**	**103**
Pitcairn Islands	**--**	**--**	**2018**	**2**	**2**
Antarctic Peninsula	**2010-17**	**737**	**--**	**--**	**737**
Colombia	**2015-18**	**137**	**--**	**--**	**137**
Ecuador	**2006-10**	**49**	**--**	**--**	**49**
A Samoa/Samoa	**2010-16**	**63**	**--**	**--**	**63**
New Caledonia	2006-12	644	--	--	644
Eastern Australia	2007-17	209	--	--	131
New Zealand	2008-12	123	--	--	123
Kermadec Islands	**2015-17**	**116**	**--**	**--**	**116**
Total		2,081		571	2,574*

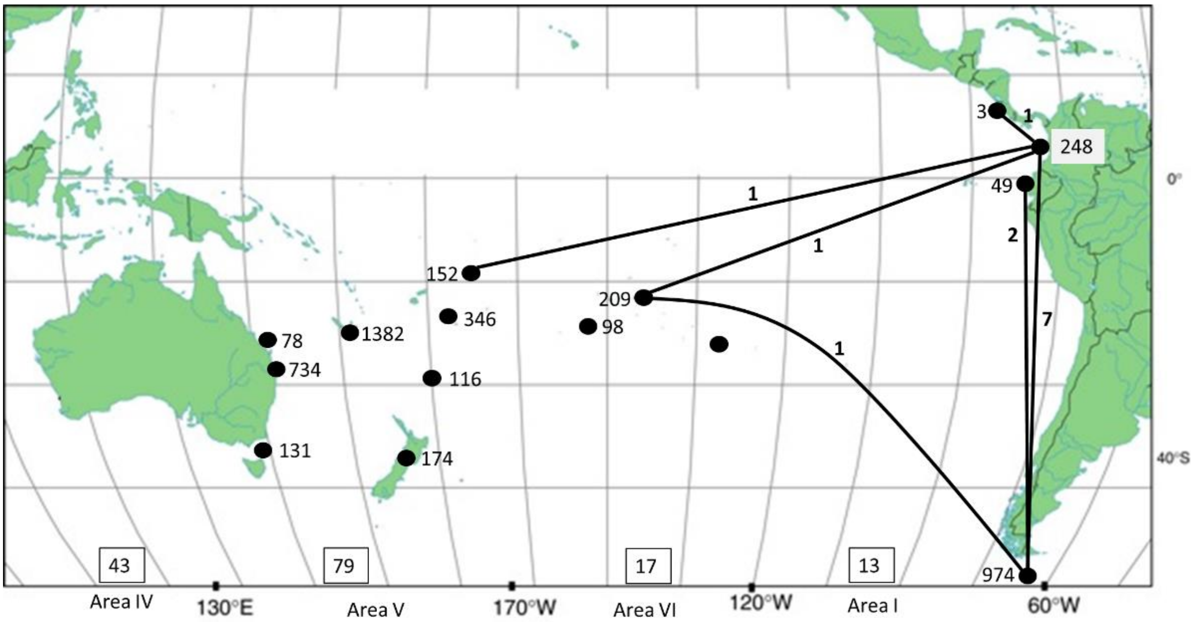

Figure 3 Migratory interchange between BSG (Panama, Colombia and Ecuador) and the Antarctic, and interchange between the eastern Pacific and Oceania as documented through initial integration with the DNA register. With initial integration, the updated DNA register now includes DNA profiles for over 4000 individual humpback whales. Regional sample sizes are shown adjacent to locations, numbers of individuals moving between locations shown adjacent to lines connection destinations.

Conclusions

The integration of new DNA profiles has nearly doubled the size of the current DNA register of humpback whales in the South Pacific, providing new records of migratory interchange between Oceania, the Antarctic Peninsula and the eastern South Pacific. Numerous other new records of interchange have been documented within Oceania and in the western South Pacific (Riekkola et al. 2018). Further analyses are underway and further samples are expected, pending CITES permit applications.

Challenges

Applications for CITES permits are burdensome and processing of application can be slow. The PI is working with regional collaborators to facilitate the process.

Outlook for the future

The project is on track with considerable progress to date and with expected outcomes, pending sample import/export.

Project outputs

An update on samples and preliminary results of migratory interchange was presented to regional collaborators at the 2019 meeting of the South Pacific Whale Research Consortium (Auckland, New Zealand, 4-6 February, 2019).

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IWC-SORP FUNDED RESEARCH PROJECT 12 (2018/19). Application of satellite telemetry data to better understand the breeding strategies of humpback whales in the Southern Hemisphere

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Introduction

Breeding areas of humpback whales (*Megaptera novaeangliae*) are located in coastal habitats generally subject to strong human pressures that affect the quality of these breeding habitats (e.g. vessel traffic, Laist et al. 2001; fisheries, Zappes et al. 2013; seismic survey, Rosenbaum et al. 2014, acoustic disturbance; Fossi et al. 2012, whale-watching; Weinrich 2009;Weinrich and Corbelli 2009). Deterioration or disappearance of these habitats could, in the long term, impact the whales' reproductive success. Identifying such habitats and environmental parameters which characterise them (e.g. bathymetry, sea-surface temperature, ocean currents), is essential to ensure better management and protection of these key areas.

During her PhD, Laurene Trudelle described the movements of humpback whales and characterised their breeding habitats around Madagascar, which represents a key wintering ground for the Western Indian Ocean population of this species (Cerchio et al. 2016; Trudelle et al. 2016). While her approach (analysis of satellite tracks in relation to environmental parameters) has provided new perspectives, a key question remains unanswered: are habitat use strategies different within and between regions and are these differences in response to the characteristics of the marine environment of the breeding grounds? She initiated a number of international collaborations at the end of her PhD and was able to access the same type of data as those obtained in Madagascar from other parts of the Southern Hemisphere: Western Australia, Eastern Australia and Central America, Brazil, Gabon, New Caledonia.

The present project aims at using a multi-year, large scale dataset of satellite tag deployments. It constitutes a unique opportunity to compare the whale coastal movements and habitat use of at least five Southern Hemisphere wintering sites and put all the tagging datasets in perspective. It will increase our knowledge on distribution patterns and habitat preferences of southern hemisphere humpback whale populations, and will improve our understanding of humpback whale ecology, thus contributing to conservation and management of the species.

Our proposed research project represents an opportunity to improve our understanding of the movements and the distribution of several southern hemisphere humpback whales populations and the links with their environment. By knowing the preferred habitat and their associated characteristics it will allow intergovernmental bodies and governments to assess how well it is protected and possible threats to both the habitat or to the whales directly. Such an assessment is enhanced by a description of the habitat and behavioural characteristics specific to a given breeding ground and those common to all calving areas in the Southern Hemisphere. The acquisition of fundamental data on the population ecology of humpback whales falls into IWC priorities in the context of the comprehensive assessment of humpback whales in the Southern Hemisphere. In addition, one of the main limits in the behavioral studies of cetaceans is data sharing. Accordingly, the various teams in the world generally work at a local or regional scale, making inter-regional studies difficult to implement. In recognition of this, organisations have a common interest in the value and limitations of satellite tracking data collected from tagged marine mammals. The proposed project will strengthen the relationship between different organisations and allows for the exploration of further collaborations and opportunities through pooling these large existing data sets developed in part through existing IWC-SORP projects.

Objectives

1. Based on large existing satellite tracking datasets, to compare the coastal movement patterns of humpback whales according to sex and breeding regions at the different stages of the breeding season.

2. To establish statistical relationships between at-sea movements and key environmental parameters at the relevant spatio-temporal scales (i.e. extracted relative to the whale tracks), and to describe

commonalities and differences in patterns of habitat use by breeding humpback whales from different regions. I will then attempt to build a general model of habitat use by breeding humpback whales according to regional environmental features.

Results

Officially, the IWC-SORP project starts in April but it has already started. Laurène is currently a visiting scientist at the Marine Mammal Laboratory, to work with an associated expert scientist to the project Dr A. Zerbini. She initiated new collaboration to increase the dataset. At present, thanks to Dr. Zerbini and collaborators, she was able to access satellite data from the following regions:

- Southwest Atl (Stock A): A. Andriolo, D. Danilewicz, A. Zerbini - (Instituto Aqualie)
- Southeast Atl (Stock B): F. Kershaw (Natural Resources Defense Council), H.C. Rosenbaum (Wildlife Conservation Society)
- Southwest Ind Oc - Comoros Archipelagos (Stock C2): S. Fossette (Association Megaptera), M.P. Heide-Jorgensen (Greenland Institute of Natural Resources), M. Vely (Association Megaptera)
- Southwest Ind Oc - Madagascar (Stock C3) : O. Adam (Sorbonne Université), S. Cerchio (New England Aquarium), F.X. Mayer (Cetamada), H.C. Rosenbaum (Wildlife Conservation Society)
- Southwest Ind Oc - Mascarenes/Reunion (Stock C4): V. Dulau (Globice), J. Fayan (Brigade Nature Océan Indien), S. Cerchio (New England Aquarium).
- Southeast Indi Oc (Stock D): V. Andrews-Goff (Australian Antarctic Division), M. Double (Australian Antarctic Division), Jason How (Department of Primary Industries and Regional Development, Western Australian Antarctic Division)
- Southwest Pac (Stock E1): V. Andrews-Goff, M. Double - Australian Antarctic Division
- Oceania - New Caledonia (Stock E2): C. Garrigue (Opération Cétacés, IRD)
- Oceania - Cook Island (Stock F1): N. Hauser (Cook Islands Whale Research)
- Southeast Pac (stock G) - Colombie: M.C. Díazgranados-Cadelo (Conservation International)
- Southeast Pac (stock G) - Costa Rica/Panama/Equateur: H.M. Guzman (Smithsonian Tropical Research Institute, Panama)
- Southeast Pac (stock G) - Amérique Central: A. Friedlaender (University of California, Santa Cruz)

Analyses are ongoing.

Outlook for the future

- Submit an abstract at World Marine Mammal Conference 2019 in Barcelona.
- Perform data exploration and analyses on the data provided
- Encourage interaction between team members through physical visits.
- Create at least one peer-reviewed publication as a lead author with all additional team members as co-authors

IWC-SORP FUNDED RESEARCH PROJECT 13. Modelling somatic growth and sex ratios to predict population-level impacts of whaling on Antarctic blue whales

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Introduction

Three main components to the project were originally proposed: (1) Assessing sex ratios in both foetuses and in the population as a whole; (2) building somatic growth models from conception to birth, and from birth to physical maturity; (3) predicting changes in length distributions of Antarctic blue whales during decline and recovery periods.

Original and revised order

In the original proposal it was planned to complete the three components above in order at the end of 2019, 2020, and 2021 respectively. However, given interest in separating northern Indian Ocean blue whales using foetal lengths, and the clear links between that priority of the IWC to appropriate modelling of Antarctic blue whale foetal growth, work has begun first on the foetal growth model. This report describes progress on developing a model for Antarctic blue whale foetal growth.

Data for Antarctic blue whale foetal lengths

The foetal growth model needs to take into account several unusual features of the collected data. The data were required to be reported for all whaling vessels, and consist of the length of all foetuses observed from whaled individuals, including the position, date, and sex of foetus. Most of the foetal lengths are recorded to the nearest foot, but some of the smaller measurements are recorded in feet and inches, or in centimetres. Smaller foetuses were normally missed, which is certainly true of the very smallest embryos which comprise just a few cells. But even those in the 1-12 inch range were often missed during whale processing. Thus any model needs to account for a detection bias that ranges from 0 detected when microscopic lengths to 100% at a few feet long. Preliminary Antarctic blue whale data were extracted for boundaries identified by Branch et al. (2018) in Figure 4, except those caught in Durban, South Africa, which are not easily assigned to Antarctic or pygmy blue whales.
For each area, the western boundary is inclusive, and the northern boundary is exclusive:

- 180°-65°W: south of 52°S (well defined separation)
- 65°W-20°E: south of 0° (all blue whales, including those caught in Saldanha Bay, Namibia, and Angola)
- 20°E-30°E: south of 46°S (based on lengths of pregnant females)
- 30°E-70°E: south of 52°S
- 70°E-80°E: south of 53°S (a few pygmy blue whales caught in this region at 52-53°)
- 80°E-180°: south of 52°S (well-defined separation)

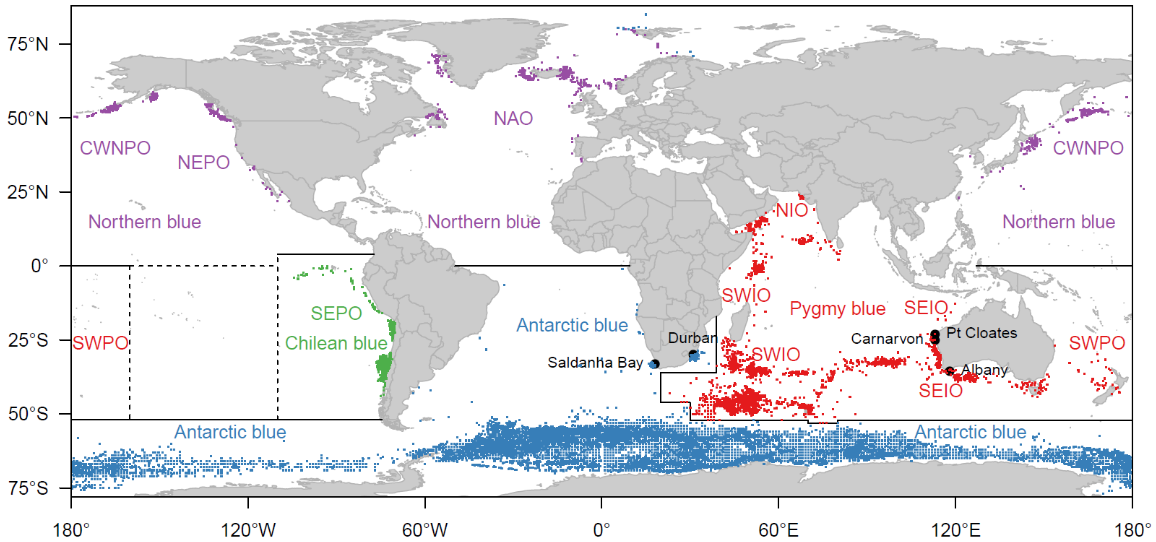

Figure 4 Map showing the boundaries used to separate blue whale subspecies (Branch et al. 2018).

The resulting data for *n* = 30,265 foetal lengths of Antarctic blue whales shows several patterns (Figures 5 and 6). Notable are the horizontal bands showing lengths rounded to the nearest 1 ft interval. Lengths smaller than 1 ft are nearly absent, and lengths at 1 ft are rare. There is an obvious seasonality to foetal lengths, suggesting that conception occurs before day 300 (27 October), and given birth lengths are about 7 m (23 ft), peak birth dates may be around day 150 (30 May), although this extrapolation is uncertain given few foetal length data come from whales caught in May-July.

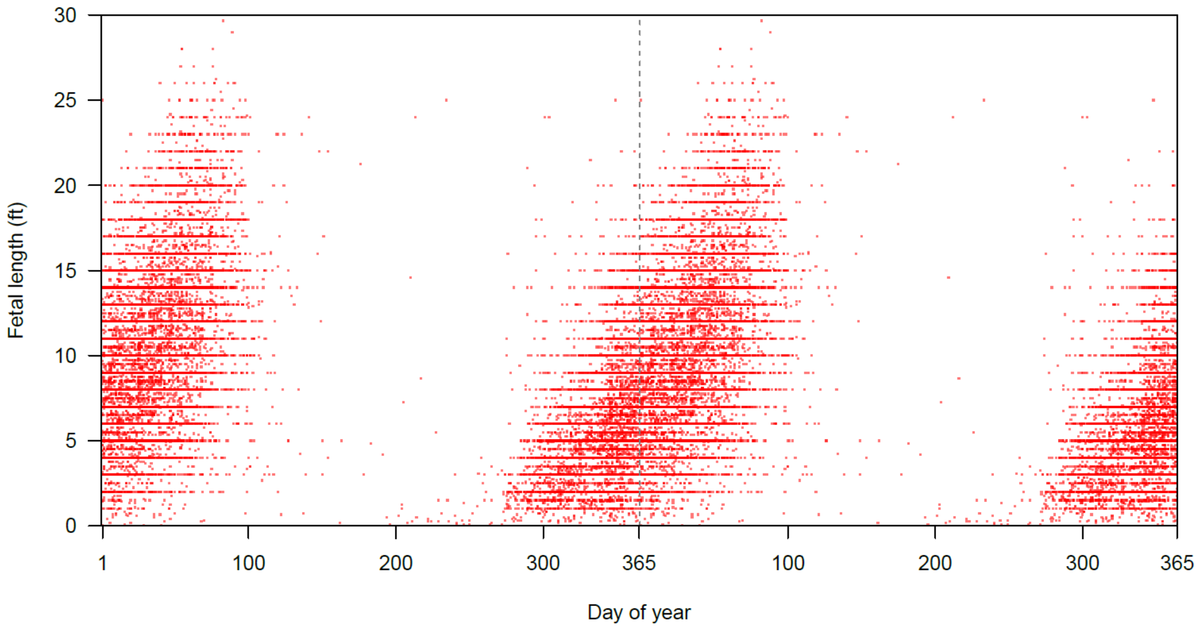

Figure 5 Foetal lengths by day of the year from regions inhabited by Antarctic blue whales. The data are repeated twice from left to right to more clearly see the pattern of foetal growth.

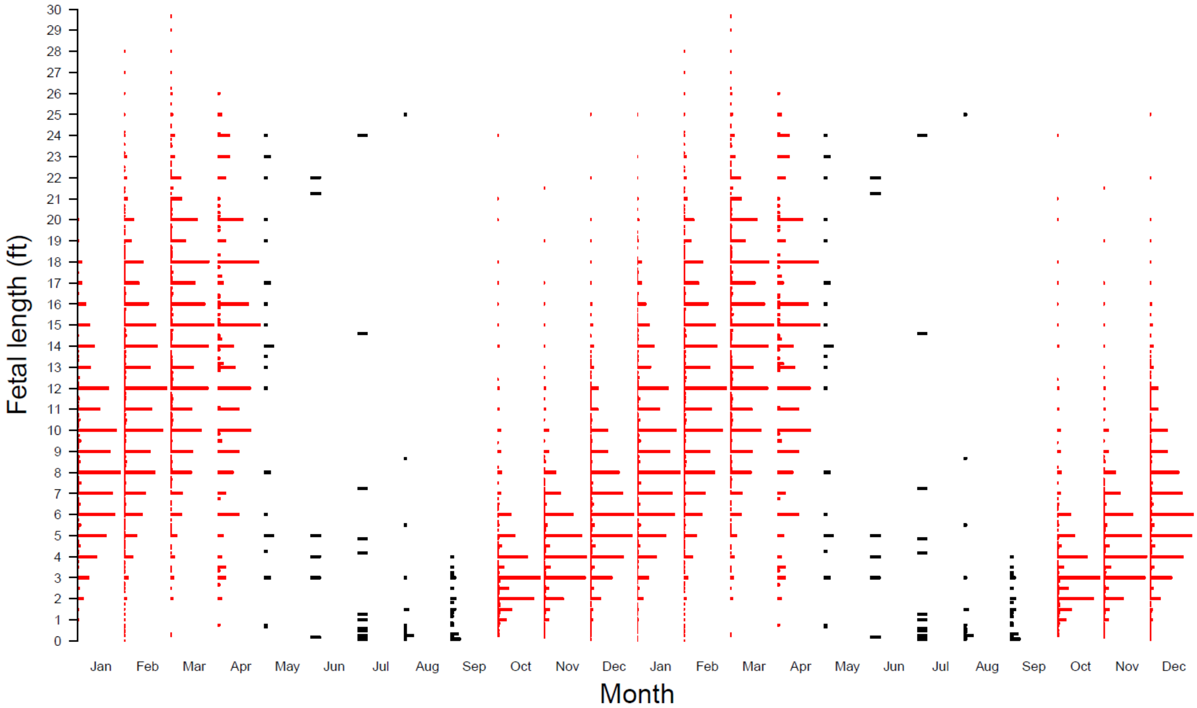

Figure 6 Histograms of foetal lengths for Antarctic blue whales by month, showing that most data were rounded to the nearest whole foot. For months with fewer than 30 data points, the heights of the bars are reduced by a factor of five and plotted in black. The data are repeated twice from left to right to more clearly see the pattern of foetal growth.

Future data analysis

More refinement is needed to the extracted data to ensure that species coded as 15 (pygmy blue whale) are excluded, and to exclude blue whales caught in this region with lengths shorter than 72 ft (21.9 m). This latter issue is to ensure that females are excluded that may be pygmy blue whales, and is chosen as a balance between length at which 50% of Antarctic blue whales are mature (77-78 ft, 23.4-23.8 m) (Mackintosh and Wheeler 1929, Branch and Mikhalev 2008) and the length at which 50% of pygmy blue whales are mature (19.2 m, 62 ft) (Branch and Mikhalev 2008). This also avoids the effects of "whale stretching" where blue whales less than the legal minimum length of 70 ft (21.3 m) were reported as being 70 ft long (Best 1989, Branch et al. 2007), and avoids length measurements rounded to the nearest 5 ft as occurred often in the earlier whaling years (Branch et al. 2007), often regarded as a signal that lengths were not in fact measured but were estimated or just written up.

Model development

The foetal length data arise from the complex interplay between conception data, growth model, variability in growth, detection bias from lack of detections of small foetuses, and a birth bias resulting in fewer foetuses at lengths around the birth length. Since at very short lengths, no foetuses can be detected, instead of modelling growth from conception (length = 0), growth is modelled from length = 1 cm, which from other vertebrates occurs at around 30 days after conception.

Conception date: two model parameters are used to model the mean conception date (date at 1 cm) and the SD around the conception date, and conception dates are assumed to be normally distributed. In addition, a small proportion (e.g. 1%) of conception dates will be uniformly assigned among all days of the year to ensure the model predictions are robust to both out-of-season conceptions and typographical errors.
Growth model: there are a variety of plausible models of growth in length by day, which are mostly variants on logistic, linear, power, and Gompertz. For the moment we have only implemented simple power models L = a(A–30)b to relate length L to age A of fetus in days from length = 1 cm and age = 30 days. This model has two parameters a and b. Currently, model inputs include gestation period (330 days) and birth length (700 cm), from which the parameters a and b are calculated.

Variability in growth: individuals grow at difference rates. For humans, there is a CV of 0.12 for foetal growth in weight (Maršál et al. 1996). Simulations assuming that weight is proportional to length cubed suggest that the corresponding CV for variability in length is 4%. Variation around length at a given age is currently assumed to be normal with a CV of 0.04 but will be changed to lognormal in later iterations of the model. This variability has considerably less impact on model uncertainty than the variability in conception date.

Detection bias: this is not implemented yet, but will be implemented as a logistic equation with two parameters that predicts the proportions of foetuses observed at particular lengths (e.g. 0 at 0 cm and 1 at 30-60 cm).
Birth bias: this bias from foetuses "disappearing" from the data when they are born, is not implemented yet, but will be implemented as a logistic equation with the mean birth length (currently assumed to be 700 cm) and a delta parameter that represents the difference between the median length at birth (700 cm) and the 5% and 95% probabilities of birth. For example, if delta is 30 cm, these would be 670 cm and 730 cm respectively. This could also be used to account for migration bias, which could occur if females about to give birth leave the whaling grounds earlier than females who are less advanced in their pregnancies. This has been shown to be true for humpback whales where births occur in coastal temperate regions, and may also be true of blue whales.
Simulations: simulated data have been generated from this model by looping through the 365 days of the year (ignoring leap years), and calculating the proportion of conceptions on each day, then projecting that number through for each day in the future using the growth curve with associated CV. This gives 365 predicted curves for each of the 365 days of the year, weighted by the proportion that are born on each day. Summing these predictions by day gives predicted proportions at length by day of the year. An example is shown in Figure 7.

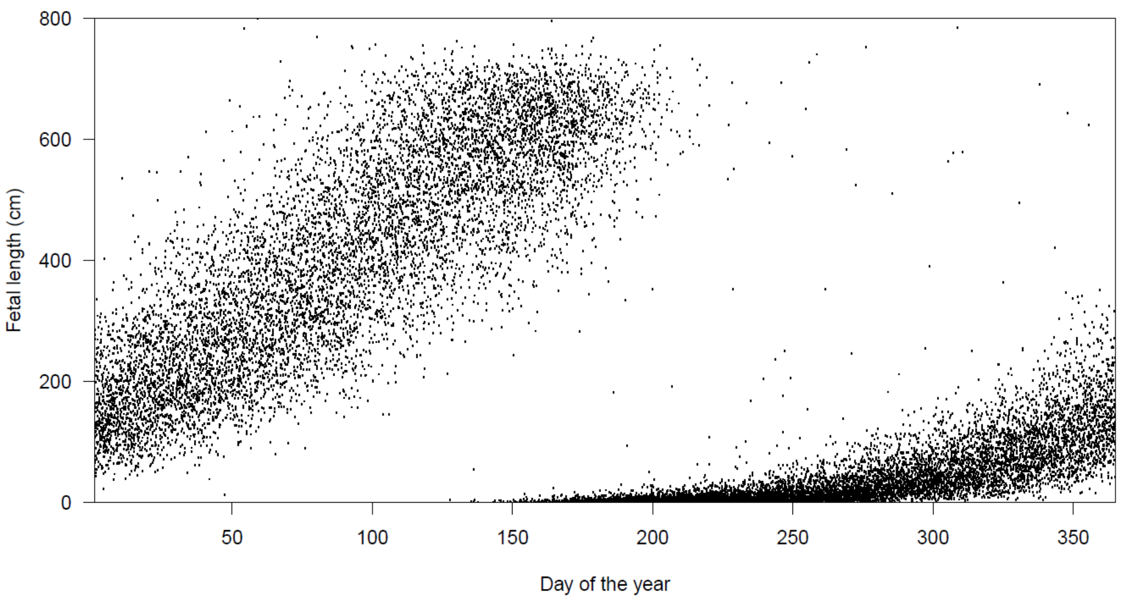

Figure 7 Simulated foetal length data assuming mean conception is on day 182 (1 July) with a SD of 30 days, birth at 700 cm, 30 days old at length 1 cm, and a CV on growth of 0.04.

Model fitting

The model predictions for each day of the year will be compared to observed lengths in each day of the year using multinomial likelihoods. (More complicated likelihood functions may also be examined.)

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IWC-SORP FUNDED RESEARCH PROJECT 14 (2018/19). Pregnancy rates in Southern Ocean humpback whales: implications for population recovery and health across multiple populations

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Introduction

Little is currently known about the post-exploitation reproductive dynamics and pregnancy rates of Southern Hemisphere baleen whales. Understanding reproductive rates will provide insight into the population health and recovery of these species. Our research group has developed and validated biochemical methods for studying pregnancy in free-ranging humpback whales. Preliminary application of this method has found an unexpectedly high frequency of pregnant females, including high rates of annual pregnancies, in humpback whales foraging around the Antarctic Peninsula. These high rates of pregnancy appear to be in contrast with calving rates in other oceans, as well as the estimated growth rates and apparent recovery status of sampled populations and we hope this proposal will help address this paradox. Furthermore, quantifying reproductive rates are crucial for setting a reference point that will allow us to effectively monitor the recovery of populations in an Antarctic environment that is changing rapidly regionally.

We aim to assemble samples to perform the largest and most extensive non-lethal analysis of pregnancy rates in Southern Hemisphere humpback whales using newly established and validated biochemical techniques. This project brings together international research groups who will contribute previously collected samples and facilitate new collection of biopsy samples from multiple populations (breeding sites: E-F; feeding areas: I, V, and VI) to be analysed for pregnancy. All laboratory analyses will be conducted by PhD student Logan Pallin under the advisement of Drs. Ari Friedlaender and Scott Baker. This project will produce a current reference point on the rates of pregnancy in humpback whales within the Southern Hemisphere, providing an opportunity to assess the impact of future climatic trends on these populations recovery.

Objectives

1. Collect biopsy samples throughout the breeding and feeding season to quantify progesterone, a lipophilic sex steroid hormone, in order to determine pregnancy in sampled female humpback whales across a number of breeding and feeding sites in the Southern Hemisphere.
2. Assess the inter-annual and seasonal variation in the rates of pregnant females across all sampled sites.
3. Assess the seasonal variation in progesterone concentrations relative to estimated peak conception and parturition.

Results

To date, we have ordered chemicals required for evaluating biopsy samples collected as part of this grant. Analysis will begin within the next month for samples collected from the WAP during the 2018/9 Antarctic season (n = 234).

IWC-SORP FUNDED RESEARCH PROJECT 15 (2018/19). Recovery status and ecology of Southern Hemisphere fin whales (*Balaenoptera physalus*)

Dr Helena Herr[1], Sacha Viquerat[2], Dr Simone Panigada[3], Professor Dr Bettina Meyer[4], Dr Anna Panasiuk[5], Dr Natalie Kelly[6], Dr Jennifer Jackson[7], Paula Olson[8], Professor Professor h.c. Dr Ursula Siebert[2]

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2. University of Veterinary Medicine Hannover (TiHo), Werfstrasse 6, 25761 Büsum, Germany
3. Tethys Research institute, Viale G.B. Gadio, 20121 Milan, Italy
4. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany
5. University of Gdansk, Institute of Oceanography, Al. J.M. Pilsudskiego 46, 81-378 Gdynia, Poland
6. Australian Marine Mammal Centre, Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7050, Australia
7. British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB30ET, UK
8. Southwest Fisheries/NMFS/NOAA, 8901 La Jolla Shores Drive, La Jolla, CA 92037, USA

Executive summary

This project focuses on the fin whales occurring off the West Antarctic Peninsula (WAP), combining analysis of existing data and collection of new information. Despite a lack of dedicated fin whale research in the Southern Ocean during past decades, data on fin whales have been collected opportunistically by various research groups. These data will be combined and analysed together to assess recent changes of fin whale abundance and distribution around the WAP. Additionally, targeted research will be conducted during two research cruises to the WAP and Scotia Sea region in 2019 and 2020. We will conduct dedicated vessel-based visual surveys for abundance estimation, investigate feeding ecology through concurrent krill surveys, collect genetic samples for the assessment of population structure, and analyse habitat use, movements and migratory pathways using satellite telemetry. The project has started on 1 March 2019, therefore work has just begun.

Introduction

Southern Hemisphere fin whales (SHFW) were the most heavily exploited whale species in the Southern Ocean during the commercial whaling period, reduced to ~2% of their pre-whaling population size. Catch numbers suggest that they once were one of the most abundant Southern Hemisphere whale species. High densities of fin whales and re-occurring feeding aggregations observed around the West Antarctic Peninsula suggest a return of fin whales to this area. In this project, we aim to estimate abundance of fin whales in the area and to relate densities to habitat parameters, particularly krill distribution. We will conduct a krill survey concurrently to a whale survey on the same temporal and spatial scale to compare distribution patterns. Furthermore, we will use satellite telemetry to track individual fin whales, in order to obtain first information on migratory routes and destinations. Biopsy samples will be used for population genetics to investigate population structure. Existing data on fin whale distribution, collected opportunistically during past decades will be compiled and used for analyses of recent changes in distribution and abundance.

Objectives

1. Compilation and analysis of existing data on fin whales from the WAP and Scotia Sea region for background information on spatio-temporal distribution, density and movements during past years.
2. Dedicated abundance estimation of fin whales in the WAP and Scotia Sea.
3. Investigation of predator-prey relationships between fin whales and different krill species in the WAP region to identify potential drivers of fin whale distribution and the return of SHFW to the WAP.
4. Collection and genetic analyses of biopsy samples to investigate population structure of the species across the Southern Hemisphere (in particular between the Pacific and Atlantic Oceans and between hemispheres).
5. Collection of photo-ID to provide the foundation for a SHFW photo-ID catalogue.

6. Analyses of short-term and long-term movement patterns to assess habitat use, to describe migratory patterns and to deduce migratory destinations.
7. Creation of a collaborative network of fin whale researchers for future projects and continued efforts to investigate the recovery status of SHFWs.

Results

This project commenced on 1 March 2019. Although work is in progress no results are ready to present. We have started compiling data from different sources and sending out requests for data contribution. The *RV Polarstern* voyage PS119 will take place from 13 April – 31 May 2019, collecting sighting data from the Scotia Sea by means of a helicopter survey.

Outlook for the future

We are confident that we will be able to fulfil all objectives as outlined and within the foreseen timeframe.

IWC-SORP FUNDED RESEARCH PROJECT 16 (2018/19). A circumpolar analysis of foraging behaviour of baleen whales in Antarctica: Using state-space models to quantify the influence of oceanographic regimes on behaviour and movement patterns

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4. Oregon State University, 2619 NE Flanders, Portand, OR, USA

Introduction

Two fundamental research priorities for IWC-SORP are i) determining the ecological interactions between Antarctic baleen whales and their prey and the impacts of climate change, and ii) understanding the connectivity between Southern Ocean humpback whale stocks. To achieve these goals, we must determine how whales behave with respect to the physical and biological environment and how these linkages change regionally as conditions vary. One of the best tools to study animal movement and behaviour at broad spatial and temporal scales is state-space movement modelling that predicts the probability of an animal to be in or transitioning between behavioural states. The behavioural state described as area-restricted-searching (ARS) is well-linked to foraging and offers an opportunity to quantify the spatial patterns and the temporal extent of where feeding occurs, and how these change seasonally as environmental conditions vary. Satellite telemetry provides the ideal data with which to develop these models and a large multi-national data set now exists to compare the foraging behaviour of humpback whales around the Antarctic continent, and contrast how regional differences in sea ice and other critical oceanographic parameters influence whale foraging behaviour and distribution.

Objectives

1. To foster collaboration among researchers from 10 countries engaged in Southern Ocean humpback whale research.
2. Combine independent satellite tag data sets to create the largest aggregate of tag data for a cetacean in the
3. Southern Ocean, leveraging a number of existing national and international research programs.
4. Develop behavioural state-switching models that have been previously tested/validated and apply these to whales foraging throughout the Southern Ocean.
5. Determine quantitative differences in the foraging behaviour of humpback whales distributed around the
6. Southern Ocean and link these to environmental covariates that affect whale behaviour, providing a novel analysis at this broad spatial scale.
7. Provide insights as to how humpback whales forage differently around the Antarctic and if these differences are related to ecological conditions, breeding stock or a combination of both.
8. Develop and maintain broad, new collaborative relationships with researchers from around the world through data sharing, mentoring, and writing of inclusive scientific manuscripts.
9. Mentor international graduate students and post-doctoral researchers to develop capacities for continuing ecological work in the Antarctic.
10. Contribute new information to IWC/SORP research objectives of understanding the ecological role of baleen whales in the Southern Ocean through a quantitative analysis of existing data.
11. Provide new information to assist the IWC to improve the assessment of the recovery of Southern
12. Hemisphere humpback whales.

Outlook for the future

The project on the circum-polar analysis of humpback whale habitat use is compiling the telemetry datasets covering the Southern Ocean waters south of the Pacific, Indian and Atlantic Oceans as well as the Antarctic Peninsula. The database will include recently collected data from South Georgia/ Las islas Georgias del Sur and is anticipating a successful programme of work tagging whales off Kenya in 2019.

IWC-SORP FUNDED RESEARCH PROJECT 17 (2018/19). A standardized analytical framework for robustly detecting trends in passive acoustic data: A long-term, circumpolar comparison of call-densities of Antarctic blue and fin whales

Dr Susannah Buchan[1], Dr Brian Miller[2], Dr Flore Samaran[3], Dr Danielle Harris[4], Professor Kate Stafford[5], Professor Ken Findlay[6], Dr Ana Širović[7]

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4. Centre for Research and Ecological Modelling, University of St Andrews, The Observatory, Buchanan Gardens, St Andrews, Fife, Scotland, UK
5. Applied Physics Lab, University of Washington Seattle, WA, United States of America
6. Centre of Sustainable Oceans Economy, Cape Peninsula University of Technology, Symphony Way, Bellville, Cape Town, 7535, South Africa
7. Department of Marine Biology, Building 3029, Room 248, Texas A&M University Galveston, P.O. Box 1675, Galveston, TX 77553, USA

Introduction

The accessibility and scale of the Southern Ocean means that long-term Passive Acoustic Monitoring (PAM) from fixed sensors is an ideal method for obtaining cost-effective broad spatial and long-term temporal coverage of endangered blue and fin whales in this region. The repeated, loud, low-frequency, and long-travelling calls from these endangered species provide an extremely efficient means of study in the remote Antarctic waters of the Southern Ocean. The IWC-SORP Antarctic blue and fin whale acoustic trends working group (ATWG) was one of the original IWC-SORP projects. The goal of ATWG is to use acoustics to examine trends in Southern Ocean blue and fin whale population growth, abundance, distribution, seasonal movements and behaviour. The AWTG presently has access to more than 300,000 hours of passive acoustic data that have been collected throughout the Southern Ocean over the past 20 years.

This project seeks to secure a postdoctoral researcher at the University of Concepción, Chile, in collaboration with the ATWG institutions to implement a standardized analytical framework for estimating calibrated call densities of Antarctic blue whales and fin whales, with a long-term view of using call densities to determine animal densities and examine population trends of Antarctic blue and fin whales in the Southern Ocean based on ATWG passive acoustic datasets. This proposal is centred on understanding the spatial and temporal distribution of Antarctic blue and fin whales in the Southern Ocean and involves the analysis of existing data sets, as well as making publicly available data and results, all of which are relevant to existing IWC-SORP themes. This project will result in: publications in peer-review journals, an IWC report with research results, presentations at scientific conferences, a calibrated call density protocol with sample code made publicly available, and research capacity building.

Objectives

1. Evaluate the performance of existing automatic detection algorithms for Antarctic blue and fin whale calls in a dataset from the ATW call library
2. Estimate detection range via acoustic propagation modelling
3. Estimate site-specific probability of detection using the passive sonar equation
4. Examine spatial and/or temporal changes in calibrated call densities over the dataset.

Progress to date

This project has just started and we are at the stage that the contract has been signed but not executed yet. Below are the outputs so far list with their corresponding dates of completion. We also propose a reviewed timeline to adjust to the outputs so far.

Outputs	*Date of completion*
Signed contract	March 2019
Contract execution underway	April 2019 onwards
Formulation of postdoc call	March 2019
Advertising for candidate	planned for May 2019

Outlook for the future

Adjusted timeline	*Projected Date of completion*
Application of automated detectors for one call type to one study site	September 2019
Removal of false positives from data	December 2019
Estimate survey area (acoustic propagation modelling) at study site	March 2020
Calculation of site-specific probability of detection	May 2020
Calibrated call density	May 2020
Comparisons of calibrated call densities	June 2020
Finalise protocols for calibrated call densities	August 2020
Submission of manuscripts and reports	August 2020

IWC-SORP FUNDED RESEARCH PROJECT 18 (2018/19). Inferring the demographic history of blue and fin whales in the Antarctic using mitogenomic sequences generated from historical baleen

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Introduction

Within the Southern Hemisphere, over two million baleen and sperm whales, including over 350,000 blue whales and 725,000 fin whales, were killed as part of modern commercial whaling operations in the 1900s. Assessing the contemporary status of these species in Antarctic waters requires evaluating changes in abundance over time as well as understanding how commercial exploitation has affected genetic diversity. During the 1946-47 and 1947-48 Japanese whaling seasons in the Antarctic, a large number of baleen plates were collected from blue and fin whales. Approximately 1600 bundles of plates from this series were sent to the United States, where they were recently rediscovered at the Smithsonian Institution.

Objectives

For this project, we plan to use next generation sequencing technology to sequence the complete mitogenomes (~16K base pairs) from a subset (n=48 from each species) of these plates. This data will be combined with existing mitogenome sequence data generated from Antarctic blue and fin whales biopsied during the IWC's IDCR/SOWER surveys between 1996 and 2009 in order to:
1) Make inferences about the minimum number of whales surviving exploitation;
2) Evaluate the loss of genetic diversity over time; and
3) Examine the demographic histories of both species in the Antarctic using techniques such as Bayesian skyline plots and Approximate Bayesian Computation.

Progress to date

Work on this project is scheduled to begin this summer. However, as part of a pilot project conducted last year, we extracted DNA from a subset of these baleen plates (n=11 blue whales, n=1 fin whale). Although mtDNA sequence data was obtained for all samples, sequencing depth and complexity varied markedly among the samples. To increase our success in future efforts, we are currently exploring different strategies for sampling the baleen. We also plan to obtain multiple DNA extractions for each sample and to perform two parallel indexing PCRs from each extraction in order to increase library concentration and complexity.

Outlook for the future

We anticipate presenting a draft manuscript(s) summarising the results at SC/68b (2020).

IWC-SORP FUNDED RESEARCH PROJECT 19 (2018/19). Assessing blubber thickness to inform satellite tag development and deployment on Southern Ocean whales

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Executive summary

Satellite tracking has greatly improved our understanding of cetacean ecology and is of significant importance because it is commonly used to address research questions relevant to the various management and conservation issues addressed by the International Whaling Commission (IWC). Satellite tracking is also an integral component of many core projects currently developed by the IWC-Southern Ocean Research Partnership (IWC-SORP). Long-term satellite tag attachment in large whales has generally been improved by the use of implantable tags with both anchoring systems and electronics embedded in the body. These tags often penetrate the blubber layer and anchoring below the blubber-muscle interface (fascia). Recent studies have shown that while these tags appear to have limited to no effect on survival and reproduction of individual animals, they can cause persistent trauma, resulting in discomfort and potentially pain. These observations suggest the need for further innovation to satellite tags to reduce the likelihood of impact to individual whales. Advances in tagging technology will likely include tags that minimize trauma by, for example, being embedded only in the blubber or, by complying with the extent of movement between blubber and muscle if penetrating the fascia. Developing of new technology and testing performance of existing implantable tags require an understanding of the variability of blubber thickness in large whales. The goal of this study is to review whaling and stranding records and evaluate the variation of blubber thickness in whales taking into consideration species, sex, age/length, season and potentially life history information. Statistical models will be developed to predict blubber thickness for five species of large whales commonly tracked with these tag types and results will be used to propose species-specific parameters that will guide development and future deployment of implantable satellite tags.

Introduction

This project intends to review whaling and stranding records and evaluate the variation of blubber thickness in whales, taking into consideration multiple covariates, with the ultimate goal of informing future development of body penetrating satellite tags. Satellite tagging has become an important research technique to understand movements, migration and habitat use of cetaceans and, as such, provides valuable information to enhance conservation and management for these animals.

Objectives

1. Assess variation in blubber thickness of large whales taking into consideration species, sex, age/length, and season.

2. Develop species-specific parameters for blubber thickness and depth of penetration to guide development and deployment of implantable satellite tags.

Results

This project was begun recently with collation of a database including information on blubber thickness of 38,215 large cetaceans (Figure 8).

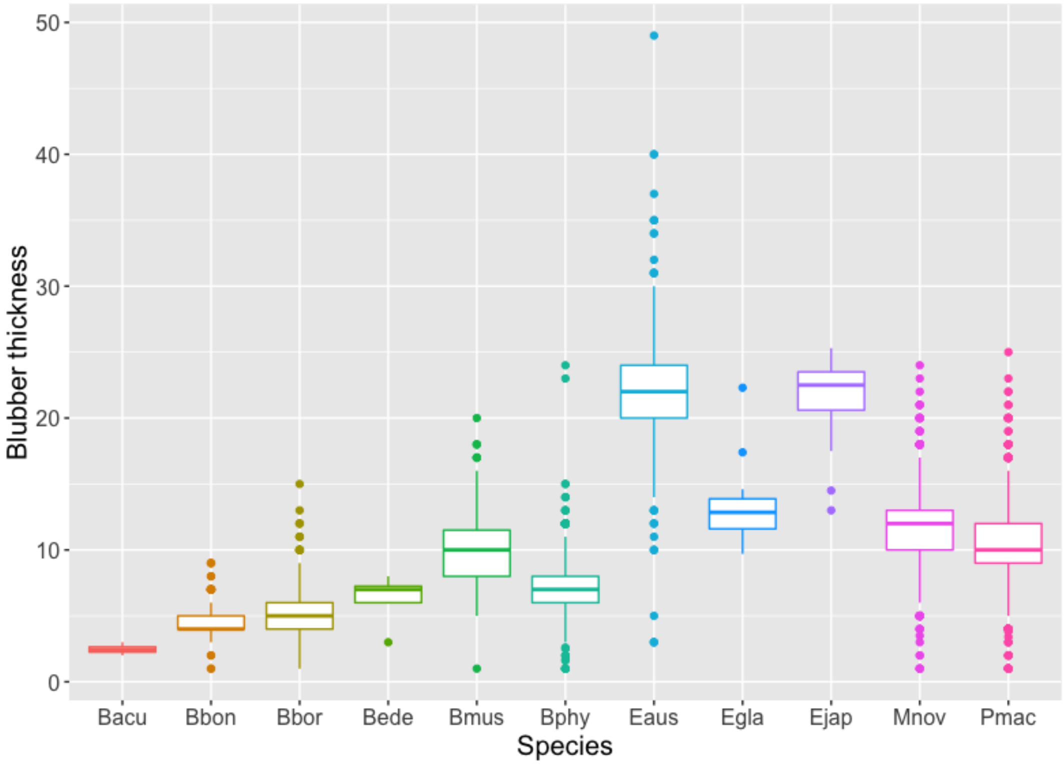

Figure 8 Boxplot of blubber thickness (in cm) by large whale species (Bacu = *Balaenoptera acutorostrata*, Bbon = *B. bonaerensis*, Bbor = *B. borealis*, Bede = *B. edeni*, Bmus = *B. musculus*, Bphy = *B. physalus*, Eaus = *Eubalaena australis*, Egla = *E. glacialis*, Ejap = *E. japonica*, Mnov = *Megaptera novaeangliae* and Pmac = *Physeter macrocephalus*).

Next steps, which are expected to be conducted within the next months, include a more detailed description of the data (e.g., ranges of blubber thickness across species, age/sex/length class) and a statistical evaluation of factors that potentially influence the width of the blubber layers in the species of interest.

Conclusions

Because this project is at its early stages, no conclusion has been reached to date.

Outlook for the future

We expect to continue with the review of data on blubber thickness within the next month (May 2019) and initiate more quantitative analysis as of June 2019. A report with results from data analysis in the context of informing future tag development will be provided to the IWC Scientific Committee at SC/68b (2020).

IWC-SORP FUNDED RESEARCH PROJECT 20 (2018/19). Acoustic ecology of foraging Antarctic blue whales in the vicinity of Antarctic krill studied during AAD interdisciplinary voyage aboard the RV Investigator

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Introduction

In austral summer of 2019, a 48 day, multi-country, interdisciplinary research voyage led by a team from Australian Antarctic Division and the University of Tasmania will head to the Antarctic with an overall goal of mapping Antarctic krill (*Euphausia superba*) and blue whale (*Balaenoptera musculus*) distributions to determine if the foraging preferences of blue whales are dictated in part by the density and shape of Antarctic krill swarms. This research voyage will combine cutting edge research techniques including AUVs, short term-tags, photogrammetry, and ship-based, real-time passive and active acoustics to answer questions about how the density, swarm shape and behaviour of Antarctic krill influence that of Antarctic blue whales.
The Acoustic Ecology of Foraging Blue Whales component will detect, track and localize blue whales to direct the ship towards aggregations of these animals so that fine scale acoustic tracking, focal follows and prey fields can be mapped. This project adds to that voyage deployment of a fixed acoustic mooring that will combine passive and active acoustics, allowing another dimension for the collection of concurrent predator and prey data. We propose to couple novel passive and active acoustic techniques in a moored setup with a broad interdisciplinary effort that is already planned to investigate cetacean-prey dynamics. By coupling moored data collection with the ship-based survey focusing on Antarctic blue whale behaviour and krill dynamics, we will be able to interpret and quantify the presence of blue whales and their prey. Findings of the research will also be communicated to both the scientific community and the wider public through peer-reviewed publications, presentations, student lectures, seminars and communication through appropriate media channels by institutional communications teams.

Objectives

By coupling moored data collection with the ship-based survey focusing on Antarctic blue whale behaviour and krill dynamics, we will be able to interpret and quantify the presence of blue whales and their prey from the moored data. Specifically, the key steps will include understanding the relationships between production of different call types, krill abundance, and number of blue whales in an area. This interpretation step will be critical to allow future use of cost-effective moored data for the development of models to quantitatively describe cetacean-prey relationships over varied time scales. Specifically, we will test the following hypotheses:

1. Production of D-calls is directly related to the number of whales in the area and krill swarm density.
2. Blue whale vocal behaviour will vary with time of day in relation to krill diel vertical migration, with more Z-calls produced at night when foraging is less efficient (krill swarm density is lower at night when krill are shallower.
3. Foraging blue whales produce D-calls or single Z-calls and traveling animals produce series of Z-calls (song).
4. Time permitting, we will also test whether moored active and passive acoustic systems are a suitable method for determining cetacean and prey dynamics over week-long time scales.

Progress to date

In 2018, Širović and Stafford were awarded a grant of £30,107 from the IWC-SORP Research Fund to join the IWC-SORP ENRICH voyage, led by the Australian Antarctic Division, 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 work conducted and preliminary results of the ENRICH voyage will be presented at SC/68b (2020).

IWC-SORP FUNDED RESEARCH PROJECT 21 (2018/19). Development of statistical and technical methods to support the use of long-range UAVs to assess and monitor cetacean populations in the Southern Ocean

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Introduction

This project aims to explore and develop methods to support the use of aerial imagery (particularly long-range UAVs) to study cetaceans in the Southern Ocean. Traditional survey methods, such as vessel or aerial line transect surveys, are expensive to run in vast and remote areas, such as the Southern Ocean; new approaches are needed to provide future data streams for conservation and management of whales. Recent studies have demonstrated the potential for the combination of digital imagery and Unmanned Aerial Vehicles (UAVs) to replace human observers on aerial surveys for marine mammals, The imagery/UAV research proposed will form the foundation for cheaper, more efficient and safer direct survey methods to monitor long-term population recovery trends for a range of cetacean species in the Southern Ocean. It will involve synthesis of existing work to produce a toolbox of statistical methods for the use of aerial digital imagery - particularly that derived from long-range UAVs (endurance of many hours) - to generate unbiased and precise estimates abundance and distribution of whales. Then, machine learning methods, such as deep neural networks, will aid in detections of animals in the large volumes of digital images. Deep neural networks have reached human level performance on object classification tasks because the neural networks were trained on millions of labelled images. Although an equivalently sized labelled dataset for marine mammals does not yet exist, we have already demonstrated that useful detectors and classifiers can be built from a dataset of a few hundred images by using ad hoc techniques. This project will leverage and extend this previous work and generate a plan for future field work and testing of long-range UAVs to study marine species in the Southern Ocean.

Objectives

1. To develop techniques/methods to deal with post-processing of digital imagery (will also involve the collation of a global library of aerial images of whales for training automatic detection algorithm). In particular, the aim is to detect and classify various species of cetaceans in aerial digital images.
2. Continue developing analytical methods/statistics for using digital imagery for deriving abundance and distribution data for cetaceans
3. To develop a plan for future field work and testing of long-range UAVs to study marine species around
4. Antarctica and the Southern Ocean

Progress to date

The research collaborative agreement between the Australian Antarctic Division and the Queensland University of Technology is nearing finalisation; money from the IWC-SORP fund will be accessed shortly thereafter. Dr Maire has found a research assistant to work with him on developing and training neural networks to detect cetaceans in aerial images. Dr Kelly is currently liaising with labs around the world to access large volumes of aerial images of cetaceans, in addition to developing a report on statistical methods to use aerial images to derive distribution and abundance data for cetacean populations. Reports of this work will be submitted to the 2020 meeting of the Scientific Committee of the International Whaling Commission.

IWC-SORP FUNDED RESEARCH PROJECT 22 (2018/19). An integrative assessment of the ecology and connectivity of killer whale populations in the southern Atlantic and Indian Oceans

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Executive summary

An eco-evolutionary approach is now widely used towards understanding the mechanisms underlying the evolution of diversity within and among populations, providing greatly improved insight. We have started integrating data on habitat use, feeding ecology, population connectivity, historical population dynamics and regional patterns of diversity in killer whales (*Orcinus orca*) using state-of-the-art methodologies. This has begun improving insights into the processes involved in the evolution of behavioural strategies, migratory patterns and reproductive isolation and connectivity. We focus on three locations in the southern Atlantic and Indian Oceans, significant because this represents a region of potential transition between temperate and polar waters, and includes the South African region, proposed to reflect much greater genetic diversity for killer whales than seen anywhere else so far investigated around the world. This work also builds on long-term studies in the Prince Edwards and Crozet Islands, providing new data to help address key questions about essential prey and habitat resources, and the evolutionary implications of movement patterns and insularity. Worldwide, killer whales show marked ecological specialisations with respect to diet and movement, often based around specialisation on either fish or marine mammal prey. However, this distinction is less clear in the study sites, where there is evidence for individual whales pursuing both types of prey. Potential 'ecotypes' are also poorly defined in this region, but further data on feeding ecology and genetics will likely resolve these questions, as it has elsewhere. Our primary objective is to provide integrative data on ecology (though stable isotope, photo-identification and telemetry data) and population history and connectivity (through genetic analyses) at these three study sites, and we have started doing so in the first months of the project. We address key questions about conservation and management directly relevant to IWC-SORP killer whale thematic priorities through a better understanding of range extent and overlap, population structure and environmental dependencies. While the project is only a few months old, some fieldwork has been conducted and preliminary analyses are already yielding genetic and isotopic insights into the comparative ecology of killer whale populations in the southern Atlantic and Indian Oceans.

Introduction

Killer whales (*Orcinus orca*) are alpha predators which can exert significant top-down influences on marine ecosystems (e.g., Estes et al. 1998, Reisinger et al. 2011b, de Bruyn et al. 2013). However, their influence on ecosystems is modulated by their movement patterns, diet and abundance, since these determine the structure and dynamics of their trophic linkages with other species. Given killer whales' high mobility (e.g., Reisinger et al. 2015) and dietary flexibility (e.g., Guinet 1992, Reisinger et al. 2016, reviewed in de Bruyn et al. 2013), these factors become even more important in determining what impacts killer whales may have.

There is an additional layer of complexity in that the population structure of killer whales is driven in part by their foraging specializations in different environments, in conjunction with their social structure (Hoelzel et al. 2007, Moura et al. 2014a, 2014b, 2015). For example, in the eastern North Pacific three sympatric but genetically distinct killer whale populations ('ecotypes') occur, which have different diets, behaviour and social structure (Hoelzel & Dover 1991, Hoelzel et al. 1998, reviewed by de Bruyn et al. 2013). In the Antarctic, at least four ecotypes have been identified based on morphology, diet and behaviour (Pitman et al. 2007, Pitman & Durban 2010, 2012) and these are also genetically distinguishable (Morin et al. 2010, Foote et al. 2011a). A fifth type, which seems morphologically and genetically distinct, has recently been described mainly from at-sea observations in the Subantarctic (Pitman & Ensor 2003, Pitman et al. 2011, Foote et al. 2013). Along the South African coast, Best et al. (2014) recently described a second regional killer whale morphotype, which appears to be a dietary specialist. A global analysis of killer whale mitochondrial DNA revealed exceptionally high genetic diversity among samples from South Africa, in contrast to low diversity observed in other populations (Moura et al. 2014b). This led to the hypothesis that South Africa hosted a relatively abundant refugial population of killer whales during the Last Glacial Maximum (Moura et al. 2014b). This phylogeographic mosaic has prompted different evolutionary explanations, debate about the relative roles of various evolutionary drivers, and questions about the global patterns and consequences of ecological specialization among killer whales (Foote et al. 2011b, de Bruyn et al. 2013, Moura et al. 2014a, 2014b, 2015, Foote & Morin 2016, Hoelzel & Moura 2015, 2016).

The vast Southern Ocean is dotted with a few small islands. Two such island groups are South Africa's Prince Edward Islands and France's Crozet Islands, situated ~1,000 km apart (at a similar latitude) in the Indian Ocean sector of the Southern Ocean. These two archipelagos are similar in hosting massive populations of land-breeding seals and seabirds which attract killer whales to their inshore waters (Guinet 1991, Reisinger et al. 2011c). These two killer whale populations have a similar diet including elephant seals, fur seals and penguins, and – at the Crozets – fishes and large cetaceans (Guinet 1991, Reisinger et al. 2011c). Depredation of Patagonian toothfish (*Dissostichus eleginoides*) from longline fishing vessels occurs around both archipelagos (Williams et al. 2009, Guinet et al. 2015 and references therein). The killer whale populations frequenting the inshore zone of the islands are quite small, numbering ~37 (95% CI 32-62) in 1998-2000 at the Crozets (Poncelet et al. 2010) and ~37 (95% CI 29-44) in 2006-2007 at the Prince Edwards (Reisinger et al. 2011a). The populations exhibit the same seasonal occurrence pattern, with peak inshore abundance in summer and a secondary peak in autumn (Reisinger et al. 2011c).

Despite the proximity of the two archipelagos (which is well within the movement range of killer whales – Durban & Pitman 2012, Reisinger et al. 2015), photographic mark-recapture data reveal that only a few (~8) individual killer whales have been recorded at both archipelagos (Reisinger & de Bruyn 2014; Tixier et al. 2014a). Further, satellite tracking of killer whales from the Prince Edward Islands shows movements only in the region of that archipelago, or rapid northward movements towards and beyond the Subtropical Front (Reisinger et al. 2015).

There is a significant gap in our understanding of the structure, movement and distribution of killer whale populations in the Subantarctic and how their movements, dietary specialization and phylogenetics interact as drivers or consequences of the observed population structure. Of particular interest is any ecotype divergence or convergence in response to environmental conditions, which could address the proximate mechanisms responsible for ecotype dynamics in this species.

The Prince Edward Islands, Crozet Islands and South African coastal waters provide a regional system with environmental similarities and contrasts that will allow us to test hypotheses about the mechanisms that determine population structure in the context of environment and ecology. This is facilitated by long-term photographic identification studies (Guinet et al. 2015, Reisinger et al. 2017), which provide socio-demographic context (e.g., Reisinger et al. 2015, 2016, 2017, Tixier et al. 2015, 2017) together with existing telemetry (Reisinger et al. 2015) and genetic data (Moura et al. 2014; A.R. Hoelzel, unpubl. data).

Objectives

1. Our primary objective is to provide sufficient integrative data on ecology (through stable isotope, photo-identification and telemetry data), population history and connectivity (through genetic analyses) to test alternative hypotheses about the evolutionary mechanisms that determine population structure and dynamics in this region. The relatively high diversity found off South Africa in contrast to lower levels at the Prince Edward Islands and the Crozet Islands permits a key hypothesis to be tested about the relative importance of long-term demographic stability and population mixing.
2. IA further objective is to consider the transferable inference from these data in the context of extensive data on the ecology and population genetics of killer whales elsewhere in the world. While regional systems differ (e.g. strong natal fidelity in the piscivorous ecotype in the North Pacific, not seen to the same extent elsewhere), we don't yet understand if the key drivers are associated with resource use or ancestry or some other combination of factors.
3. IWe will provide data with direct relevance to the conservation and management of regional killer whale populations through the provision of data on their distribution, population connectivity and evolutionary diversity (including diversity at functional loci).

Results

Genetics analyses
Analyses of existing samples is underway; analyses of new samples will begin once the samples have been collected in the field (until 03/2021).

Stable isotope analyses
Stable isotope analyses of new samples will begin once the samples have been collected in the field (until 03/2021).

Satellite tracking
Tags have been purchased. Some of these are already on Marion Island for the first field season (04/2019 – 03/2020). Approximately 5 tags will be deployed at Marion Island and ~5 tags along the South African coast (until 03/2021). Approximately 10 tags (ANR [France] in-kind support) will be deployed around the Crozet Islands (until 03/2021).

Boat surveys off South Africa
A first campaign of boat surveys (1 week over 25 March – 3 April) was conducted in the Western Cape, South Africa. We were not able to get biopsy samples from or deploy satellite tags on killer whales. However, the surveys precipitated a sighting network and local collaboration network (coordinated by SeaSearch Africa) that we will rely on for sampling and tagging opportunities (Figure 9). This local network includes some in-kind survey and tracking support from various organizations. Dr Hoelzel was able to travel to South Africa for the surveys using the project funding. He will make a second trip in 2020.

Figure 9 Call for the public to report sightings of killer whales along the southern African coast, distributed on various social media networks.

Comparative stable isotope analyses of Crozet Islands and Prince Edward Islands killer whales (lead author: Paul Tixier)

Here, we used stable isotopes and diet reconstruction analyses to investigate the role of Patagonian toothfish *Dissostichus eleginoides* in the diet of killer whales at the Crozet Islands, where they depredates this fish from fisheries. The isotopic niche of the Crozet killer whales was large. It overlapped with that of sperm whales sampled at Crozet and Kerguelen, but not with that of killer whales from adjacent Marion Island (Figure 10). Mean isotopic values of Crozet killer whales were δ13C = -19.0 ± 0.5 SD ‰ and δ15N = 13.6 ± 0.4 SD ‰ (n = 18 sampled individuals). There was no difference between killer whales that depredated toothfish from fisheries before sampling and those that did not. MixSIAR mixing models indicated that prey groups including large/medium sized toothfish and seal pups represented ~ 60% of the diet relative to prey groups including penguins, baleen whales and coastal fish. Together, these results indicate that toothfish is an important natural prey item of killer whales at the Crozet Islands. More broadly, this study suggests that for killer whales prey switching to depredation primarily occurs when fisheries facilitate access to a resource that is already part of the diet of individuals.

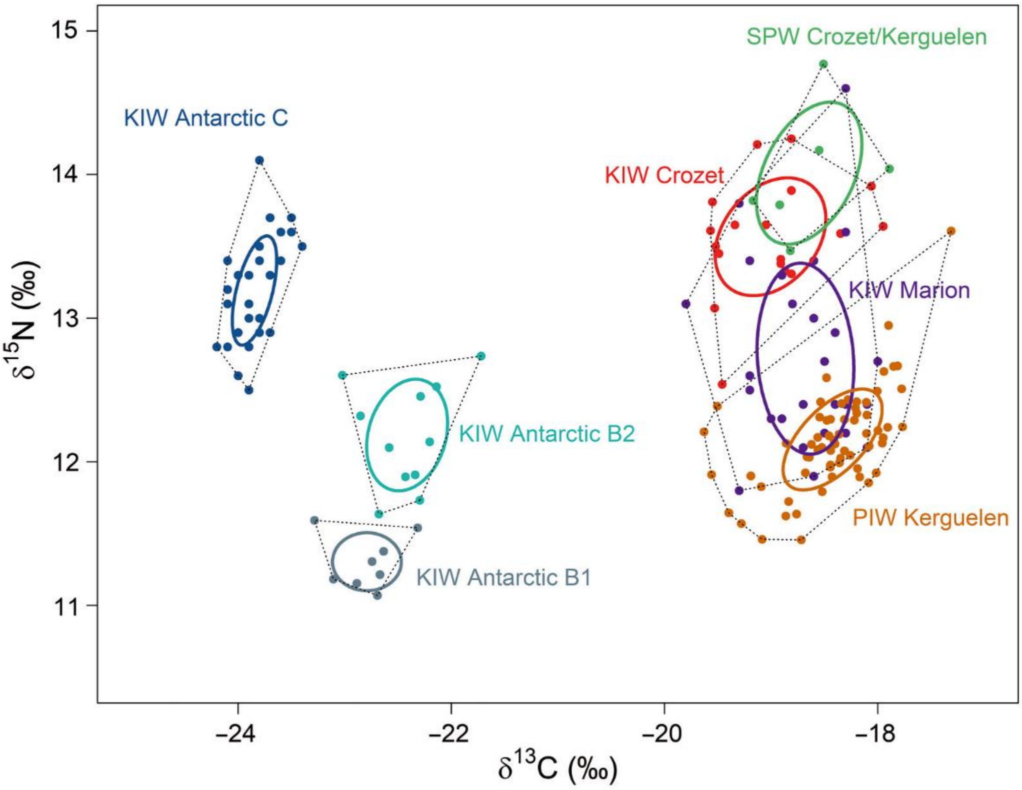

Figure 10 Sample-size corrected standard ellipse areas (SEAc; solid lines) and convex hull areas (dotted lines) for killer whales (KIW), sperm whales (SPW) and southern pilot whales (PIW) in Antarctic and subantarctic waters. Individual values of δ13C and δ15N of skin samples (points) for Crozet, Marion (Reisinger et al. 2016), Antarctic Type C (Krahn et al. 2008), Antarctic Type B1 and B2 (Durban et al. 2017) killer whales, sperm whales from Crozet/Kerguelen and southern pilot whales from Kerguelen (Fontaine et al. 2015) are shown. From Tixier et al. (2019).

The Crozet and Marion Island killer whale populations had similar trophic niche width but showed limited isotopic overlap. Marion Island lies ~ 1000 km west of Crozet at a similar latitude and supports the same prey species. The Marion killer whales have also been observed feeding on elephant seals, fur seals and penguins in inshore waters (Reisinger et al., 2011). While the two populations had similar δ13C values, indicating that they derived dietary carbon from similar latitudes/environments, δ15N values of Crozet killer whales were higher by 1 ‰ than those of Marion killer whales. Some of the Marion killer whales (9 individuals out of 58, (Reisinger and de Bruyn, 2014; Tixier et al., 2014) that had been sighted occasionally interacting with fishing vessels around Crozet had significantly higher δ15N (13.2 ± 0.3 ‰) than those that had never been sighted at Crozet (12.1 ± 0.5 ‰) (Reisinger et al., 2016). We therefore ascribe the isotopic niche differences between the two populations to a higher proportion of toothfish in the diet of the Crozet population. Toothfish stocks around Marion Island may be lower than at Crozet as they were decimated by the early 2000s, largely due to intense illegal fishing (Boonzaier et al., 2012). In addition, the fishing effort and the catch by licenced vessels is lower at Marion (2 licenced vessels catching 200-300 tonnes per year since 2010, CCAMLR 2017a) than at Crozet (7 licenced vessels catching 600-1100 tonnes per year since 2010, CCAMLR 2017b). Such differences in the proportion of toothfish in the diet of the two populations might therefore be due to: i) lower levels of artificial provisioning through longlining around Marion Island compared with Crozet; and/or ii) lower abundance of toothfish around Marion Island due to lower natural stock abundance and/or to the historical stock collapse; and/or iii) reduced opportunities to depredate because of lower fishing effort and catches at Marion.

Preliminary genetic analyses (lead author A. Rus Hoelzel).
Preliminary genetics analyses (A.R. Hoelzel, unpubl. data) suggest two lineages among killer whales from the Crozet Islands. One of these lineages falls within the Prince Edward Islands lineage, which itself is related to Antarctic Types B and C. The other Crozet lineage falls in a lineage including individuals from South Africa and the South Atlantic Ocean. These data suggest historical or low-level contemporary genetic flow among South African, Subantarctic and Antarctic killer whale populations, and satellite tracking and photographic mark-recapture studies support this idea to some degree.

Conclusions

While the project is only a few months old, some fieldwork has been conducted and preliminary analyses are already yielding genetic and isotopic insights into the comparative ecology of killer whale populations in the southern Atlantic and Indian Oceans.

Challenges

Our first boat surveys in South Africa have highlighted the challenges of sampling and tagging killer whales along the South African coast. However, we have established a local network that will enable us to accomplish our planned work.

Outlook for the future

We are still on track for outputs according to the following schedule:

Expected outputs	*Date of completion*
Deployment of satellite tags	March 2021
Biopsy sampling	March 2021
Stable isotope analysis	June 2021
Genetics analysis	March 2021
Data analysis	August 2021
Data analysis (stable isotopes)	August 2021
Data analysis (genetics)	March 2021
Paper write-up	November 2021

Project outputs

Peer-reviewed papers (published, submitted)
Busson M, Authier M, Barbraud C, Tixier P, Reisinger RR, Janc A, Guinet C (*Accepted*) The role of sociality in the response of killer whales to an additive mortality event. Proceedings of the National Academy of Sciences of the USA.

Tixier P, Giménez J, Reisinger RR, Méndez-Fernandez P, Arnould J, Cherel Y, Guinet C (2019) Assessing the importance of toothfish in the diet of generalist subantarctic killer whales: implications for fisheries interactions. Marine Ecology Progress Series 613:197-210. https://doi.org/10.3354/meps12894

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IWC-SORP FUNDED RESEARCH PROJECT 23 (2018/19). Implementation of humpback whales for Antarctic sea-ice ecosystem monitoring; Inter-program methodology transfer for effective circumpolar surveillance

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Introduction

The Southern Ocean Observing System (SOOS), recently endorsed implementation of southern hemisphere humpback whales as a sentinel species for long-term, circum-polar surveillance of the Antarctic sea-ice ecosystem. This initiative was the outcome of 10 years of monitoring of the E1 breeding stock conducted under CI Bengtson Nash's Southern Ocean Persistent Organic Pollutants Program (SOPOPP), combined with in-house development of non-lethal, chemical/biochemical markers for the measurement of humpback whale adiposity and diet. Inclusion of further breeding stocks into monitoring translates to greater visibility of the circum-polar region in response to intense climatic variability. Annual population assessment is conducted at the height of winter migration, in the respective population's breeding ground, to ensure collaboration with PI Christiansen, who is responsible for parallel developments in baleen whale energy reserve assessments with Unmanned Aerial Vehicles (UAVs). As yet, breeding stock G, which represents the commercially important Western Antarctic Peninsula (WAP) region, is not included in the program. The long-term efforts of PI Friedlaender and PI Johnston working with this breeding stock in the WAP, however, have utilised UAV measurements of body condition for the investigation of humpback whale feeding ecology. PI Friedlaender's ongoing core IWC-SORP project holds significant potential to inform efforts regarding the proximate ecosystem drivers of inter-annual change in humpback whale diet and adiposity. This project therefore seeks to integrate the findings and ongoing efforts of the respective monitoring programs, targeting humpback whale foraging ecology in relation to the dynamics of their principal prey item, Antarctic krill. We propose facilitating program integration via, a) Fundamental method comparison and validation, and b) Same-year feeding vs breeding ground population comparisons (diet and energetic reserves). The anticipated outcome of this effort is translation of methods as well as the establishment of a logistical framework (breeding stock representative), along the Colombian Pacific Coast for ongoing collaborative population assessment.

Objectives

1. Collect parallel adiposity measures (Adipocyte Index (AI); UAV morphometry measures, Persistent Organic Pollutant POPs Concentration Indices (CI)) on population G individuals; targeting the population in the breeding ground, and also at two time-points (early and late) in the feeding ground.
2. Interpret dietary markers (Lipid profiles; Bulk Stable C and N Isotopes, and POP biomagnification factors) in whales in their winter breeding grounds vs early- (return to Antarctica) and late-summer (post-summer feeding).
3. Determine the average energetic cost of migration through adiposity measures between feeding and breeding ground. These will serve both as a reference point for future monitoring program comparisons for the G population, as well as empirical measures for future energetic modelling.

Results

- A contract has been signed by the chief investigator (Bengtson Nash).
- The first of three project field campaigns has been completed by Ari Friedlaender's team along the Antarctic Peninsula.
- The Colombian field team has been assembled and logistical planning is underway (transportation of equipment, researcher flights etc.).

IWC-SORP FUNDED RESEARCH PROJECT 24 (2018/19). Circumpolar foraging ecology of southern right whales: past and present

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Introduction

The Southern Right Whale Theme was established in 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. This IWC-SORP funded project represents the first within the new Theme.

Objectives

1. Compilation and validation of southern right whale isotope dataset
   a. Compile existing stable isotope data (δ13C and δ15N), and associated metadata on individual SRW (e.g., sex and demographic class).
   b. Compile data on methodology used to generate these stable isotope data, including lipid extraction procedures, international and internal standards and corrections used.
2. Undertake a validation study whereby a subset of samples are analysed in each of the two main laboratories that generated the stable isotope data (Durham and Utah).

3. Isoscape modelling
   a. Identify location of foraging grounds by comparison of stable isotope data from skin samples with Southern Ocean isoscapes. Both isoscapes developed from empirical data (particulate organic matter collected by many oceanographic voyages) and modelled outputs will be used to compare to the compiled SRW stable isotope dataset.
4. Habitat modelling: present and past distribution
   a. Create habitat models for those summer foraging grounds associate with populations strongly recovering and those that are poorly recovered
   b. Compare the geographic location of foraging grounds identified through habitat modelling to published historical whaling data and the putative historical and contemporary foraging grounds to understand changes in SRW foraging ecology over the last 200 years.
5. Pilot study to investigate heterogeneity and historical stable isotope data
   a. Use sex and demographic class metadata associated with the stable isotope profiles, and augmented by new data supplementing under-represented classes (e.g., males), to explore whether there is heterogeneity in prey or foraging ground location choice across age classes.
   b. Conduct a pilot study to generate stable isotope profiles for historical (pre-whaling or whaling era) bone collagen samples. This will allow us to begin to understand what proportion of whales were foraging in regions not captured by whaling voyage data.

Progress to date

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.

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.

Outlook for the future

Work will continue in 2019 and 2020 to meet the stated objectives of the project. An abstract on the IWC-SORP project has been submitted to the World Marine Mammal Conference.

IWC-SORP FUNDED RESEARCH PROJECT 25 (2018/19). Habitat use, seasonality and population structure of baleen and toothed whales in the Scotia Sea and the western Antarctic Peninsula using visual and passive acoustic methods and genetics

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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 22nd 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 11).

Visual surveys were conducted over a total of 48.5 h and 850 nm (Figure 12). 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 11 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.

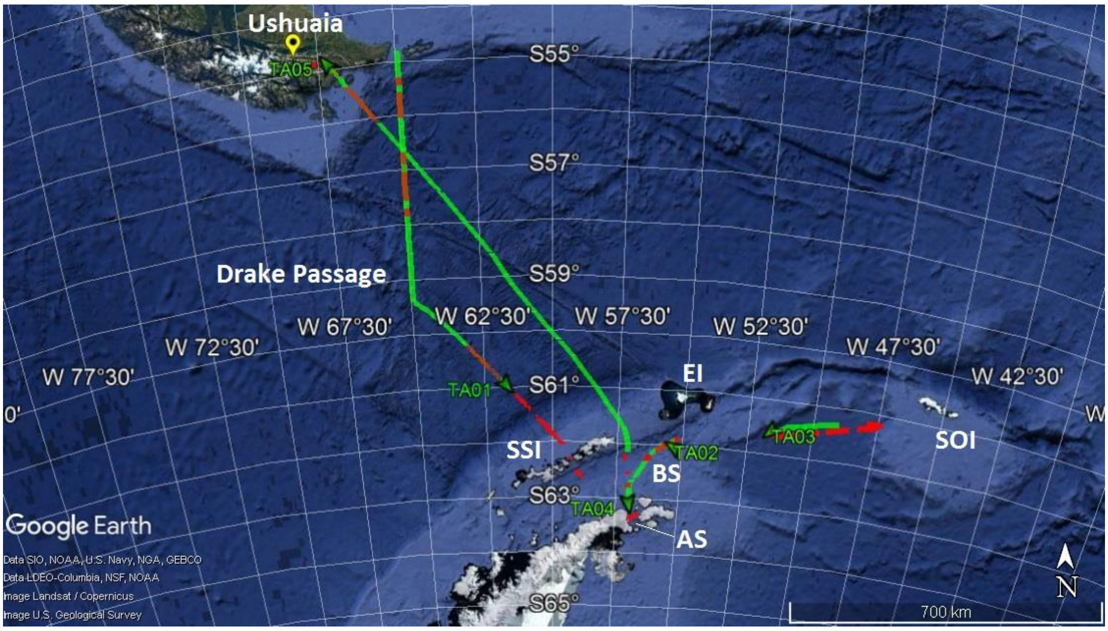

Figure 12 On-effort visual (red lines) and acoustic (green lines) tracks using a towed hydrophone array (TA: Towed Array). SSI: Islas Shetland del Sur/ South Shetland Islands/; EI: Isla Elefante/ Elephant Island; BS: Mar de la Flota/ Bransfield Strait; SOI: Islas Orcadas del Sur/South Orkney Islands; AS: Estrecho Antarctic/Antarctic Sound.

Table 10 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*

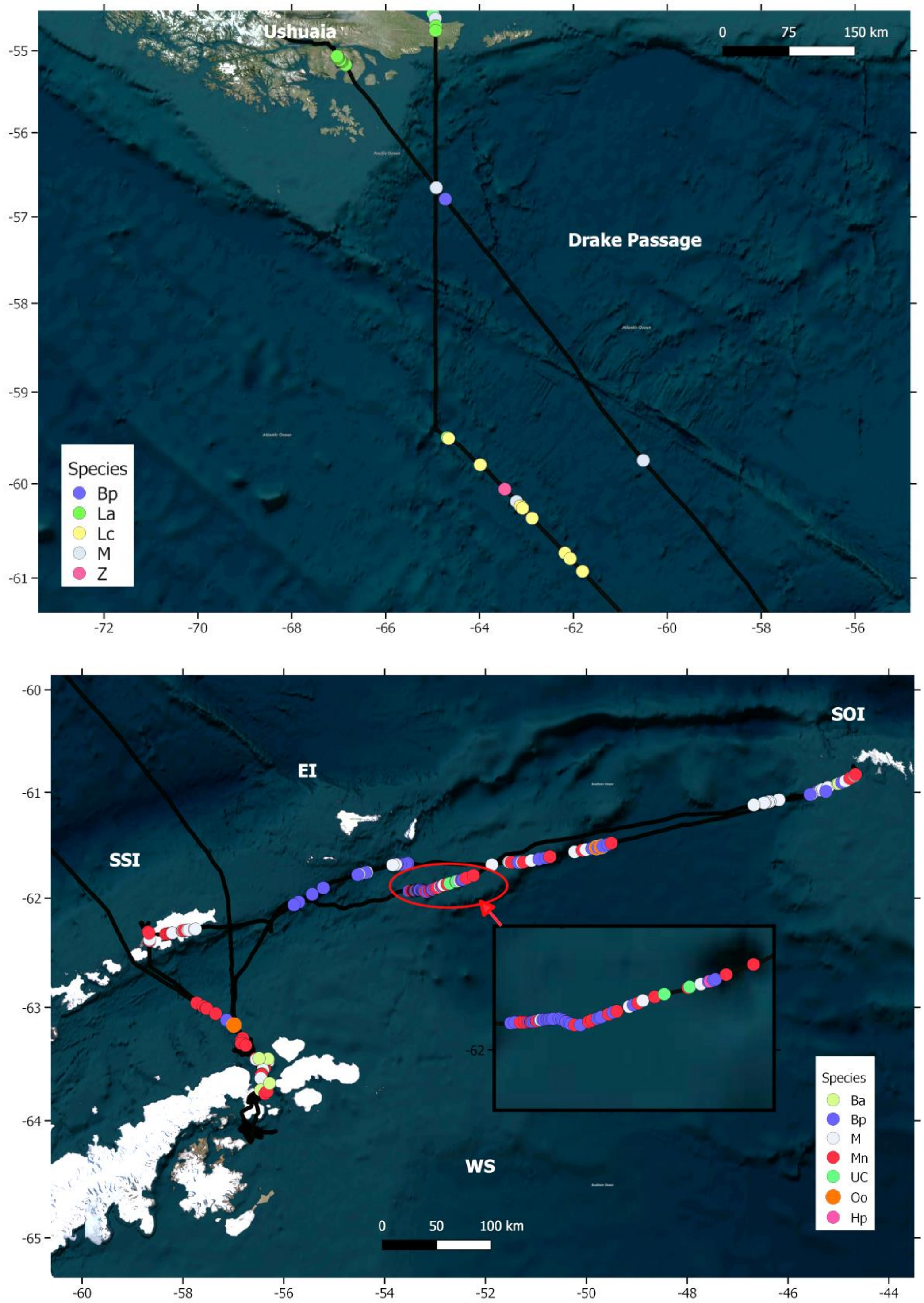

Figure 13 Cetacean sightings between February 22nd and March 22nd, 2019. (A) Drake Passage (B) North-eastern Antarctic Peninsula, Mar de Scotia/ Scotia Sea and Islas Orcadas del Sur/ South Orkney Islands. SSI: Islas Shetland del Sur/ South Shetland Islands; EI: Isla Elefante/ Elephant Island; WS: Mar 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.

Project outputs

IWC/SC papers

Jackson J, Sremba AL, Zerbini AN, Reyes Reyes MV, Herr H, Archer FI, Sirovic A, Scott Baker CS, Olson P, Torres-Florez JP, Lang AR, Rogers TL, Samaran F, Fretwell P, De la Mare W, Aguilar A, Kelly N, Bell EM, Miller BS, Cerchio S, Leslie MS (2018) Southern Hemisphere fin whale stock structure: A summary of published information to date. Paper SC/67b/SH/15.

Reports

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.

Conference presentations

Reyes Reyes MV, Bedriñana-Romano L, Hevia M, Marino A, Iñíguez Bessega MA (2018) Modelling summer distribution and abundance of Southern right whales, *Eubalaena australis*, in Argentinean shelf waters. XVIII Conference of Specialists on Aquatic Mammals from South America and 12th SOLAMAC Congress. Lima, Perú, 5th – 8th November 2018. (Poster).

Media interest

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

Scientific references cited in report

Reyes Reyes MV, Trickey JS, Baumann-Pickering S, Melcón, M.L., Hildebrand JA, Iñíguez MA (2014). Sightings and acoustic records of cetaceans during the SORP Voyage 2014. Paper SC/65b/SH16rev presented to the IWC Scientific Committee, May 2014 (unpublished) 7pp.