Annual Report of the Southern Ocean Research Partnership (SORP) 2012/13

ELANOR M. BELL[1] (Compiler)

[1] *Australian Marine Mammal Centre, Australian Antarctic Division, DSEWPAC, 203 Channel Highway, Kingston Tasmania 7050, AUSTRALIA*

ABSTRACT

The Southern Ocean Research Partnership (SORP) was proposed to the International Whaling Commission (IWC) in 2008 with the aim of developing a multi-lateral, non-lethal scientific research program that will improve the coordinated and cooperative delivery of science to the IWC. There are now 10 member countries in the Partnership: Argentina, Australia, Brazil, Chile, France, Germany, New Zealand, Norway, South Africa and the United States. A framework and set of objectives for SORP were presented to the IWC in 2009, where they were endorsed. Six international research projects were selected to form the basis of SORP research and progress reports were presented to the IWC in 2010 and 2011. One of these projects, the Living Whales Symposium, held in Chile in March 2012 has been completed. This paper reports on the continued progress of SORP and that of the five ongoing research projects since the Scientific Committee meeting in 2012.

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

INTRODUCTION

In 2008 Australia proposed to the International Whaling Commission (IWC) the development of regional non-lethal cetacean research partnerships. These research partnerships would use modern, non-lethal, scientific methods to provide the information necessary to best conserve and manage cetacean species. The proposal was received very positively by IWC member nations. The Australian Government is now supporting the Southern Ocean Research Partnership (SORP), established in March 2009. The aim of SORP is to develop a multi-lateral, non-lethal scientific whale research program that will improve the coordinated and cooperative delivery of science to the IWC. Current Partnership members include Argentina, Australia, Brazil, Chile, France, Germany, New Zealand, Norway, South Africa and the United States of America.

The objectives, research plan, and procedural framework for the partnership were developed through a workshop held in Sydney, Australia in March, 2009. Subsequently, a framework and set of objectives for SORP were endorsed by the IWC at its Annual Meeting in June 2009. An Annual Report of SORP (SC/63/O12; SC/64/O13) and revised project plans (SC/63/O13) were presented to the IWC in 2011 and 2012 which summarised progress within SORP and the six SORP research projects. One of these projects, the Living Whales Symposium, held in Chile, was completed in March 2013 and reported to the Scientific Committee in 2012 (SC/64/O14). This paper reports on SORP progress and the results of the five ongoing research projects since the 64th Meeting of the Scientific Committee in 2012.

BRIEF SUMMARY OF PROGRESS

The following items detail the major progress that has been made by SORP since the 64th Annual Meeting of the Scientific Committee. Further details of this work can be found on the SORP website presently hosted by the Australian Antarctic Division at http://www.marinemammals.gov.au/sorp.

SORP conference and workshops, 31 May – 2 June 2013

The SORP Secretariat organised a conference, 31 May – 2 June 2013, immediately preceding the meeting of the IWC Scientific Committee (65a), on Jeju Island, Republic of Korea. The event highlighted the results of the five ongoing SORP research projects. Existing project plans were updated during workshops convened by the principal investigators and these were presented to the Southern Hemisphere sub-Committee for consideration during SC/65a. The future development of the Partnership was also discussed and recommendations made to ensure both the continuation of this multi-national, regional collaboration and the delivery of high quality scientific information, in line with the priorities of the Scientific Committee, through the application of non-lethal methods. A full report of the conference can be found in Bell (2013; SC/65a/SH25).

SORP Research Projects

Brief summaries of progress on each of the six current SORP research projects are given below. Full project reports are included in Annex 1.

SORP Project 1: Antarctic Blue Whale Project (ABWP; formerly known as the 'Year of the Whale' project)

The Antarctic Blue Whale Project is a major initiative of the Southern Ocean Research Partnership. Its objectives are to describe our current understanding of the status of the Antarctic blue whales after fifty years of protection from exploitation, the role of these whales in the Antarctic ecosystem and what scientific information is now required to assist in the ongoing conservation and management of this iconic animal.

The catch records from the whaling fleets and subsequent sighting surveys allow the reconstruction of the rapid depletion and very slow recovery of Antarctic blue whales. Nevertheless a new, accurate and precise abundance estimate is required to assess the current status of these whales. As systematic sightings surveys are no longer conducted around Antarctica, this project's first objective is to identify the most efficient approach to derive a new abundance estimate for Antarctic blue whales. Initial analyses recommend the mark-recapture method, which will also provide an opportunity to deliver information on the project's secondary objectives of investigating population structure, migratory movements and behaviour on the feeding grounds. However, further development of survey techniques for mark-recapture will be required.

This project is ambitious and needs coordinated and sustained international cooperation to deliver the necessary data to achieve a new abundance estimate for Antarctic blue whales. Preliminary results are promising, in terms of acoustic tracking to locate Antarctic blue whales, identification of individuals and successful satellite tagging of two Antarctic blue whales. The Scientific Steering Committee for the project has been appointed. The members are actively seeking ship time and research funding to achieve the objectives.

Voyage to the Ross Sea region
The main activity of the ABWP since IWC64 was the successful Australian-led voyage that took an international team of researchers into the Southern Ocean in search of Antarctic blue whales. This was the first in a planned series of voyages by SORP Partners that will collectively produce a new estimate of abundance for Antarctic blue whales. Scientific personnel conducted studies near the ice edge in a survey area west of the Ross Sea (about 135°E – 170° W). Analyses of historical catch data, IWC-SOWER sighting data and sonobuoy deployments have associated this area with higher densities of blue whales (Kelly *et al.* 2012, SC/64/SH10).

An acoustic-assisted mark-recapture approach (using DIFAR sonobuoys) was successfully employed to detect concentrated areas of blue whale abundance at distances of hundreds of kilometres. Following acoustic bearing angles, these concentrations of Antarctic blue whales were located and sampled. Photographs of 50 individuals and biopsy samples from 23 individuals were obtained. Approximately thirty hours of detailed behavioural data were collected to help link acoustic behaviour to a broader context of Antarctic blue whale behaviour. Rigorous sighting surveys detected 39 sightings of 84 individual Antarctic blue whales in 10,595 km of searching in the survey area (with a total of 530 sightings of 1,313 cetaceans, including Antarctic blue whales). Two satellite

tags were also deployed on Antarctic blue whales, the first in history. Further details of the results are available in the Voyage Report by Double *et al*. (2013, SC/65a/SH21) and in papers Olson *et al.* (2013a; SC/65a/SH11); Miller *et al.* (2013a; SC/65a/SH18).

Ships of opportunity
To achieve circum-polar sampling for the estimate of abundance, the potential of using tourist ships, fishing vessels and naval vessels has been explored. Through the Buenos Aires Group in South America, approaches have been made to the Argentinean coastguard 'Prefectura' and the Chilean navy (please refer to the report of the Buenos Aires Group meeting held in Buenos Aires, 17-18 April 2013, Iñiguez *et al.* 2013, Annex 2). Fishing vessels are being approached through CCAMLR.

SORP workshop, 17-18 April 2013, Buenos Aires, Argentina

- Argentina, Brazil and Chile, as foundation members of SORP, attended. Ecuador was warmly welcomed as a new member. Peru and Uruguay expressed an interest but were unable to attend.
- The participants reinforced their commitment to non-lethal methods of research on whales.
- A summary of Latin American 2013 research projects of SORP/ Antarctic Blue Whale Project (ABWP) was presented, including the recent Australian voyage using non-lethal techniques, the Argentinean voyage of 'Puerto Deseado', and Chilean work on the IWC photo identification catalogue.
- The potential resources from Latin American countries were discussed and the capacity for whale research investigated.
- Argentina announced the availability of the 50 m vessel 'Tango' for research in 2013-2014.
- The opportunities for capacity building for whale research amongst Latin American nations were discussed.
- To continue the momentum of the workshop held in Buenos Aires, a proposal for a coordinator was considered.
- A report from the meeting will be presented to IWC/SC/65a in Korea in May 2013.
- A press release was prepared by Argentina in order to communicate the results of the meeting.

A full report of this workshop is presented in Annex 2.

Citizen science and the International Association of Antarctic Tour Operators (IAATO) Annual meeting 24-25 April 2013, Punta Arenas, Chile
A presentation was given by Dr Victoria Wadley to tourist operators at the annual meeting of the International Association of Antarctic Tour Operators (IAATO), 24-25 April 2013, Punta Arenas, Chile. The presentation included an invitation to operators and tourists in Antarctic waters to contribute to research on Antarctic blue whales. Delegates at the meeting were introduced to the photo-identification database of the International Whaling Commission, hosted by Chile, as well as a newly launched sightings portal hosted by the Australian Marine Mammal Centre that aims to encourage the submission of, and collate, sightings information and photographs contributed by the general public, vessel operators, tourists and fishers travelling in the Southern Ocean. The information is automatically disseminated to the relevant catalogues and databases maintained by researchers and agencies around the world. Such 'citizen science' is integral to the success of the Antarctic Blue Whale project and the other SORP projects that rely heavily on the identification of individuals, and the location and behavioural data that can be derived from photographs. Please refer to the sightings portal at www.marinemammals.gov.au/sorp/sightings

The presentation attracted considerable support and interest in submitting identification photos via the new online facility. Liaison will continue with IAATO and interested operators will be provided with information packs, fliers and posters (in both English and Spanish) that can be used on cruise ships to assist tourists in contributing their images to this 'citizen science' initiative. The information will also be rolled out to other stakeholders, including but not limited to fishing vessels, research vessels and international polar research programmes.

South African Blue Whale Project (SABWP)
SORP provided financial support for the South African Blue Whale Project (SABWP) that aims to initiate a long-term programme of monitoring the distribution, abundance and movements of blue whales in the Antarctic sector south of South Africa (0˚-20˚E, an area of probably the highest polar abundance of the species), coupled with investigations of the seasonal pattern of abundance at lower latitudes, including local waters. SORP funds allowed Meredith Thornton, University of Pretoria, to travel to Greenland in September 2012 to participate in the 3-week oceanographic cruise to deploy five Autonomous Acoustic Recorders (AARs). A full report is presented in SC/65a/O10.

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

The SORP killer whale project has had a successful and productive year since SC/64. Fieldwork has been undertaken in the Ross Sea, western Antarctic Peninsula and around Marion Island, sub-Antarctic.

Work conducted at McMurdo Station, Ross Sea, by Robert Pitman and John Durban December 2012 to January 2013, led to 7 type C killer whales (and 3 Antarctic minke whales) being satellite-tagged; 3 killer whales; two minke whales being tagged with location-only tags; and 'dive depth/location' tags being deployed on 4 killer whales and 1 minke whale. Tags are still functioning on 5 killer whales and 2 minkes well into the third month of transmissions. The successful Antarctic minke whale tagging was the first ever for this species and dive depth data should be valuable for calibrating IWC Antarctic minke whale line transect estimates from the Southern Ocean. Furthermore, biopsies were collected from 2 adult male and 2 adult female killer whales to compare SI and fatty acid signatures with minke whales foraging under the fast ice in the same areas and samples collected from the area 10 years ago; over 4000 photo-identification photos were taken for use in estimating the population size (roughly 100-200 individuals), residency patterns, and movements within the McMurdo Sound and Ross Sea; and over 3 hrs of type C killer whale vocalizations were recorded for comparison with other Antarctic killer whale types.

Subsequent, work undertaken by Robert Pitman, John Durban, Nick Gales, Ari Friedlaender and others around the western Antarctic Peninsula (WAP) in January and February 2013, led, for the first time, to satellite tags being deployed on all 4 of the different Antarctic killer whale types, including depth profile tags on both adult males and adult females of types A, small B and C (one adult male large B was tagged, but not a female). Preliminary results suggest that mammal-eaters (types A and large B) typically forage to less than 80 m in depth, while known (type C) and suspected (small type B) fish-eaters are routinely diving to 300-400 m (probably to the bottom). Males may be diving longer, but not deeper than females. Through photographs taken by the PIs and those submitted by naturalists and tourists on tour ships operating in the Antarctic Peninsula area, photographs of over 75 killer whale encounters in the WAP this year have been obtained. The project's total photo collection now comprises over 40,000 images and probably includes most of the individuals of the 3 types that regularly occupy the Peninsula area. With appropriate funding, within the next couple of years it is likely that population estimates can be generated, ranges delimited and the habitat use of the different types that occur in the WAP identified.

In February 2013, Dr. Luciano Dalla Rosa and colleagues involved in Projeto Baleias, Brazilian Antarctic Program, surveyed the waters of the Bransfield and Gerlache Straits, Antarctic Peninsula, as well as the Powell Basin at the southern margin of the Drake Passage, aboard the Brazilian Navy's icebreaker, *Almirante Maximiano*. Nearly 300 nautical miles of cetacean search effort was conducted, resulting in three killer whale group sightings. One group was identified as the type A ecotype and another as the type B. The third group could not be identified. Photo-identification was conducted on both identified groups; one biopsy sample was collected; and 30 min of vocal recordings were collected from the type B group of around 40 individuals in waters of the Antarctic Sound. One individual in this group carried a satellite tag deployed by Drs. Robert Pitman and John Durban earlier in the season, demonstrating that killer whale groups have been re-sighted by the collaborating research teams both within and between seasons.

In March 2013, new sub-Antarctic research component has been added to this SORP project, led by Dr. P.J.N. (Nico) de Bruyn, University of Pretoria, South Africa. The aim of this study is to better understand the foraging range of killer whales in the sub-Antarctic region of the Southern Ocean by building on an existing study at Marion Island. The key objectives of the new project component are:

- To further an understanding of killer whale foraging ranges and movements related to resources on Marion Island, particularly in relation to nearby Crozet Island and the South African mainland.
- Use this knowledge to develop a broader study on sub-Antarctic killer whales (development to be undertaken by Nico de Bruyn in 2013) that will potentially include satellite tracking of killer whales at Îsles Crozet, Macquarie Island and at sea in the Southern Ocean.
- To investigate the evidence for dietary specialisation of sub-Antarctic killer whales in the context of optimal foraging theory.

Since SORP support of this work commenced, there have been 70 dedicated hours of land-based killer whale observation undertaken from Marion Island; more than 500 images taken for photographic mark-resight; 3 biopsy samples collected from 3 individual killer whales and; 2 time depth recorder (TDR) satellite linked tracking devices deployed and presently transmitting.

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

The main objectives of this research project are to:

- Conduct ecological research on cetaceans around the Antarctic Peninsula and develop methodological tools that can be applied across Antarctic regions to better understand the short and long term movement patterns and behaviours of baleen whales in relation to prey and environmental variability; and
- Develop a research proposal for the National Science Foundation to apply tag and prey mapping technologies to further quantify the relationships between humpback and minke whales and krill.

In February 2013, a National Science Foundation supported research cruise took place on the *R/V Point Sur* in collaboration with the US Antarctic Program and the Australian Antarctic Division. The goals of this research were to deploy both long-term satellite tags, and short-term multi-sensor suction cup tags on both humpback and minke whales while concurrently mapping the distribution, abundance, and behaviour of Antarctic krill. Over a two-week span, 19 Argos-linked satellite tags were deployed on humpback whales and 13 on Antarctic minke whales. Four multi-sensor suction cup tags were also deployed on humpback whales and 2 on Antarctic minke whales. The deployments of both types of tags on minke whales represent the first successful efforts for either tag on the species. At the time of this report, 5 humpback and 3 minke tags are still functioning, generating substantial data on the movement patterns of both species.

Through a series of collaborative, multi-disciplinary research cruises supported by the National Science Foundation, the Southern Ocean Research Partnership, and the Australian Antarctic Division, the Principal Investigators (PIs) have begun to quantify and understand the foraging ecology of baleen whales in Antarctic waters in unprecedented ways. From broad-scale density, distribution, and movement patterns we are beginning to understand the habitat of both humpback and minke whales in great detail. The ability to successfully deploy these tags on minke whales for the first time is a significant achievement. Currently, quantitative habitat and movement models for both species are being completed that will be related to changes in the physical and biological landscape. This information will allow the PIs compare and contrast these sympatric krill predators in novel ways that will increase our ecological understanding of how changes in this region, and elsewhere, will affect these animals. From short-term multi-sensor recording tags, the first quantitative study of how the foraging and diving behaviour of humpback whales is affected by changes in the distribution, behaviour, and abundance of Antarctic krill has recently been completed. Recent success in deploying similar tags on Antarctic minke whales for the first time is another significant accomplishment. The PIs are in the process of completing analysis of the diving behaviour, foraging strategies and kinematic patterns of these whales that will offer great insights into the energetic needs and consumption rates of these whales. The first manuscript discussing minke whale tag data is now in review. The PIs are also now in a position to compare and contrast the fine-scale and vertical habitats of minke and humpback whales to better understand how these sympatric krill predators partition resources.

The methodologies and analytical framework being used currently provide a template for future research across Antarctic regions that will allow us to better understand how the ecological relationships between baleen whales and their environment are affected by different oceanographic regimes, ice conditions, and prey availability. The success of this project also highlights the importance and utility of international and collaborative efforts to maximize the opportunities to conduct ecological research on cetaceans in Antarctica. Summaries of the findings presented in peer-reviewed publications are given in ANNEX 3.

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

The humpback connectivity project has focused on the goals of understanding the genetic links between the whales of New Zealand and American and Independent Samoa to other Oceania regions and east Australia. Preliminary analyses show that whales from the Samoa's mainly match to the eastern South Pacific, and the

whales primarily on their northern migration past New Zealand match to east Australia and New Caledonia, in the western South Pacific. This research supports the plan to satellite tag whales on their southern migration past Raoul Island and from their American Samoa breeding ground. The results are likely to provide a more thorough understanding of the location of the Oceania whales' Antarctic feeding grounds. Technical issues with the satellite tags have delayed this research by a year but it is hoped that tagging will be undertaken in 2014. A full project report is included in Annex 1.

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

In 2011/2012, after the analysis of available acoustic data to identify the geographic and seasonal occurrence of blue and fin whales around the Antarctic, the Acoustic Trends Steering Group (hereafter the Group) has agreed upon the need for a coordinated effort to collect new acoustic data using consistent spatial and temporal coverage, instruments, and analysis methods. Since SC/64, the Group has been focusing on strategies to create a pan-Antarctic monitoring system in the near future.

In October 2012, the Group met at an Acoustics Trends Steering Group Meeting held at the Alfred Wegener Institute (AWI), Bremerhaven, Germany, to review ongoing work on Southern Hemisphere blue and fin whale acoustic projects, discuss current and future data collection and analyses, and refine the vision of the project into a strategic plan that can be used to guide research efforts over the next five years. The meeting was very productive and among the discussions, a number of strategies were agreed upon including collection of new data through future instrument deployments in each of the six IWC management areas, storage of data and metadata and analysis of the data through the production of blueprints of analysis methods. Moreover, during the meeting we underscored the importance of collecting behavioural data simultaneously with acoustic recordings during the 2013 Antarctic Blue Whale Voyage. During winter and spring 2012/2013 the blueprint was developed through different studies using existing blue whale acoustic datasets (from AWI and PELAGIS).

In the autumn of 2012, Ken Findlay from the Mammal Research Institute Whale Unit, University of Pretoria, South Africa, joined the Group. He is directing the South African Blue Whale Project (SABWP). In spring 2013, Danielle Harris, who works in Len Thomas' research team at the Centre for Research into Ecological and Environmental Modelling (CREEM), University of St Andrews, joined the Group. She brings experience of abundance estimation using acoustic data. Overall, a strong, multi-disciplinary and multi-national team has been developed to continue to move this project into the future.

LIST OF SORP RELATED PAPERS SUBMITTED FOR CONSIDERATION TO SC/65a

SC/65a/SH03 Andrews-Goff V, Olson PA, Gales NJ and Double MC (2013) Satellite telemetry derived summer movements of Antarctic blue whales.

SC/65a/O11 Bell (2013) Annual report of the Southern Ocean Research Partnership (SORP) 2012/13

SC/65a/SH25 Bell (2013) Report of the Southern Ocean Research Partnership Conference, 31 May - 2 June, 2013.

SC/65a/O10 Best PB, Findlay K, Thornton M and Stafford K (2013) SORP research report: the South African Blue Whale Project.

SC/65a/SH21 Double (2013) Cruise report of the 2013 Antarctic blue whale voyage of the Southern Ocean Research Partnership.

SC/65a/IA12 Gales N, Bowers M, Durban JW, Friedlaender AS, Nowacek DP, Pitman RL, Read AJ and Tyson RB (2013) Advances in non-lethal research on Antarctic minke whales: biotelemetry, photo-identification and biopsy sampling.

SC/65a/Forinfo08 Kelly N (2013) A new circumpolar abundance estimate for Antarctic blue whales: potential survey methods.

SC/65a/SH18 Miller BS, Barlow J, Calderan S, Collins K, Leaper R, Kelly N, Peel D, Olson P, Ensor and Double MC (2013a) Long-range acoustic tracking of Antarctic blue whales.

SC/65a/SH19 Miller BS, Barlow J, Calderan S, Leaper R, McDonald M, Ensor P, Olson P, Olavarria C and Double MC (2013b) Blue whale songs recorded around South Island, New Zealand.

SC/65a/SH11 Olson PA, Ensor P, Schmitt N, Olavarria C and Double MC (2013a) Photo-identification of Antarctic blue whales during the SORP Antarctic Blue Whale Voyage 2013.

SC/65a/SH12 Olson PA, Ensor P, Olavarria C, Schmitt N, Childerhouse S, Constantine R, Miller BS and Double MC (2013b) New Zealand blue whales: initial photo-identification of a little-known population.
SC/65a/Forinfro09 Peel D (2013) Examination of an acoustic-assisted mark recapture survey method for whales.
SC/65a/SH05 Robbins J, Zerbini AN, Gales N, Gulland FMD, Double M, Clapham PJ, Andrews-Goff V, Kennedy AS, Landry S, Mattila DK and Tackaberry J (2013) Satellite tag effectiveness and impacts on large whales: preliminary results of a case study with Gulf of Maine humpback whales.

OTHER SORP RELATED PAPERS

SC/63/O12 Childerhouse S (2011) Annual Report of the Southern Ocean Research Partnership 2011.
SC/63/O13 Childerhouse S (2011) Southern Ocean Research Partnership Revised project plans.
SC/64/O13 Bell E (2012) Annual Report of the Southern Ocean Research Partnership 2011/12.
SC/64/O14 Baker CS, Galletti B, Childerhouse S, Brownell RL Jr, Friedlaender A, Gales N, Hall A, Jackson J, Leaper R, Perryman W, Steel D, Valenzuela L and Zerbini A (2012) Report of the Living Whales Symposium: Advances in non-lethal research techniques for whales in the Southern Hemisphere.
SC/64/IA10 Kelly N, Murase H, Kitakado T, Kock K-H, Williams R, Feindtherr and Walløe L (2012) Estimating abundance and distribution of Antarctic minke whales within sea ice areas: data requirements and analysis methods.
SC/64/SH10 Kelly N, Miller B, Peel D, Double MC, de la Mare W and Gales N (2012) Strategies to obtain a new circumpolar abundance estimate for Antarctic Blue Whales: survey design and sampling protocols.
SC/64/SH11 Miller BS, Kelly N, Double MC, Childerhouse SJ, Laverick S and Gales N (2012) Development of acoustic methods: cruise report on SORP 2012 Antarctic Blue Whale voyages.
SC/64/SH12 Miller BS (2012) Real-time tracking of Blue Whales using DIFAR sonobuoys.
SC/64/SH13 Wadley V, Lindsay M, Kelly N, Miller N, Gales N, de la Mare W and Double MC (2012) Abundance estimation of Antarctic Blue Whales: preliminary voyage plan for SORP in March 2013.
SC/64/SH14 de la Mare WK (2012) Estimating relative abundance from historic Antarctic whaling records.
SC/64/SH15 Schmitt NT, Double MC, Baker CS, Steel D, Jenner KCS, Jenner M-NM, Paton D, Gales R, Jarman SN, Gales N, Marthick JR, Polanowski AM and Peakall R (2012) Low levels of genetic differentiation characterize Australian humpback whale (*Megaptera novaeangliae*) populations.
SC/64/SH26 Peel D and Kelly N (2012) Exploratory analyses of potential encounter rates for an acoustic tracking survey method for blue whales.

ANNEX 1 - PROGRESS REPORTS ON THE SORP RESEARCH PROJECTS FOR 2012/13

SORP Project 1. Antarctic Blue Whale Project (ABWP)

Victoria Wadley[1]

[1]*Scientific Coordinator, Antarctic Blue Whale Project, Australian Marine Mammal Centre, Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7050, Australia*

Introduction

During the twentieth century, about a third of a million Antarctic blue whales (*Balaenoptera musculus intermedia*) were taken during commercial whaling in the Southern Hemisphere. Close to extinction, in 1964 the International Whaling Commission banned the hunting of blue whales, although some whales were still caught by illegal operations until 1973. Today, the Antarctic blue whale is classified as critically endangered by the International Union for Conservation of Nature and is of global interest as one of the most at risk baleen whale species in the Southern Ocean.

The inception of the Antarctic Blue Whale Project was inspired by the cessation of the systematic circumpolar sightings surveys in 2003/04 and the lack of a new strategy to assess the status and recovery of this severely impacted, rare and iconic species.

Objectives

The objectives of the ABWP are:

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

Results

Preliminary voyages to develop acoustic methods

Since IWC64, the results from two preliminary voyages off S-E Australia seeking pygmy blue whales have been analysed. Based on these data, the acoustic methods and processing protocols were refined in preparation for the project's major Southern Ocean voyage of 2013. This preparation was instrumental in the successful use of passive acoustics to track Antarctic blue whales in the Ross Sea.

Voyage to the Ross Sea region

An important result in early 2013 was the Australian-led voyage that took an international team of researchers into the Southern Ocean in search of Antarctic blue whales. This is the first in a planned series of voyages by SORP Partners that will collectively produce a new estimate of abundance for Antarctic blue whales. The 65 m *FV Amaltal Explorer* was chartered for a 47 day voyage leaving from and returning to Nelson, New Zealand. Scientific personnel conducted studies near the ice edge in a survey area west of the Ross Sea (about 135°E – 170° W). Analyses of historical catch data, IWC-SOWER sighting data and sonobuoy deployments have associated this area with higher densities of blue whales (Kelly *et al.* 2012, SC/64/SH10).

The main purpose of the voyage was to evaluate methods that can be used to estimate blue whale abundance and to initiate the collection of necessary data. Prior research shows that mark-recapture methods using photographic and genetic identification may be the most cost-effective method to estimate Antarctic blue whale abundance (Kelly *et al.* 2012, SC/64/SH10). However these methods depend on the collection of sufficient identification photographs (photo-IDs) and biopsy samples.

Blue whales make extremely loud, low frequency sounds that travel for hundreds of kilometres, and can be used to find areas where blue whales are concentrated. The acoustic tracking techniques were successfully tested by

members of the Antarctic Blue Whale Voyage team in the Bonney Upwelling in northern Bass Strait during January and March 2012. The subsequent 2013 voyage to the Southern Ocean was designed to test whether acoustic detection and localisation of blue whales can facilitate the collection of an adequate sample of photo-IDs and biopsies to serve as a foundation for a new estimate of Antarctic blue whale abundance.

All of the scientific objectives of the voyage were met. Most importantly, disposable directional hydrophones (DIFAR sonobuoys) were able to detect concentrated areas of blue whale abundance at distances of hundreds of kilometres. Following acoustic bearing angles, these concentrations of Antarctic blue whales were located and sampled. Photographs of 57 individuals and biopsy samples from 23 individuals were obtained from the *Amaltal Explorer* and an outboard-powered launch. Approximately thirty hours of detailed behavioural data were collected to help link acoustic behaviour to a broader context of Antarctic blue whale behaviour. Rigorous sighting surveys detected 39 sightings of 84 individual Antarctic blue whales in 10,595 km of searching in the survey area (with a total of 530 sightings of 1,313 cetaceans, including Antarctic blue whales). Two satellite tags were deployed on Antarctic blue whales, the first in history. Further details of the results are available in the Voyage Report by Double *et al*. (2013, SC/65a/SH21) and in papers Olson *et al*. (2013a; SC/65a/SH11); Miller *et al.* (2013a; SC/65a/SH18).

Ships of opportunity

To achieve circum-polar sampling for the estimate of abundance, the potential of using tourist ships, fishing vessels and naval vessels has been explored. Through the Buenos Aires Group in South America, approaches have been made to the Argentinean coastguard 'Prefectura' and the Chilean navy (please refer to the report of the meeting by Iñiguez *et al.* 2013, Annex 2). Fishing vessels are being approached through CCAMLR.

SORP workshop, 17-18 April 2013, Buenos Aires, Argentina

A SORP workshop was held in Buenos Aires, Argentina (17-18 April 2013) with the aim of coordinating whale research efforts amongst Latin American country members of SORP in the Antarctic Peninsula area. Representatives of Argentina, Brazil and Chile, as foundation members of SORP, attended. Ecuador was warmly welcomed as a new member. Peru and Uruguay expressed an interest but were unable to attend. A summary of the outcomes follows:

- The participants reinforced their commitment to non-lethal methods of research on whales.
- A summary of Latin American 2013 research projects of SORP/ Antarctic Blue Whale Project (ABWP) was presented, including the recent Australian voyage using non-lethal techniques, the Argentinean voyage of 'Puerto Deseado', and Chilean work on the IWC photo identification catalogue.
- The potential resources from Latin American countries were discussed and the capacity for whale research investigated.
- Argentina announced the availability of the 50 m vessel *Tango* for research in 2013-2014.
- The opportunities for capacity building for whale research amongst Latin American nations were discussed.
- To continue the momentum of the workshop held in Buenos Aires, a proposal for a coordinator was considered.
- A report from the meeting will be presented to IWC/SC/65a.
- A press release was prepared by Argentina in order to communicate the results of the meeting.

A full report of this workshop is presented in Annex 2.

International Association of Antarctic Tour Operators (IAATO) Annual meeting 24-25 April 2013, Punta Arenas, Chile

A presentation was given by Dr Victoria Wadley to tourist operators at the annual meeting of the International Association of Antarctic Tour Operators (IAATO), 24-25 April 2013, Punta Arenas, Chile. The presentation included an invitation to operators and tourists in Antarctic waters to contribute to research on Antarctic blue whales. Delegates at the meeting were introduced to the photo-identification database of the International Whaling Commission, hosted by Chile, as well as a newly launched sightings portal hosted by the Australian Marine Mammal Centre that aims to collate sightings information and photographs contributed by the public, vessel operators, tourists and fishers travelling through in the Southern Ocean, and disseminate the information to the relevant catalogues and databases maintained by researchers and agencies.
www.marinemammals.gov.au/sorp/sightings

The presentation attracted considerable support and interest in submitting identification photos via the new online facility. Liaison will continue with IAATO and interested operators will be provided with information packs, fliers and posters (in both English and Spanish) that can be used on cruise ships to assist tourists in contributing their images to this 'citizen science' initiative. The information will also be rolled out to other stakeholders, including but not limited to fishing vessels, research vessels and international polar research programmes.

Conclusions

The progress to date demonstrates that locating and sampling Antarctic blue whales is possible, within the parameters required for a new estimate of abundance. All the objectives of the project are achievable, based on the experience of the *Amaltal Explorer* voyage. Refinement of the methods, particularly the mark-recapture techniques, will be required. Circum-Antarctic sampling from research vessels and other platforms necessitates long-term support for the project.

Challenges

The major challenge for the ABWP project is to coordinate the results from multiple sampling platforms around the Southern Ocean. A cogent synthesis of the data into a precise, accurate estimate of abundance will require advanced technical skills and excellent communication between partners in the project.

Outlook for the future

To guide the project, a Scientific Steering Committee of five leading cetacean researchers was appointed in 2012, with Professor Philip Hammond as Chair. Professor Hammond is highly respected within the IWC Scientific Committee and brings a wealth of experience in broad scale field programs. A project overview was prepared to facilitate research proposals and bids for sea time.

Resources for meetings of the Scientific Steering Committee, including support from the Secretariat, will be important in the future for guidance of the project. In particular, uptake of new advances in statistics and genetic analyses has the potential to influence and accelerate the research. Given the cost of sampling in the Southern Ocean, it is essential that the Scientific Steering Committee is active in bringing these advances to the forefront of the international program.

Project outputs

Papers

Kelly N, Peel D, Bravington MV, Double MC. A new circumpolar abundance estimate for Antarctic blue whales: assessment of survey methods. (Submitted to Methods in Ecology and Evolution on 15 April 2013)

Peel D, Miller BS, Kelly N, Dawson S, Slooten E, Double MC. Examination of acoustic assisted mark-recapture survey methods for whales. (Submitted to Methods in Ecology and Evolution on 15 April 2013)

Reports

Report of meeting of Buenos Aires Group, 16-17 April 2013. Submitted to the Scientific Steering Committee of the ABWP, June 2013.

Popular articles

Cahalan S (2013) Protecting the icons of the ocean. International innovation – Environment, April 2013:65-66

Conference presentations

Presentation on ABWP and *Explorer* voyage to meeting of Buenos Aires Group, 16-17 April 2013.

Presentation on ABWP at the Annual meeting of International Association of Antarctic Tour Operators, 24-25 April 2013, Punta Arenas, Chile. Authors: Victoria Wadley, Michael Double, Natalie Kelly, Elanor Bell, Philip Hammond.

Media interest

The *Antarctic Blue Whale Voyage* (January – March 2013) attracted considerable media in Australian and overseas, including 38 broadcasts, 24 print and online articles and 5 TV items

Papers submitted to the Scientific Committee

Please refer to p 6 of this document for a list of the ABWP-related papers submitted to the Scientific Committee this year.

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

Robert L. Pitman[1], John W. Durban[1], Luciano Dalla Rosa[2], P.J.N. (Nico) de Bruyn[3]

[1]Protected Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service, 8604 La Jolla Shores Dr., La Jolla, California 92037, USA
[2]Laboratório de Tartarugas e Mamíferos Marinhos, Instituto de Oceanografia, Universidade Federal do Rio Grande – FURG, Av. Itália km. 8 s/n, Campus Carreiros, Rio Grande, RS 96201-900, Brazil
[3]Mammal Research Institute, Department of Zoology & Entomology, University of Pretoria, South Africa

Robert Pitman and John Durban, West Antarctic Peninsula

McMurdo Station, Ross Sea

Robert Pitman and John Durban spent one month during December 2012 and January 2013 at McMurdo Station, in the Ross Sea, as part of a National Science Foundation grant to study top predators in McMurdo Sound. While there, 7 type C killer whales (and 3 Antarctic minke whales) were satellite-tagged. In addition to deploying location-only tags (3 killer whales; two minke whales), 'dive depth/location' tags were also deployed on 4 killer whales and 1 minke whale. Tags are still functioning on 5 killer whales and 2 minkes well into the third month of transmissions. The successful Antarctic minke whale tagging was the first ever for this species and dive depth data should be valuable for calibrating IWC Antarctic minke whale line transect estimates from the Southern Ocean. It is hoped that a larger minke whale tagging operation will be conducted next year.

Dive data indicate that the killer whales are regularly diving to 300-400 m, and to over 700 m at times; minke whales routinely dive to only 80 m. On the last date checked (14 March), all of the tagged whales were in the central Ross Sea and heading north, in front of the advancing fast ice. Biopsies from 2 adult male and 2 adult female killer whales were obtained to compare SI and fatty acid signatures with minke whales foraging under the fast ice in the same areas (both species could be feeding on Antarctic silverfish), and to compare with samples collected from the area 10 years ago.

Over 4000 photo-identification photos were also taken for use in estimating the population size (roughly 100-200 individuals), residency patterns, and movements within the McMurdo Sound and Ross Sea. There is some clear evidence of philopatry in this population with at least one photo match of a distinctive female photographed 10 years earlier at the same location in McMurdo Sound.

Over 3 hrs of type C killer whale vocalizations were also recorded for comparison with other Antarctic killer whale types.

Western Antarctic Peninsula (WAP)

In January 2013, operations were moved to the western Antarctic Peninsula (WAP) where the Principal Investigators (PIs) participated in 3, 10-day cruises aboard a tour ship (M/V *National Geographic Explorer*), where 2 small type B and 3 type A killer whales were satellite-tagged, and a total of 11 individual groups of killer whales photographed.

On 4 February, the PIs joined a Duke University humpback-tagging group on the NSF vessel R/V *Point Sur* and spent 1 month in the waters off the WPA. During that time 3 more small type B and 1 large type B killer whale were satellite-tagged, and 11 different groups of killer whales photographed. Three additional minke whales were satellite-tagged. Nine killer whale biopsy samples were also obtained for on-going phylogenetic studies at our lab; for use in examining skin regeneration regimes in Antarctic killer whales, and to compare chemical signatures in the different forms. In total, 9 satellite tags were deployed.

This year, for the first time, satellite tags were deployed on all 4 of the different Antarctic killer whale types, including depth profile tags on both adult males and adult females of types A, small B and C (one adult male large B was tagged, but not a female). Preliminary results suggest that mammal-eaters (types A and large B) typically forage to less than 80 m in depth, while known (type C) and suspected (small type B) fish-eaters are routinely diving to 300-400 m (probably to the bottom). Males may be diving longer, but not deeper than females. Through photographs taken by the PIs and those submitted by naturalists and tourists on tour ships

operating in the Antarctic Peninsula area, photographs of over 75 killer whale encounters in the WAP this year have been obtained. The project's total photo collection now comprises over 40,000 images and probably includes most of the individuals of the 3 types that regularly occupy the Peninsula area. With appropriate funding, within the next couple of years it is likely that population estimates can be generated, ranges delimited and the habitat use of the different types that occur in the WAP identified.

Luciano Dalla Rosa, West Antarctic Peninsula and Powell Basin

Between February 9 and March 2, Dr. Luciano Dalla Rosa and colleagues involved in the Projeto Baleias, Brazilian Antarctic Program, surveyed the waters of the Bransfield and Gerlache Straits, Antarctic Peninsula, as well as the Powell Basin at the southern margin of the Drake Passage, aboard the Brazilian Navy's icebreaker, *Almirante Maximiano*. Nearly 300 nautical miles of cetacean search effort was conducted, resulting in three killer whale group sightings. One group was identified as the type A ecotype and another as the type B. The third group could not be identified.

Photo-identification was conducted on both identified groups. In addition, one biopsy sample and 30 min of vocal recordings were collected from the type B group of around 40 individuals in waters of the Antarctic Sound. One individual in this group carried a satellite tag deployed by Drs. Robert Pitman and John Durban earlier in the season, demonstrating that killer whale groups have been re-sighted by the collaborating research teams both within and between seasons. Our type B catalogue will be updated in the next few months, and should provide several new matches when compared with other catalogues held by other SORP collaborators.

P.J.N. (Nico) de Bruyn, Marion Island, sub-Antarctic

A new sub-Antarctic research component was added this SORP project, led by Dr. P.J.N. (Nico) de Bruyn, University of Pretoria, South Africa. The aim of this study is to better understand the foraging range of killer whales in the sub-Antarctic region of the Southern Ocean by building on an existing study at Marion Island.

The key objectives of the new project component are:

- To build on significant work already underway on Marion Island. This work includes photo-identification (for population dynamics & social organisation studies), dedicated and opportunistic predation observations, remote biopsy sampling (for genetic, isotopic and fatty acid analysis to augment social organisation and foraging studies).
- To further an understanding of killer whale foraging ranges and movements related to resources on Marion Island, particularly in relation to nearby Crozet Island and the South African mainland.
- Use this knowledge to develop a broader study on sub-Antarctic killer whales (development to be undertaken by de Bruyn in 2013) that will potentially include satellite tracking of killer whales at Îsles Crozet, Macquarie Island and at sea in the Southern Ocean.
- To investigate the evidence for dietary specialisation of sub-Antarctic killer whales in the context of optimal foraging theory.

Since inception of the long-term project in April 2006, there have been:

- 6,800 hours of dedicated land based observation
- 20,000 images taken for photographic mark-resight
- 57 catalogued individual killer whales
- 25 biopsy samples collected from 21 individuals
- 15 killer whales tracked with satellite devices for longer than 24hrs
- 7 tracks lasting longer than 10 days
- 2 time-depth-recording (TDR) satellite trackers deployed.

Since inception of SORP support in March, 2013, there have been:

- 70 dedicated hours of land-based killer whale observation
- >500 images taken for photographic mark-resight
- 3 biopsy samples collected from 3 individuals
- Two TDR satellite linked tracking devices deployed and presently transmitting.

Project outputs

Papers
Durban JW, Pitman RL (2011) Antarctic killer whales make rapid, round-trip movements to sub-tropical waters: evidence for physiological maintenance migrations? Biology Letters doi: 10.1098/rsbl.2011.0875

Popular articles
Pitman RL (ed.) (2011) Killer whale: the top, top predator. Whalewatcher (Journal of the American Cetacean Society) 40(1):1-67

References cited

Andrews R, Pitman R, Ballance L (2008) Satellite tracking reveals distinct movement patterns for Type B and Type C killer whales in the southern Ross Sea, Antarctica. Polar Biology 31:1461-1468

Durban J, Pitman R (2011) Antarctic killer whales make rapid, round-trip movements to subtropical waters: evidence for physiological maintenance migrations? Biology Letters, doi: 10.1098/rsbl.2011.0875

Johnson D, London J, Lea M, Durban J (2008) Continuous-time correlated random walk model for animal telemetry data. Ecology 89:1208-1215

Johnson DS, London, JM, Kuhn CE (2011) Bayesian Inference for Animal Space Use and Other Movement Metrics. Journal of Agricultural, Biological, and Environmental Statistics 16:357-370

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

Dr. Ari S. Friedlaender[1]

[1.] *Duke University, Suite 710 Erwin Square, 2200 West Main Street, Durham, NC 27705, USA*

Introduction

Little is known regarding the ecological relationships between baleen whales and their prey, specifically in the Antarctic. Recent advances in tag technology and analytical methods allow for detailed understanding of the underwater movement and behaviour of cetaceans to quantify feeding behaviour at fine spatio-temporal scales. Linking these with concurrent measurements of krill provides a means for understanding how the distribution and abundance of prey affects the behaviour of baleen whales. As well, satellite-linked telemetry and time-depth recording tags can offer insights into the movement and behavioural patterns of cetaceans at broad spatio-temporal scales that are extremely valuable.

Around Antarctica, there are regional differences in oceanographic and sea ice conditions and prey abundance. Furthermore, there are differences in the types and abundance of baleen whales in these regions. Generating quantitative, repeatable methodologies for conducting ecological research on the foraging ecology of baleen whales is critical for understanding local predator-prey relationships and for being able to compare how these relationships are affected regionally.

Objectives

The main objectives of our research are to:

1) conduct ecological research on cetaceans around the Antarctic Peninsula and develop methodological tools that can be applied across Antarctic regions to better understand the short and long term movement patterns and behaviours of baleen whales in relation to prey and environmental variability; and

2) develop a research proposal for the National Science Foundation to apply tag and prey mapping technologies to further quantify the relationships between humpback and minke whales and krill.

Results

The results of our research program have been and are currently being published in the peer-review literature. A summary of our results can be found in Annex 1, which provides the abstracts and significant figures for our published research to date. Further information can be found Gales *et al*. (2013, SC/65a/IA12). Below, are a list of some of the major accomplishments and findings to date:

In the austral autumn we observed an extremely high density (5.1 whales per km^2) of humpback whales (*Megaptera novaeangliae*) feeding on a super-aggregation of Antarctic krill (*Euphausia superba*) in Wilhelmina Bay. The krill biomass was approximately 2 million tons, distributed over an area of 100 km^2 at densities of up to 2000 individuals m^{-3}; reports of such 'super-aggregations' of krill have been absent in the scientific literature for >20 years.

We surveyed 653.9 km of track line in the Gerlache Strait and adjacent bays during 26 April to 1 June 2009. We detected 371 groups of humpback whales in a distance-sampling framework that allowed us to calculate estimates of whale density along track lines in open and enclosed habitats within our study area. Density estimates along track lines ranged from 0.02 to 1.75 whales km^{-2}; the highest densities were found along track lines in the enclosed regions of Wilhelmina Bay, the Errera Channel, and Andvord Bay.

To understand the kinematics of humpback lunge feeding, we attached high-resolution digital recording tags incorporating accelerometers, magnetometers, pressure and sound recording to humpback whales. We found that feeding lunges contain extreme accelerations reaching 2.5 ms^{-2} in certain instances, which are then followed by decelerations. When animals are intensively feeding the inter-lunge interval is similar for both deep and shallow lunges suggesting a biomechanical constraint on lunges. However, the number of lunges per dive varies

from one for shallow feeding (<25 m) to a median of six for deeper dives. Different feeding patterns were evident in the kinematic record, for deep and shallow feeding bouts with the much greater mean turn rates occurring in shallow feeding.

Tag data show clear diel behavioural patterns, in which whales feed exclusively and continuously at night, including significant changes in feeding depths over time consistent with diel vertical prey movement. The majority of shallow feeding dives included a single lunge, a strategy that increases feeding efficiency through proximity to the surface, reducing the energetic costs of diving. Whales appear to maximize their energetic intake through the timing of behavioural state changes and feeding at times when energetic costs of diving are minimized. Our results also provide the first quantitative description of feeding behaviour by humpback whales in Antarctica.

Humpback whale feeding behaviour follows optimal foraging theory predictions, even when accounting for spatio-temporal dynamics of their prey. In the Antarctic, humpback whales feed at night on shallow, dispersed krill patches, but increase the density of prey targeted with increased feeding depth. This strategy allows the whales to minimize the energetic costs associated with diving and searching for smaller, dense krill patches, while at the same time increasing foraging rates. This information is important when considering the functional role and ecological relationships between predators and prey across marine ecosystems, specifically for those that include increasing baleen whale populations.

Minke whales are among the most abundant and widely distributed balaenopterid cetaceans, yet we know little of their underwater behaviour. For example, the diving, foraging, and kinematic patterns of Antarctic minke whales (*Balaenoptera bonaerensis*) are completely unknown. To understand these aspects of their biology, we deployed multi-sensor suction cup tags on two Antarctic minke whales in Wilhelmina Bay, Western Antarctica Peninsula, in February 2013. These whales fed almost constantly and at an average depth of 19 meters (max. = 106) on 1.5-minute dives (max = 9.4). Water filtered per unit time was 219 m^3/h, 18x less than a blue whale feeding at a similar depth. Average lunge rate was 112/h, four times higher than reported for baleen whales, including 40 dives with >15 lunges (max = 24). A significant relationship existed between feeding depth and lunge frequency overall, but k-means clustering suggests that several dive types exist, with differing combinations of depth, duration, and feeding rates. Feeding rate increased with depth in only the shallowest and shortest feeding dives. Our results provide the first direct observations of the subsurface behaviour of Antarctic minke whales, including feeding under sea ice.

Table 1. Summary table of tag deployments from 2009-2013 around the Western Antarctic Peninsula. Durations for suction cup tags are maximum lengths, for satellite tags they reflect average durations. Eight satellite tags remain active as of the time of this report, all transmitting for >115 days (3 minke and 5 humpback whales).

Tag Type	Species	Number	Duration
Multi-sensor suction cup	Humpback	23	24 hours
Satellite-position only	Humpback	30	>65 days
Multi-sensor suction-cup	Minke	2	19 hours
Satellite- position only	Minke	13	>60 days
Satellite- position & TDR	Minke	3	50 days

Conclusions

Through a series of collaborative, multi-disciplinary research cruises supported by the National Science Foundation, the Southern Ocean Research Partnership, and the Australian Antarctic Division, we have begun to quantify and understand the foraging ecology of baleen whales in Antarctic waters in unprecedented ways. From broad-scale density, distribution, and movement patterns we are beginning to understand the habitat of both humpback and minke whales in great detail. Our ability to successfully deploy these tags on minke whales for the first time is a significant achievement. We are in the process of completing quantitative habitat and movement models for both species that we will relate to changes in the physical and biological landscape. This information will allow us to then compare and contrast these sympatric krill predators in novel ways that will increase our ecological understanding of how changes in this region, and elsewhere, will affect these animals. From short-term multi-sensor recording tags, we have recently completed the first quantitative study of how the foraging and diving behaviour of humpback whales is affected by changes in the distribution, behaviour, and

abundance of Antarctic krill and this provides great insights into the energetic needs and consumption rates of these whales. Our recent success in deploying similar tags on Antarctic minke whales for the first time is another significant accomplishment. We are in the process of completing analysis of the diving behaviour, foraging strategies and kinematic patterns of these whales that will offer great insights into the energetic needs and consumption rates of these whales. We are also now in a position to compare and contrast the fine-scale and vertical habitats of minke and humpback whales to better understand how these sympatric krill predators partition resources.

The methodologies and analytical framework being used currently provide a template for future research across Antarctic regions that will allow us to better understand how the ecological relationships between baleen whales and their environment are affected by different oceanographic regimes, ice conditions, and prey availability. The success of our research also highlights the importance and utility of international and collaborative efforts to maximize the opportunities to conduct ecological research on cetaceans in Antarctica.

Challenges

We have made great strides in the field work and methodologies for conducting this type of ecological research, however challenges still remain in terms of being able to have dedicated vessel time and tags available for work with minke whales around the Antarctic Peninsula and Ross Sea. With our successes in deploying tags on both humpback and minke whales and conducting prey mapping surveys, it would be tragic not to have enough logistical support to continue to build on these accomplishments.

The other challenges that we face are the support for replicating our research model in other regions due to ship time and financial support from other countries. We have offered as much of our equipment as possible for collaborators to use if dedicated ship time and effort can be allocated.

Outlook for the future

We will continue to submit research proposals to the US NSF to conduct ecological research around the Antarctic Peninsula, with a focus on minke whales and better understanding their ecological role. This would include dedicated ship time to deploy both multi-sensor suction cup and satellite-linked depth recording tags and conduct prey surveys. We are confident that our results to date will generate significant interest in augmenting effort for this work.

As well, we are eager to help facilitate similar research with other National Antarctic research programs in other areas of Antarctica (e.g. East Antarctica, Weddell Sea), and will provide as much in-kind support for these efforts as possible and will help develop collaborative research proposals as the opportunities arise. We will also submit to the IWC SC a proposal to help support the purchase of satellite-linked dive recording tags that we can deploy on minke whales in 2014 to extend our temporal breadth and gain more insights into the seasonal distribution, movement, and behavioural patterns of minke and humpback whales.

Our goal is to have successfully completed similar ecological research on baleen whales in at least two other Antarctic regions within the 5-year span of our research proposal.

Request for SORP financial support for 13/14

We will not request financial support from SORP in 2013/14 with the knowledge that limited funds remain for all of the endorsed projects. Instead, we will approach the IWC SC to help procure tags to deploy on existing research cruises and allocated platforms.

Project outputs

We have published 10 peer-reviewed manuscripts relating directly to our current research, and have another 6 manuscripts in preparation. We have helped to support 3 PhD, >10 Masters, and 6 undergraduate students and 4 post-doctoral scholars through our research and have the opportunity to provide data for students in the future. We have generated significant interest in our research through mainstream media and university-supported platforms. We are completing work on a documentary film focusing on our research with the National Geographic Society.

References cited

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

Friedlaender AS, Johnston DW, Fraser WR, Burns J, Halpin PN, Costa DP (2011) Ecological niche modeling of sympatric krill predators around Marguerite Bay, Western Antarctic Peninsula. Deep-Sea Research II 58: 1729-1740, doi:10.1016/j.dsr2.2010.11.018

Friedlaender AS, Tyson R., Stimpert, Nowacek D. *Accepted with revisions.* Extreme diel variation in the feeding behavior of humpback whales along the Western Antarctic Peninsula in autumn. Marine Ecology Progress Series.

Friedlaender AS, Kaltenberg A, Johnston DW, Tyson RB, Stimpert RB, Hazen EL, Nowacek DP. *To be submitted 6/2013.* Prey-mediated optimal foraging behavior of humpback whales in Antarctica. Ecology Letters.

Friedlaender AS et al. *In review.* Breaking the ice: first records of feeding behavior and diving kimematics of Antarctic Minke whales, the smallest baleen whale. Nature Communications.

Johnston DW, Friedlaender AS, Read AJ, Nowacek DP (2011) Initial density estimates of humpback whales (*Megaptera novaeangliae*) in the inshore waters of the Western Antarctic Peninsula during late autumn. Endangered Species Research 18:63-71.

Nowacek DP, Friedlaender AS, Halpin PN, Hazen EL, Johnston DW, Read AJ, Espinasse B, Zhou M, Y Zhu (2011) Super-aggregations of krill and humpback whales in Wilhelmina Bay, Antarctic Peninsula. PLOS One 6(4) e19173.

Robbins J, Dalla Rossa L, Allen JM, Matilla DK, Secchi ER, Friedlaender AS, Stevick PT, Nowacek DP (2011) Mammalian migration record: implications for the recovery of an endangered species. Endangered Species Research 13:117-121.

Stimpert A, Peavey L, Friedlaender AS, Nowacek DP (2012) Humpback whale "loud noises": song and foraging behavior on an Antarctic feeding ground. PLoS One 7(12): e51214. Doi:10.1371/journal.pone.0051214

Tyson R, Friedlaender AS, Ware C, Stimpert A, Nowacek DP (2012) In Synch? Humpback whale mother and calf foraging behavior: insights from multi-sensor suction cup tags. Marine Ecology Progress Series, doi: 10.3354/meps09708

Ware C, Friedlaender AS, Nowacek DP (2010) Shallow and deep lunge feeding of humpback whales off the West Antarctic Peninsula. Marine Mammal Science, doi:10.1111/j.1748-7962.2010.00427.x

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

Rochelle Constantine[1], Debbie Steel[2] and Emma Caroll[1]

[1]School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland, New Zealand
[2]Oregon State University Marine Mammal Institute, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon 97365, USA

Introduction

Our understanding of the migratory routes and the summer distribution of humpback whale populations around Antarctica is based on information provided by Discovery tags, photo-identification, individual genotyping and satellite tagging. Generally these data are sparse and therefore patterns of distribution and mixing have not been described well for most of the seven populations.

An improved understanding of the movements and mixing of humpback whales around Antarctica is a priority for the IWC because such information is integral to the Recovery/Stock Assessments, a prerequisite of which is the allocation of catches to particular breeding populations. An improved understanding of the migratory and feeding behaviour of humpback whales would allow the more appropriate allocation of catches made in this region which would improve the accuracy of recovery assessments and estimates of pre-whaling population sizes.

The IWC population assessment process would benefit from a greater understanding of the distribution and mixing of all SH humpback whale populations but priority should now be given to Antarctic Areas V and VI where the complex E (Australia and western Oceania) and F (eastern Oceania and French Polynesia) endangered populations feed (see Constantine *et al.* 2010, SC/62/SH18). Although this project proposal focuses on these priority areas, coordinated research efforts in other regions would be highly desirable and in time should be developed.

With the success of the genotype and photo-ID matching between Antarctic Whale Expedition (Gales 2010; Constantine *et al.*, In Review) we propose to focus our efforts on using satellite telemetry to understand the connections between Oceania breeding grounds and feeding grounds (Garrigue *et al*. 2010; Gales *et al*. 2009, SC61/SH/17; Hauser *et al*. 2010). Reports from the Raoul Island (part of the Kermadec Island group) show October has a high density of whales passing nearby. Raoul Island is also the southernmost location with a high density of whales travelling south to Antarctica. American Samoa is an interesting area as it sits on the cusp of breeding stocks E3 and F and the whales travel east and west of this area (Garrigue *et al*. 2011b). For these reasons we propose Raoul Island and American Samoa as tentative locations for satellite tagging in 2014.

Objectives

The two main questions are:

1. *What is the connection between the humpback whales from Area V feeding grounds and their migratory corridors and breeding grounds in Australia and Oceania?*

2. *Do whales from Area V represent a single breeding ground or are they a mix of individuals from several distinct breeding grounds?*

Results

New Zealand genetic analyses:

Between 1998 and 2013, total of 212 humpback whale samples were collected from New Zealand from two sources; biopsy samples of whales on their northbound migration past Cook Strait (n = 193) and from stranded specimens (n = 19; Table 1). Of the 212 samples, 190 passed quality control (QC, 11 or more loci amplified), and comparison revealed there were 173 unique haplotypes. We compared genotypes to samples from the breeding grounds of Oceania (n=1,171) and a migratory corridor along east Australia (n=865). Comparison between NZ and Oceania revealed six matches (2 females and 4 males) to New Caledonia (n=387) and no matches to any of the other Oceania breeding grounds. There were also four matches to east Australia (3 males

and 1 female). Preliminary tests of differentiation based on mitochondrial DNA (mtDNA) haplotype frequencies showed the NZ migratory corridor differs from all sampled breeding grounds in this region; including east Australia and New Caledonia.

Table 1: Number of tissue samples collected from humpback whales from New Zealand during dedicated surveys (SURVEY) and beach-cast whales (STRANDING). The number of samples that generated DNA profiles that passed quality control are listed (N_{QC}), as is the number of unique DNA profiles per year (N_{UNIQUE}). The number of males, females and whales of unknown sex are listed by year also.

YEAR	SURVEY	STRANDING	TOTAL	N_{QC}	N_{UNIQUE}	M	F	U
1998	0	1	1	1	1	0	0	1
2003	0	1	1	1	1	0	0	1
2004	12	3	15	11	10	6	2	2
2005	11	1	12	11	11	7	3	1
2006	10	1	11	10	10	6	3	1
2007	10	1	11	11	11	7	2	2
2008	16	0	16	13	12	5	7	0
2009	20	5	25	16	15	8	4	3
2010	24	0	24	21	21	11	10	0
2011	43	1	44	43	37	23	11	3
2012	47	5	52	52	44	30	8	6
TOTAL	193	19	212	190	173	103	50	20

American Samoa and Independent Samoa genetic analyses

Between 2001 and 2012 a total of 131 samples were collected from the two Samoas (n=9 from Independent Samoa and n=122 from American Samoa, Table 2). Genetic profiling of these samples including sex, mtDNA dlp haplotype sequencing and microsatellite genotyping at 16 loci is being done following standard protocols. To date all samples have been extracted and attempted for sex determination and mtDNA haplotyping. Five samples were unsuccessful for sex and 15 for mtDNA and are being repeated. All samples collected up to and including 2009 (n=97) have been genotyped for 16 loci. Of these 97, n=5 failed to pass an initial quality control criteria of amplification at 9 or more loci (QC9) and are being repeated. Comparison of the n=92 samples that passed QC9 resolved n= 86 individuals with four within year resights and two between year recaptures (2004-2006 and 2007-2009). These individuals have also been compared to individuals from other regions within Oceania (n=1,084) and 14 between region matches were identified (n=7 to French Polynesia, n=4 to Tonga and n=3 to the Cook Islands, no matches to New Caledonia).

Currently the 2010 samples have been analysed for seven microsatellite loci and work is underway to complete these, the 2011 and 2012 samples and to repeat the n=5 samples from 2001-2009 that failed to pass QC9.

Table 2: Summary of sample analysis to date. N. samples is the number of samples collected in that region and year; N. mtNDA is the number of samples with a mtDNA haplotype; N. usats is the number of samples to pass QC9; N. individuals is the number of individuals after both within and between year replicates have been removed; M is the number of males; F is the number of females; Unk is the number with unknown sex. The shaded cells indicate completed data analyses.

Year	Location	N. samples	N. mtDNA	N. usats	N. Individuals	M	F	Unk
2001	Samoa	2	2	2	1	1		
2003	A. Samoa	19	19	19	17	12	5	

2004	A. Samoa	18	18	16	15	10	5	
2005	A. Samoa	8	8	8	8	7	1	
2006	A. Samoa	15	15	15	14	11	3	
2007	A. Samoa	11	8	10	10?	7	3	
2007	Samoa	6	4	5	5?	3	2	
2008	A. Samoa	5	4	4	4?			4
2009	A. Samoa	13	10	13	12	9	2	1
2010	A. Samoa	12	8	0	?	8	4	
2011	A. Samoa	21	19	0	?	18	3	
2012	Samoa	1	1	0	?		1	
Total		131	116	92	75	91	33	7

Conclusions

New Zealand

Even though preliminary analyses show differences in mtDNA haplotype frequencies between NZ and east Australia, they must be interpreted with caution as the majority of samples are from Cook Strait during the northern migration. Systematic surveys have not been conducted elsewhere in NZ despite a gradual increase in reports of whale sightings from coastal waters. The data analysis to date suggests that there is a mixing of whales migrating north past NZ and/or a contribution from an as yet unsampled migratory destination. Analysis of these data will continue using mixed stock and population assignment tests to determine the proportion of whales from each sampled breeding ground that pass through the NZ migratory corridor. Nonetheless, it is interesting to note that the findings are consistent with early historical 'Discovery' marking and reported photo-identification matches with New Caledonian breeding grounds (Garrigue *et al.* 2011a). Future surveys in other areas may answer some of the remaining questions about whales passing NZ.

American Samoa and Independent Samoa

The matches of Samoan whales to other Oceania regions are confined to the mid and eastern parts of the South Pacific. This is not unexpected and continues to match earlier findings using photo-identification data (Garrigue *et al.* 2011b). Whilst the genotype analyses need to be completed, it is clear the satellite tagging at Raoul Island in the western South Pacific and American Samoa more to the east will provide valuable data on humpbacks migrating south to their as yet undescribed feeding grounds.

Challenges

There have been issues with tag design that have delayed the onset of the planned tagging programme. These will hopefully be resolved later this year at the conclusion of research being conducted in the Gulf of Maine (Jooke Robbins and Alex Zerbini are contributing to this work). Funding remains an issue but grants are being pursued to further the research.

Outlook for the future

Funding for this research is still required and the Principal Investigators have requested funding from the New Zealand Government without success. Another funding application will be made in the next financial year but the ongoing support from SORP is appreciated.

References cited

Constantine R, Garrigue C, Steel D, Jackson J, et al. (2010) Abundance and interchange of humpback whales in Oceania based on fluke photo-identification and DNA profiling. Paper SC/62/SH18 presented to the Scientific Committee 2010.

Gales N, Double M, Robinson S, Jenner C, Jenner M, King E, Gedamke J, Paton D, Raymond, B. (2009) Satellite tracking of southbound East Australian humpback whales (*Megaptera novaeangliae*): challenging the feast or famine model for migrating whales. Paper SC61/SH/17 presented to the IWC Scientific Committee 2009.

Garrigue C, Zerbini AN, Geyer Y, Heide-Jørgensen M-P, Hanaoka W, Clapham P. (2010) Movements of satellite-monitored humpback whales from New Caledonia. Journal of Mammalogy 9:109-115.

Garrigue C, Franklin T, Constantine R, Russell K, Burns D, Poole M, Paton D, Hauser N, Oremus, M, Childerhouse S, Mattila D, Gibbs N, Robbins J, Clapham P, Baker CS (2011a). First assessement of interchange of humpback whales between Oceania and the East coast of Australia. Journal of Cetacean Research and Management (Special Issue) 3:269-274.

Garrigue C, Constantine R, Poole M, Hauser N, Clapham P, Donoghue M, Russell K, Paton, Mattila DK, Robbins J, Baker CS (2011b) Movement of individual humpback whales between wintering grounds of Oceania (South Pacific), 1999 to 2004. Journal of Cetacean Research and Management (Special Issue) 3:275-281.

Hauser N, Zerbini AN, Geyer Y, Heide-Jørgensen M-P, Clapham P (2010) Movements of satellite-monitored humpback whales, *Megaptera novaeangliae*, from the Cook Islands. Marine Mammal Science 26:679-685.

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

The SORP blue and fin whale acoustics steering committee: Flore Samaran[1], Kathleen Stafford[2], Jason Gedamke[3], Ilse Van Opzeeland[4], Brian Miller[5] with contributions from Olivier Adam[6], Mark Baumgartner[7], Sarah Mussoline[7] and Guillaume Pressiat[6].

[1] PELAGIS Observatory CNRS-UMS 3462, University of La Rochelle, France
[2] Applied Physics Lab University of Washington Seattle WA, USA
[3] NOAA Ocean Acoustics Program Manager Office of Science and Technology National Marine Fisheries Service Silver Spring, MD, USA
[4]Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven Germany
[5]Australian Marine Mammal Centre, Australian Antarctic Division, DSEWPaC, Hobart, Australia
[6] Centre Neurosciences Paris Sud CNRS-UMR 8195, Université Paris Sud, Orsay, France
[7]Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Introduction

The Southern Ocean Research Partnership (SORP) is an international collaborative initiative that started in 2009 in order to develop novel research techniques and conduct non-lethal research on whales in the Southern Ocean. One of the original five research projects of the SORP is the Blue and Fin Whale Acoustic Trends Project which aims to implement a long term acoustic research program that will examine trends in Southern Ocean blue and fin whale population growth, distribution, and seasonal presence through the use of passive acoustic monitoring techniques.

Sighting surveys are traditionally the means by which cetacean population abundance estimates are obtained. In the Southern Ocean however, these surveys are few and far between due to the particularly difficult working environment and the costs of surveys, and are also restricted by the inherent limitations of visual surveys (e.g. daylight, weather, sea ice, visual detection range, etc.) (Thomas *et al*. 1986, Leaper and Scheidat 1998, Gillespie 1997). The acoustic techniques proposed here, however, overcome many of these difficulties with data that are relatively inexpensive to obtain, and can be collected continuously for years on end, under ice cover, and in any weather conditions or sea-states. Obtaining accurate absolute abundance estimates from passive acoustic data is challenging. A suite of statistical methods has been developed (Thomas and Marques 2012, Marques *et al.* 2013) but absolute abundance estimation from passive acoustic data relies strongly on detailed knowledge about the vocal behaviour of a given study species. For most cetacean species, including blue and fin whales, vocal behaviour is relatively poorly understood and so accurate absolute abundance estimates from passive acoustic data are currently unobtainable. This highlights the need for further behavioral studies to complement passive acoustic monitoring efforts. However, in the absence of appropriate behavioral information, acoustic datasets can be consistently analysed to give easily comparable measures of calls densities, which, under certain assumptions, may be interpreted as measures of relative abundance. Comparison of relative abundance estimates from individual locations across many years, whether collected by visual surveys (Noad *et al.* 2008) or acoustic surveys similar to that proposed here (*e.g.* Stafford *et al.* 2009), can provide an indication of population growth. Comparison of relative abundance estimates within and between locations and years can further be used to assess trends in distribution and seasonal presence over time (Širovic *et al*. 2004, Stafford *et al.* 2009).
In 2011/2012, after the analysis of all the available acoustic data showing the geographic and seasonal occurrence of blue and fin whales around the Antarctic, the Group concluded that a coordinated effort to collect new acoustic data using consistent spatial and temporal coverage, instruments and analysis methods, would be the best way forward. We met in fall 2012 to review ongoing work on Southern Hemisphere blue and fin whale acoustics, discuss current and future data collection and analysis efforts, and to refine the vision of the project into a strategic plan that can be used to guide research efforts over the next five years. Among the discussions, strategies were decided including **collection of new data** through future instrument deployments in each of the six IWC management areas and **analysis of the data** through the production of blueprints of analysis methods. These two main projects will be discussed in this current report.

This year we are pleased to have new members of our steering group. Dr. Ken Findlay from the Mammal Research Institute Whale Unit, Pretoria, South Africa has joined the Group as the lead of the South African Blue Whale Project (SABWP), which will be using acoustic monitoring to define the distributions and seasonality of Antarctic blue whales in the south-eastern Atlantic and Southern Ocean south of South Africa. This new project could be highly integrated with the SORP Blue and Fin Whale Acoustic Trends Project, which focuses largely

on long-term acoustic recordings, as well as the complimentary SORP Antarctic Blue Whale Project, which focuses on blue whale abundance, population structure and in-situ observations of behavior. Dr. Danielle Harris, who works in Len Thomas' research team at the Centre for Research into Ecological and Environmental Modelling (CREEM), University of St Andrews, has joined the Group as well and provides expertise in the use of passive acoustic data from single instruments for adundance estimation.

Objectives

Passive acoustic monitoring is a robust means of monitoring blue and fin whales in remote areas over long time periods, including around the Antarctic. The analysis of all the available data has shown the geographic and seasonal occurrence of blue and fin whales around the Antarctic (SC/64/O13). However the lack of overlap in the years and locations monitored, and the differences among instruments and analysis methods used, underlines the need for coordinated effort. To best exploit passive acoustic data in the long term, the placement and maintenance of a pan-Antarctic monitoring system has been proposed. Further, blueprints for analysis methods for each species are being prepared to suggest how data might be analysed in a uniform manner.

Collection of data: Towards a pan-Antarctic monitoring system

Spatial Coverage

Ideally, continuous circumpolar acoustic monitoring would be conducted over multiple decades. However, it was generally acknowledged that this ideal spatiotemporal coverage was not possible based on cost and logistics. Logistics in particular, dictated that multi-year datasets could only be reliably collected along supply routes for Antarctic stations and oceanographic moorings that are serviced regularly. Further, instruments or instrument packages have to be simple to deploy and retrieve to minimize ship time spent on mooring operations. Circumpolar coverage is important in order to provide an indicator of changes in population numbers or relative abundance that might otherwise be confounded with changes in distribution. It is a realistic goal to attempt to have at least one instrument in each of the six IWC management areas. A list of previous, present, and planned deployments was compiled. The resulting map (Figure 1) reveals that the Alfred Wegener Institute (AWI) has excellent coverage of Area II. The British Antarctic Survey (BAS) is applying for funding for instrumentation for Area II including South Georgia. The University of Brest in collaboration with the PELAGIS UMS 3462-CNRS (Centre de Recherche sur les Mammifères Marins) has had good coverage in the Indian/Subantarctic Ocean (between Areas III and IV) since 2010 and until 2015. Planned deployments by the Australian Antarctic Division will provide coverage of area IV in 2013/14, while collaboration between the PELAGIS UMS 3462-CNRS (Centre de Recherche sur les Mammifères Marins) and the Australian Antarctic Divsion would provide coverage of Area V. The Group also recommended that a series of acoustic moorings be maintained between 0 and 20°E (the area that the SABWP will be monitoring) to improve coverage of Area III. Areas I and VI were identified as areas in need of monitoring effort with few historical recordings (especially Area VI) and no planned data collection in either area in the near term.

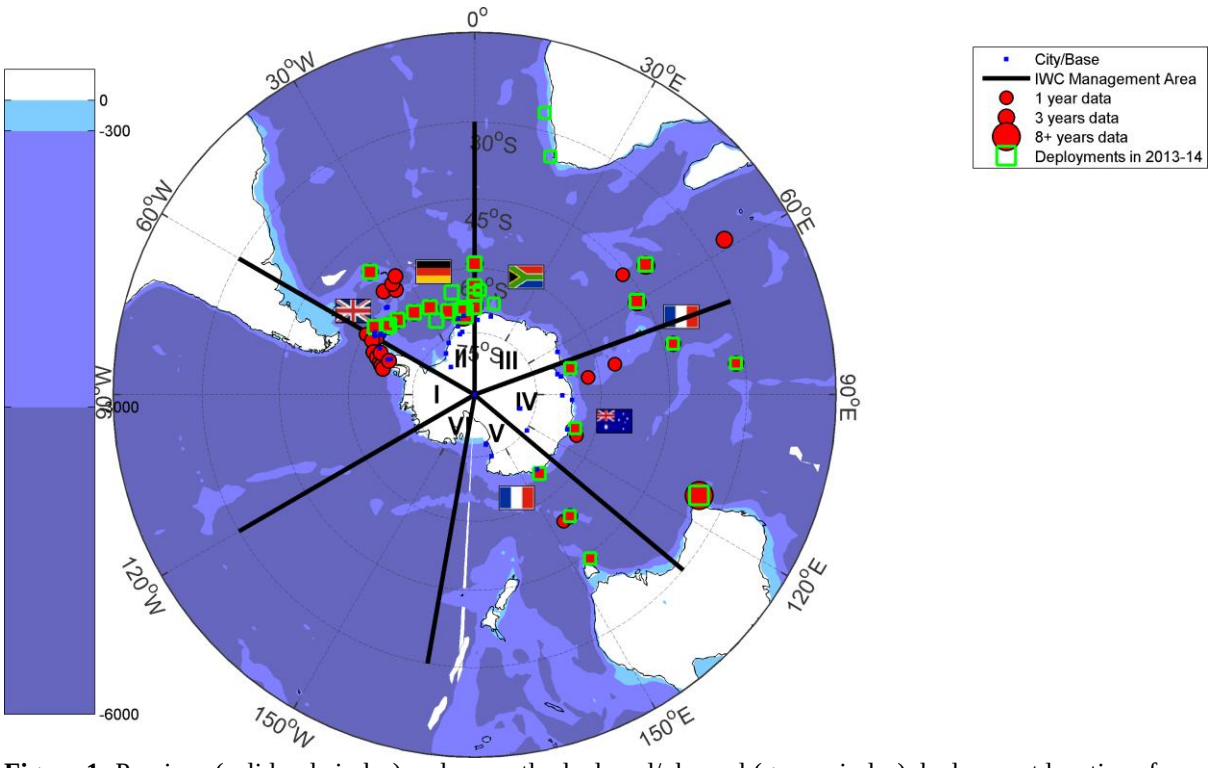


Figure 1: Previous (solid red circles) and currently deployed/planned (green circles) deployment locations for long-term acoustic recorders. The size of the symbol is proportional to the duration of the data collection. Blue squares indicate Antarctic stations on the continent. Light blue shading indicates areas shallower than 300 m. Light purple indicates areas between 300 and 3000 m depth. Dark purple indicates areas deeper than 3000 m. Blue dots indicate Antarctic stations.

Temporal Coverage

Consistency of data collection over a long time period was identified as a top priority to be addressed by the project. It was recommended that, initially, data collection at available sites should be continuous over the first six years of a deployment in order to include at least one El Niño/Southern Oscillation event. Furthermore, data collection over long periods increases the chances of temporal overlap of data collected at different sites. A review of trends after the first six years of data collection would then determine the future requirements for data collection (e.g., every other year, or every fourth year). It was suggested that instruments should record continuously, in order to facilitate comparison of inter-call intervals within and between sites. If a duty cycle is logistically necessary however (e.g. due to the length of the deployment), each recorded sample should be long enough to include at least several calls for these measurements. To measure acoustic trends over the suggested time period, changes over this time must be greater than the baseline inter-annual variation. However, presently there is not sufficient understanding of baseline inter-annual variation, and thus multi-year data collection in sufficient sites must first occur before this can be investigated further.

Blueprints of analysis methods

The previous review of existing analysis methods demonstrated that the scientific question of interest will drive the analysis methods chosen. In our project there were two main questions: 1) where and when are blue and fin whales present? and 2) what are the relative acoustic densities of both species and do they show temporal patterns? The aim of the blue and fin blueprint manuscript is to provide an overview of available analysis methods and identify the most suitable method that can answer these questions. Furthermore, the blueprint will provide details on the precision and accuracy of the available methods, how the chosen method applies to the research questions, the type of data required (continuous/subsampled) and the feasibility of applying the chosen method for 'regular users' (i.e. non-acousticians/programmers).

For the moment we focus on Antarctic blue whale calls and our approach is to work on available datasets from PALAOA (AWI) and DEFLO-HYDRO (PELAGIS) projects.

The PALAOA dataset for blue whale calls

Different subsets of data (e.g. one month in which the blue whale 28Hz band is present, one month in which clear single calls are present, one month with lots of ice-breaking sounds/background noise, one month with no/few calls) will be selected from the PALAOA data Subsampled data sets will then be created (to simulate a subsampling recording regime) and analyses performed on the continuous and subsampled data sets using different methods (LTSA, PSD, spectrogram cross-correlation (XBAT) and applying a blue whale equivalent of the 'fin-index', see Nieukirk et al. 2012). Different ways of validating the output of automated analyses will be explored. Subsampling regimes will be evaluated further by deriving representative information on call rates and intercall intervals for the purpose of acoustic density estimates.

The DEFLO-HYDRO dataset for the blue whale calls

The DEFLO-HYDRO dataset will be examined to explore how to best exploit a dataset to extract the most information possible. We will test the effect of the recording regime to obtain seasonality of different types of detected whale calls. Other questions to be addressed include: how do detections of D calls versus 28 Hz calls affect assessments of Antarctic blue whale occurrence and seasonality?; what is the importance of validating automatic detection output and what should the standard for doing this be?; how important is obtaining the SNR of each detected call?; how does monthly ambient noise variation affect the detection radius?; are there diel patterns in call detections?

A second blueprint for fin whale calls will be developed separately.
The output of the blue whale and fin whale blueprints will be a recommended standard for analyzing PAM data for fin and Antarctic blue whale presence and relative abundance and a 'recipe' of how to best analyze acoustic data based on the scientific question of interest.

Moving towards abundance estimation from acoustic data

Acoustic data from sparsely distributed arrays of hydrophones (effectively operating as single hydrophones) present a number of specific challenges to abundance estimation. Firstly, as with all abundance estimation methods using acoustic data, we need to improve our knowledge of the acoustic behavior of the study species, specifically the average rate of call production. Secondly, the probability of detecting calls in a given area around the instruments also needs to be estimated (this accounts for calls that were produced but were missed by the recording or detection process). For "single sensor" data, the probability of detection is estimated in a simulation-based framework using information about the call source level, sound propagation (requiring environmental information), ambient noise levels and the efficiency of the automatic detector being used (Küsel *et al*. 2011; Marques *et al.*, 2013). In summary, the statistical methodology to estimate the abundance of whales from acoustic data collected on sparsely distributed instruments has been developed and we anticipate that if we improve our understanding of the factors above, and have a carefully considered survey design, abundance estimation using passive acoustic data may become the state of the art for monitoring Antarctic blue and fin whales. The unique opportunity to collect behavioral data simultaneously with acoustic recording during the 2013 ABWP voyage is one example of how we can acquire important auxiliary behavioral information, and every opportunity to collect further data about the vocal behaviour of blue and fin whales should be taken.

Note: the SABWP has applied for and received access to analyze recordings from the IWC SOWER sonobuoy dataset which includes over 750 deployments around the Southern Ocean. A PhD student has been appointed, and transfer of these data for analyses and student training are currently being organized.

Results

Collection of data: Towards a pan-Antarctic monitoring system

Alfred Wegener Institute (AWI)

Currently, 16 deep-sea moorings provide the platform for the acoustic recorders maintained by the AWI in the Weddell Sea and along the Greenwich Meridian south of 59° S. Moorings are maintained every second or third year, using the AWI's icebreaking research vessel 'Polarstern'. In December 2010, a first set of four recorders were recovered and partly redeployed along with additional new recorders, resulting in a total of 10 moored recorders (Figure 2). In 2012, 7 recorders were exchanged and additional units were deployed. Three recorders

had to be left in place due to heavy ice conditions preventing access to the mooring location. Now a total number of 24 passive acoustic recorders await their recovery in 2014/2015. Four moorings are equipped with recorders at different depths (~200, ~100 and ~2500m) to compare reception over different parts of the water column. Two types of acoustic recorders, SonoVaults (Develogic GmbH, Hamburg, Germany) and AURAL (Multi-Électronique (MTE) Inc., Quebec, Canada) are included in the moorings. The SonoVault version that was recovered in 2012 was the first generation of this recorder type which was custom-developed to meet the requirements of collecting continuous acoustic records during long-term deployments at depths around 1000m. These requirements are partly related to the mooring design and maintenance cycle and the presence of ice bergs. In the Southern Ocean, moorings are generally equipped with the top floatation not shallower than 200 to 250 m below sea-surface, to avoid being displaced by passing ice bergs, which exceeds the pressure rating of most recorders. Apart from some issues with electronic noise which are currently under evaluation, the recorders performed well and recorded between 6 and 21 months.

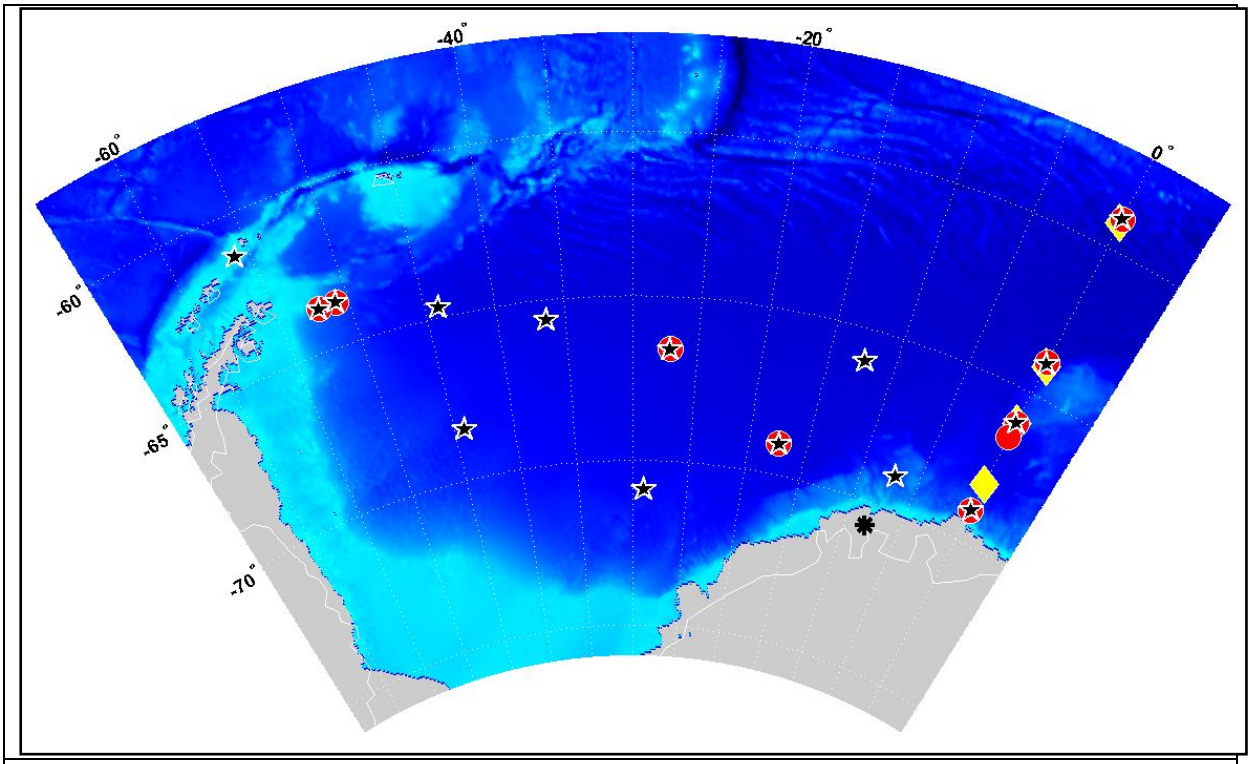


Figure 2: The AWI's oceanographic moorings in the Atlantic Sector of the Southern Ocean containing passive acoustic recorders. Yellow diamonds indicate recorders that operated between 2008-2010, red circles are recorders that collected data from 2010-2012 and black stars are moorings with recorders that were deployed in 2012 that will be recovered in 2014/15. The black asterix indicates the German research station Neumayer III.

Australian Antarctic Division (AAD)

In January 2013 on the resupply voyage to Davis Station, the Australian Antarctic Division deployed a prototype acoustic recorder and stand-alone long-term mooring (location: 66.6°S, 77.7°E, 1787 m depth). The mooring was designed to be easily deployed and recovered from Antarctic supply vessels and to minimise the deployment and recovery time of the instrumentation. The basic mooring design includes glass floatation spheres and a glass instrument housing mounted into a titanium frame. The titanium frame is attached via a nylon strap to a pair of acoustic releases, which are in turn connected via a nylon strap to a heavy anchor. The recorder electronics sample at 12 kHz 16-bit depth and storage includes up to 64 SD cards with an expected battery life in excess of 15 months of continuous recording. This prototype recorder and mooring will be recovered after 8-12 months of continuous data acquisition at 12 kHz sample rate. The Australian Antarctic Division is currently building 3 more recorders and moorings to be deployed this year, and an additional 4 the following year in order to enable continuous recording at four Antarctic locations yet to be determined.

The OHASISBIO project

In the sub-Tropical and sub Antarctic part of the Indian Ocean, 9 deep-sea moorings provide the platform for the acoustic recorders maintained by the University of Brest (France) in collaboration with the PELAGIS UMS 3462-CNRS and the Centre d'Etudes Biologiques de Chizé (UPR 1934). Moorings have been maintained since

2010, using the research vessel Marion Dufresne. Every year, each recorder is recovered and redeployed at the same site. The recorders are custom-developed by the University of Brest to meet the requirements of collecting continuous acoustic records during long-term deployments in the SOFAR channel (~ 800 – 1300m). The southernmost stations (~ 46°S) are composed of a triplet of hydrophones moored between Crozet Islands and Kerguelen Island (Figure 3). Apart from some issues with electronic noise which are currently under evaluation, the recorders performed well and recorded between 10 and 21 months.

In May 2013, a meeting will be held at Paris to write a proposal to moored one acoustic recorder in the supply voyage to DDU Station using the Astrolab vessel in 2014/2015.

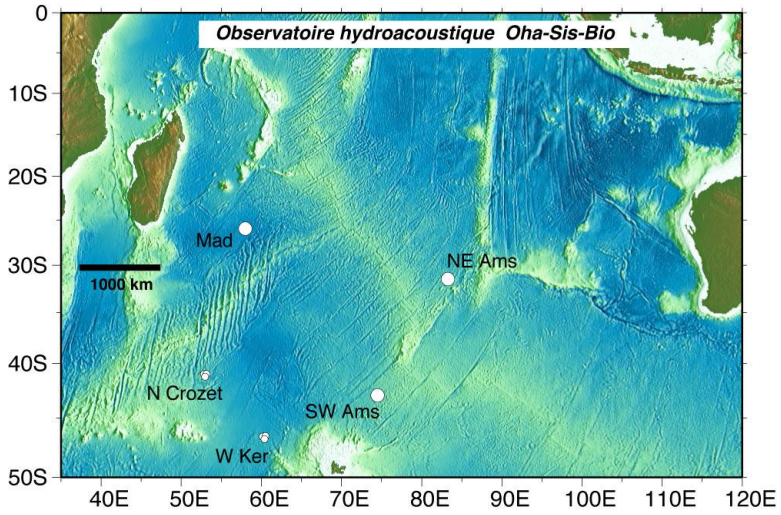


Figure 3: Map showing the positions of the recorders of the OHASISBIO project in the sub-tropical and sub Antarctic part of the Indian Ocean.

List of underwater acoustic recording devices

In recent years there has been a proliferation of long-term underwater recording devices with a variety of different specifications, prices, and scenarios of intended usage. The Group has begun to compile a list of these recorders with links to manufacturers as a resource to potential collaborators (Appendix A). Due to the rapid nature of technological developments in underwater recording devices this list should be used only as a starting point rather than the final word on these devices.

The blueprint of analysis methods

Analyses for the blue whale blueprint are currently in progress. However we can already present a few new results:

Effect of the recording regime to obtain seasonality of Antarctic blue whale using 28 Hz calls

We used an automated correlation method (XBAT) to detect stereotyped Antarctic blue whale calls through one year of continuous recordings and through the ten first minutes of each hour in order to simulate a subsample if recorded with 10 min ON / 50 min OFF. The seasonality of the number of calls detected was compared between the two datasets and no significant difference in seasonal pattern occurred between the analysis on the whole and the subsample datasets.

Are there diel patterns in call detections?

By exploring one year of records from a Sub Antarctic station (SWAMS from Deflo-Hydro dataset) we know that the number of Antarctic blue whale calls detected differs during the day and nighttime, across all seasons. The evidence of a diel pattern in calling activity might help to understand the behavior of the calling whales. These new results highlight the importance of performing an analysis on a continuous dataset or at least with an hourly subsample.

Conclusions

The two main objectives of the Group have been clearly aimed towards the best exploitation of passive acoustic data in the long term. The installation and maintenance of a pan-Antarctic PAM monitoring system and the blueprints for analysis methods for fin and blue whales are ambitious projects, but given the Group's multi-disciplinary and multi-national composition, and therefore large network and broad range of expertise, we trust to reach this goal in the near future. The project is still in its early stages, but important progress was made in 2012/2013. Additional collaborators and financial support are required, particularly in regard to circumpolar data collection. The project has much to offer to potential collaborators, and at present, the project has good support from the Australian, French, and German polar programs, with future support from the South African Antarctic program under consideration. Despite the long-term focus of the project, it is expected that there will be substantial output in the form of peer-reviewed publications as well as guidelines and recommendations from the Group.

Challenges

At present, there are numerous international partners who would be willing to deploy and retrieve acoustic recorders. The biggest challenge is *which* recorder to use and *where* to find funding for these. Once these challenges have been overcome, getting instrumentation to different collaborators, and retrieving and archiving data will become the next challenges. Ideally, this project would present an opportunity for graduate students or young scientists to be trained in PAM methodologies and data analysis.

Outlook for the future

- In summer 2013, the Group will organize another meeting in Europe which focuses on data analysis of Antarctic blue whale calls for the blueprint. The aim of this workshop will be share and exchange new results and start a draft of the blueprint manuscript for the analysis of blue whale data. Financial support for travel and accommodation is needed.

- In 2013/2014 the Group will focus on the blue whale blueprint. Financial support is needed for graduate student or young scientists to perform the analyses.

- The Group would like to develop a PAM data archive. A need to have a central and standardized location for recording metadata with links to actual data was identified by the Group as important in order to facilitate analysis of trends among different sites and over different time scales. Suggestions for metadata storage included the data catalogue for the International Whaling Commission, the PANGAEA information system (http://www.pangaea.de/about/), the Australian Antarctic Data Centre (http://data.aad.gov.au/), and the Australian Ocean Data Network (http://portal.aodn.org.au/webportal/).

- Propose leasing/funding structure for countries to acquire (standard, easy deployable) recorders?

Project outputs

Papers

Samaran F, Stafford KM, Branch T, Gedamke J, Royer J-Y, Dziak RP, Guinet C. Seasonal and geographic variation of southern blue whale subspecies in the Indian Ocean. PLoS One (*In Revision*)

Samaran F, Stafford KM, Diel variation of acoustic behaviour of southern blue whale subspecies in the Indian Ocean. (*In Prep*)

Reports

The SORP acoustic trends steering group. SORP Blue and Fin Whale Acoustic Trends Project: Report of 2012 steering committee meeting

Conference presentations

Olaf Boebel (Ocean Acoustics Lab, AWI) - SOOS meeting in Hobart in November 2012.

Samaran F, Stafford KM, Pressiat G, Adam O, Royer J-Y Guinet C. (2013) Geographic, seasonal and diel patterns of Antarctic blue whales calls in the Indian and Southern Oceans. 27th European Cetacean Society, Setubal, Portugal- Samaran F (2013) A l'écoute des baleines bleues : l'observatoire acoustique dans les océans Indien et Austral. Marine mammals day, Museum National d'Histoire Naturelle, Paris, France

Miller B (2013) Passive acoustic research on whales in the Southern Ocean. Marine Mammals and Ocean Sound TTCP Maritime Systems Group Outreach Workshop. DSTO, Canberra, Australia. 5 November 2012.

Submitted to SMM:

The SORP acoustic trends steering group. Listen to the blue: Towards a pan-Antarctic monitoring system and blueprint of analysis methods to study Antarctic blue whales in the Southern Ocean

Thomisch K , Boebel O, Clark CW, Kindermann L , Rettig S, van Opzeeland I Spatio-temporal patterns of Antarctic blue whale (*Balaenoptera musculus intermedia*) vocal behaviour in the Weddell Sea

Samaran F, Stafford KM, Royer JY, Guinet C Diel variation of the acoustic activity of two blue whale subspecies in the Indian and Southern Oceans

References cited

Küsel ET, Mellinger DK, Thomas L, Marques TA, Moretti DJ, Ward J (2011) Cetacean population density estimation from single fixed sensors using passive acoustics. Journal of the Acoustical Society of America 129:3610-3622.

Leaper R, Scheidat M (1998) An acoustic survey for cetaceans in the Southern Ocean sanctuary conducted from the German government research vessel Polarstern. Report of the International Whaling Commission 48: 431-437.

Leaper R, Gordon J (2001) Application of photogrammetric methods for locating and tracking cetacean movements at sea. Journal of Cetacean Research and Management 3(2):131–141.

Marques TA, Thomas L, Martin S, Mellinger D, Ward J, Moretti D, Harris D, Tyack P (2013) Estimating animal population density using passive acoustics. Biological Reviews. Article in online-early form at publisher's web site: doi:10.1111/j.1748-7692.2011.00561.

Noad MJ, Dunlop RA, Paton D, Cato DH (2008) An update of the east Australian humpback whale population (E1) rate of increase. Paper SC/60/SH31 presented to the IWC Scientific Committee, Anchorage. Unpublished.

Širović A, Hildebrand JA, Wiggins SM, McDonald MA, Moore SE, Thiele D (2004) Seasonality of blue and fin whale calls and the influence of sea ice in the Western Antarctic Peninsula, Deep-Sea Research, Part II 51:2327–2344.

Stafford KM, Citta JJ, Moore SE, Daher MA George J (2009) Environmental correlates of blue and fin whale call detections in the North Pacific Ocean, 1997-2002. Marine Ecology Progress Series 395:37-53.

Thomas L, Marques TA (2012) Passive acoustic monitoring for estimating animal density. Acoustics Today 8(3):35-44.

Thomas JA, Fisher SR, Ferm LM, Holt RS (1986) Acoustic detection of cetaceans using a towed array of hydrophones. Report of the International Whaling Commission (Special issue 8): 139-148.

Table 1 : Summary of 'long-term' acoustic recording devices

Name	Make	Storage Capacity	Battery Capacity	Depth Rating (m)	Purchase/lease
SM2M[a)]	Wildlife Acoustics	512 GB	42 days		Purchase
icListen LF[b)]	Ocean Sonics	32 GB	External battery	3500	Purchase
DSG[c)]	Loggerhead Instruments	256 GB	6 months	6000	Purchase
Aural M2[d)]	Multi Electronique	640 GB	200 days +	300	Purchase
Sono.Vault[e)]	Develogic Subsea Systems	4 TB	3 years	6000	Purchase
RUDAR[f)]	Cetacean Research Technology	TB	Days	1000	Purchase
USR[g)]	Curtin University	640 GB	1year +	3000	Leased
AMAR G3[h)]	JASCO	4 TB	6 month	2500	Leased
MARU[i)]	Cornell University Bioacoustic Research Program	120 GB	90 days	6000	Leased
(H)ARP[j)]	Scripps Whale Acoustics Lab	2 TB	Year	6000	Leased
AAD Moored acoustic recorder	Australian Antarctic Division	2 TB	15+ month	3000	Build your own (designs available)

a) http://www.wildlifeacoustics.com/products/marine-monitoring,
b) http://oceansonics.com/products/
c) http://www.loggerheadinstruments.com/
d) http://www.multi-electronique.com/pages/auralm2en.htm
e) http://www.develogic.de/products/ss-r/sonovault/
f) http://www.cetaceanresearch.com/hydrophone-systems/rudar/index.html#rudar
g) http://cmst.curtin.edu.au/products/usr.cfm
h) http://www.jasco.com/
i) http://www.birds.cornell.edu/brp/hardware/pop-ups
j) http://cetus.ucsd.edu/technologies_AutonomousRecorders.html
All URLs accessed on 12 December 2012.

ANNEX 2 - Southern Ocean Research Partnership (SORP) Workshop
Buenos Aires, 17-18 April 2013
Miguel Iñiguez[1]

[1]*Alternate Commissioner of Argentina to the IWC*

Summary

- The countries Argentina, Brazil and Chile, as foundation members of SORP, attended. Ecuador, as a new member, was warmly welcomed. Peru and Uruguay showed interest but were unable to attend.
- The participants reinforced their commitment to non-lethal methods of research on whales.
- A summary of Latin American 2013 research projects of SORP/ Antarctic Blue Whale Project (ABWP) was presented, including the recent Australian voyage using non-lethal techniques, the Argentinean voyage of 'Puerto Deseado', and Chilean work on the IWC photo identification catalogue.
- The potential resources from Latin American countries were discussed and the capacity for whale research investigated.
- Argentina announced the availability of the 50 m vessel 'Tango' for research in 2013-2014.
- The opportunities for capacity building for whale research amongst Latin American nations were discussed.
- To continue the momentum of the workshop held in Buenos Aires, a proposal for a coordinator was considered.
- A report from the meeting will be presented to the IWC/ SORP/ ABWP meeting in Korea in May 2013.
- A press release was prepared by Argentina in order to communicate the results of the meeting.

1. Welcome

The workshop was officially opened by Victor Marzari, IWC Alternate Commissioner of Argentina, who welcomed the participants and thanked the Australian government for the cooperation in this project. In his inaugural speech, Argentina's Commissioner also informed that Argentinean Coast Guard offered one of its vessels for non-lethal whales research.

Chris Schweizer, IWC Alternate Commissioner from Australia, thanked Argentina for hosting the meeting and the Buenos Aires Group for its particularly important role in non-lethal research. Australia's Commissioner also thanked Argentina for the offer of the vessel and pointed it out as an exciting opening of the meeting.

2. Appointment of Chair and Rapporteur

Miguel Iñíguez Bessega was elected Chair. Carolina Cassani was appointed rapporteur.

3. Review and adoption of Agenda

The Chair welcomed the participants to the workshop and thanked the Australian government for the support to this project. He also mentioned that Peru and Uruguay were also invited to the meeting but weren't able to participate, they will be informed about the outcomes.

The adopted agenda is given as Annex B and includes an invitation from the Argentinean Coast Guard to a reception at the 'Houssay' vessel.

4. Workshop details

Dr. Victoria Wadley, Scientific Coordinator of the ABWP, gave an update on SORP: an international consortium of scientists investigating the status of Southern Ocean whale populations using non-lethal techniques such as photo-identification, genetics and satellite tagging. Further details of SORP and its projects can be found at http://www.marinemammals.gov.au/sorp

Annex C shows the governance structure for the ABWP of SORP.

Dr. Wadley shared with the participants the results of the 2013 Whale Research Voyage together with the details

of the prioritized objectives, studied area, the vessel, techniques and equipment used. This information can be found at the report to IWC 65 Scientific Committee.

The participants showed very much interest in the use of acoustic techniques and devices. After a discussion it was concluded that it would be useful to consider a cooperative purchase of acoustic equipment.

Workshop objectives

Iñíguez Bessega presented the core objective of this workshop, which is to coordinate whale research efforts amongst Latin American countries members of SORP in Antarctic Peninsula area.

5. SORP projects standards

It´s recognized that there are different ways of engagement. Australia provided core funding for the development of this program, meanwhile other countries are able to contribute in some other ways: vessel time, researchers, etc. All these contributions could be coordinated through the technical committee.
In order to facilitate the collection of data and analysis, it was pointed out the need of bringing acoustic recordings, photo identification and DNA samples together.

It was noted that a data sharing and archive policy for the SORP has been discussed in previous meetings and was agreed that any further protocols will be defined by the ABWP Technical Committees.

The participants took note of the importance of building up a list of regional experts that could participate in the SORP. The Australian representative expressed they have a small team already allocated to the SORP but offered to share expertise and train Latin American scientists. They also discussed the importance to identify needs to run these projects, such as funding, vessel time, human resources, equipment, etc.

Antarctic Peninsula is where many vessels from Argentina, Brazil, Chile, Peru and other countries operate. Barbara Galetti, IWC Chilean Scientific Advisor expressed the worry of the consequences of a lack of coordination that could lead for example to an overlapping of vessels in one determined area at the same time. She also mentioned the need to consider a long term period, at least a decade, for the research.

These considerations were accepted and options to avoid the vessels overlapping would be considered as for example each country could send a vessel in turns to the zone, and/ or it could be geographically divided into Atlantic and Pacific.

Dr. Wadley pointed out the fact that South America is a route for tourist cruises to Antarctica. She suggested the group could think about how to use these vessels as opportunistic platforms. She expressed also the need to develop an analysis team to bring together all the data (samples, photo ID, acoustic).

6. The Antarctic Blue Whale project 2013/ 2014

The Antarctic Blue whale is a species that was heavily exploited by the whaling industry because of its large size, carrying the population to <1% of its original size nowadays.

The aim of the ABWP is to make a circumpolar survey to find out the present status of the population.
Dr. Wadley introduced the results of the 2013 ABWP voyage at the Ross Sea. The results, objectives, techniques of this research can be found at www.marinemammals.gov.au/iwc-inititives/bluewhale-sorp. Some highlights of the Dr. Wadley's presentation were:

- They found many more blue whales than expected
- The acoustic technique showed to be very successful to trace the whales after their calls are heard.
- The mark-recapture technique with assistance of acoustics is the most efficient approach.
- The importance of reinvesting year after year

Dr. Wadley also shared a video produced by scientists on the ship, just to give a flavour of the working conditions.

Afterwards, the 2013-2014 project was discussed: to look how to work in a cooperative way in the Antarctic

Peninsula. Participants noted the need to optimize regional resources.

Three options for engagement in the ABWP were discussed:

1. **Ideal Option** *research vessel with ice-strengthened hull*
Vessel with capacity for biological and oceanographic studies. Dedicated sea time as part of an integrated, multidisciplinary marine science voyage, to characterise the habitat and undertake passive acoustic studies and biopsies of blue whales. Elements of Options 2 and 3 could be included.

2. **Intermediate Option** *vessels with ice-strengthened hulls*
Vessels with capacity for consecutive days at the ice edge, to undertake passive acoustic studies and biopsies of blue whales. Opportunistic sea time as part of operational voyages or in conjunction with other research studies. Elements of Option 3 could be included.

3. **Transit Option** *vessels to deploy acoustics moorings*
Vessels in transit and platforms of opportunity, for annual deployment and retrieval of acoustics moorings. Likely locations are around the Antarctic Peninsula, however final positions will be determined after discussion.

The participants discussed the vessels that are operating in the Antarctic Area and agreed to consider future available options for their potential participation in the projects. It was agreed that an updated list should be compiled.

The value of continuing to use all the vessels available as platform of opportunity was noted (i.e. supply vessels for Antarctic bases, cruise ships, etc) being aware of the fact that routes are established and fixed.
The participants noted the challenges to date of sighting Antarctic blue whales around the Antarctic Peninsula and the high degree of effort involved. Notwithstanding these challenges the participants were of the view that ongoing effort was worthwhile. The participants also noted useful opportunities to participate in other existing SORP projects:

- Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean.
- Foraging ecology and predator-prey interactions between baleen whales and krill: a multi-scale comparative study across Antarctic regions.
- Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean.
- What is the distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica?

The group discussed the possibility of a new specific project for the Antarctic Peninsula taking into consideration the regional needs and resources.

In the context of highlighting the importance of the training in the field in order to share knowledge and standardize methodology, an offer made by Chile to organize a capacity building workshop in Chiloe Island in 2014 for ABWP was warmly welcomed.

7. Latin American country participation in the SORP/ ABWP

Argentina presented results of an opportunistic survey performed from 19/Feb to 15/Mar from 'Puerto Deseado' vessel in the Scotia Sea. In 214.4 hours of sightings effort, 138 sights from 10 different species of cetaceans, mainly fin and humpback whales. The total travel distance covered by the survey was of 4.329 nautical miles. The results of this planned annual survey will be presented at the IWC65 Scientific Committee in 2013.

Chile presented the website http://www.simposioballenas.cl where all information regarding the SORP project Living Whales Symposium is available. It was a very high-quality symposium with international experts. Centro de Conservación Cetácea (CCC) is working on Blue whale photo identification under the auspices of IWC. They developed an online program for people to upload pictures (Southern Hemisphere Blue Whale Catalogue).It was noted that pictures taken by Australian researchers were yet to be provided to the coordinators of the catalogue. Australia agreed to follow-up on this action.

The group noted that the opportunistic surveys and the Blue Whale Photo Identification Catalogue are very important projects that need to be continued. The catalogue is central to the mark recapture method for the estimation of abundance.

Ecuador reported that there are very few reports of Blue whales in their waters.

Brazil expressed its government's commitment to the conservation of whales and non-lethal research.

8. Use of vessels for whale research

At this section there was a presentation on Oceanographic Motor Vessel 'Dr. Bernardo Houssay' of 45m length by Prefecto Mayor Roberto Annichini from Prefectura Naval Argentina (Argentina´s Coast Guard). Prefecto Principal Fernando Santucci, captain of Houssay, was also present. Annichini also presented 'Tango', a rescue cutter of 50m length, now configured as multi-purpose vessel. This year it was Tango's first Antarctic operation. Details of both vessels are presented in ANNEX D.

The Argentinean Coast Guard expressed the interest in contributing to the SORP by offering the use of any of the vessels for the season 2013-2014, showing themselves open to discuss terms and conditions of how to contribute to these efforts.

In the future it would be worthwhile to investigate the characteristics of vessels which already operate in the Antarctic Peninsula region in terms of their suitability for whale research projects. From the experience of the recent Australian expedition it was noted that useful features included:

- a high bridge with good visibility for observers
- a high mast for the acoustic antenna
- acoustically quiet operation e.g. fixed propeller
- a winch to deploy the small inflatable boat
- transportable platforms to provide wind protection for the observers

Further details are available at the voyage report to IWC 65 Scientific Committee 2013.

9. Funding available for SORP research programs

The participants noted the Australian financial commitment to this multinational project to date and that future contributions from other SORP partners could include funds, vessels, equipment, human resources, etc. They also noted the contribution from Chile with respect to the Living Whale Symposium and the Southern Hemisphere Blue Whale Catalogue.

Options for investment by other SORP partners were discussed. The nature of the research is long term, which requires careful planning and the timely commitment of resources. The value of investment will increase over time as the benefits of the research are realized.

10. Future actions facing IWC/65 Scientific Committee 2013

A report from the Latin American countries present at this meeting will be submitted to the SORP meeting in May 2013 at the start of the IWC Scientific Committee meeting.

A press release will be prepared by Argentina, to announce the results of this workshop.

The need for a coordinator to take forward the work under SORP, and the ABWP in Latin American countries was identified. Possible tasks for such a Coordinator would include amongst others:

1) Update list of vessels working in the Antarctic Peninsula; provide details of the capacity of each vessel and match vessels to research tasks; determine the number of berths available for scientists; plan to optimize shiptime, tasks and location;
2) Explore the possibility of developing a new project under SORP in the Antarctic Peninsula area, considering the species of whales encountered (humpbacks, sei, fins, southern rights) and the location

of ships; alternatively to add to existing SORP projects;
3) Identify the needed equipment and where/ how to obtain it/ funding; consider strategic purchases and sharing of equipment for future projects;
4) Identify preliminary list of members by country/ research expertise;
5) Identify research capacity building - needs & opportunities/ places/ online training possibilities; include potential training of naval and coastguard officers during research voyages e.g. in passive acoustics;
6) Compile an inventory of what each country is able to contribute, to recognize offers of people, ships, equipment, funds;
7) Keep all the countries informed; circulate updates to all countries; report to SORP-IWC on developments.

In developing a proposal for such a coordinator for SORP/ ABWP, the following needs to be considered:

- how much time will it take (e.g. 1-2 days per week)
- indicative budget/ how much the position will cost per year (Annex E)
- potential candidates – must be fluent in written and spoken Spanish and English

Concerning the process of appointing a coordinator: it was suggested that Iñíguez Bessega, as a member of the Scientific Steering Committee of ABWP, present a proposal to the Chair of the ABWP, Professor Hammond, to use remaining IWC-ABWP funds (about USD 11,000) as start-up. If approved, the IWC would appoint the coordinator.

The coordinator position could be rotated between the Latin American countries. For example, the country providing the vessel could nominate the coordinator in order to facilitate consultations.

11. Adoption of Report

Votes of thanks to Argentina for hosting and organizing the meeting, and providing both the Chair and the rapporteur, and to Australia for providing financial support, were supported by all participating countries. Thanks were also given to the Argentinean Coast Guard for the opportunity to visit the Oceanographic Motor Vessel 'Dr. Bernardo Houssay', and for the warm reception.

The workshop report was adopted on the 18th of April at 13:18 hours.

List of Annexes:

ANNEX A: List of participants
ANNEX B: Agenda
ANNEX C: Governance structure for the ABWP of SORP
ANNEX D: Details of Argentinean Coast Guard Vessels 'Dr. Bernardo Houssay' and 'Tango'
ANNEX E: Budget for a South American region Coordinator of SORP/ABWP
ANNEX A: List of Participants

Argentina
Susana Ruiz Cerutti – IWC Commissioner
Víctor Marzari – IWC Alternate Commissioner
Miguel Iñíguez Bessega – IWC Alternate Commissioner
Roberto Annichini – Prefectura Naval Argentina
Fernando Santucci – Prefectura Naval Argentina
Pablo Almada – Prefectura Naval Argentina
Carolina Cassani - Rapporteur

Australia
Chris Schweizer – IWC Alternate Commissioner
Victoria Wadley – IWC Scientific Advisor
Lisa Davidson – Australian Embassy in Buenos Aires
Fernando Perez Tain – Australian Embassy in Buenos Aires

Brazil
Patricia Soares Leite – Brazilian Embassy in Buenos Aires

Chile
José Fernández Barahona – IWC Alternate Commissioner
Barbara Galletti – IWC Scientific Advisor

Ecuador
Gustavo

ANNEX 3 – Annotated bibliography on the published findings of the foraging ecology of humpback whales project (Ari Friedlaender)

Nowacek DP, Friedlaender AS et al. (2011) Super-Aggregations of Krill and Humpback Whales in Wilhelmina Bay, Antarctic Peninsula. PLoS One 6(4):e19173. doi:10.1371/journal.pone.0019173

Abstract

Ecological relationships of krill and whales have not been explored in the Western Antarctic Peninsula (WAP), and have only rarely been studied elsewhere in the Southern Ocean. In the austral autumn we observed an extremely high density (5.1 whales per km^2) of humpback whales (*Megaptera novaeangliae*) feeding on a super-aggregation of Antarctic krill (*Euphausia superba*) in Wilhelmina Bay. The krill biomass was approximately 2 million tons, distributed over an area of 100 km^2 at densities of up to 2000 individuals m^{-3}; reports of such 'super-aggregations' of krill have been absent in the scientific literature for >20 years. Retentive circulation patterns in the Bay entrained phytoplankton and meso-zooplankton that were grazed by the krill. Tagged whales rested during daylight hours and fed intensively throughout the night as krill migrated toward the surface. We infer that the previously unstudied WAP embayments are important foraging areas for whales during autumn and, furthermore, that meso-scale variation in the distribution of whales and their prey are important features of this system. Recent decreases in the abundance of Antarctic krill around the WAP have been linked to reductions in sea ice, mediated by rapid climate change in this area. At the same time, baleen whale populations in the Southern Ocean, which feed primarily on krill, are recovering from past exploitation. Consideration of these features and the effects of climate change on krill dynamics are critical to managing both krill harvests and the recovery of baleen whales in the Southern Ocean.

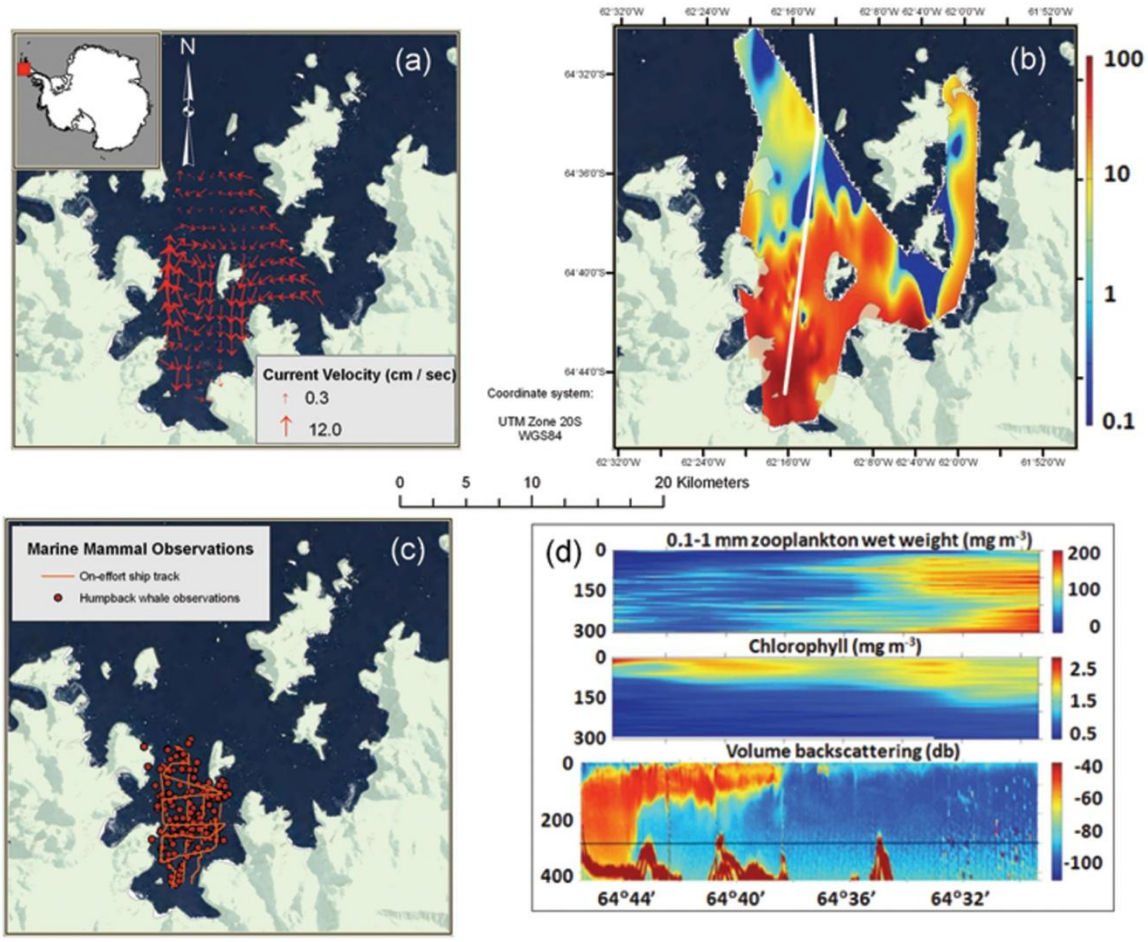


Figure 1. The physical and biological environment of Wilhelmina Bay, WAP, May 2009.
Southerly katabatic winds and coastal currents produced the circulation field and retentive gyre shown in (a). Panel (b) shows the krill super-aggregation, scaled for biomass concentrations from 0.1–100 kg/m^2. The white line indicates the transect followed to collect the data shown in (d). Humpback whale sightings (5.1 whales/km^2) and surveys are shown in (c).

Panel (d) shows meso-zooplankton (top), chlorophyll concentration (middle), and the vertical profile of the krill super-aggregation margin from south to north along the x-axis. High chlorophyll levels indicate a fall bloom; the lack of meso-zooplankton in the area of the krill aggregation is likely due to krill grazing. doi:10.1371/journal.pone.0019173.g001

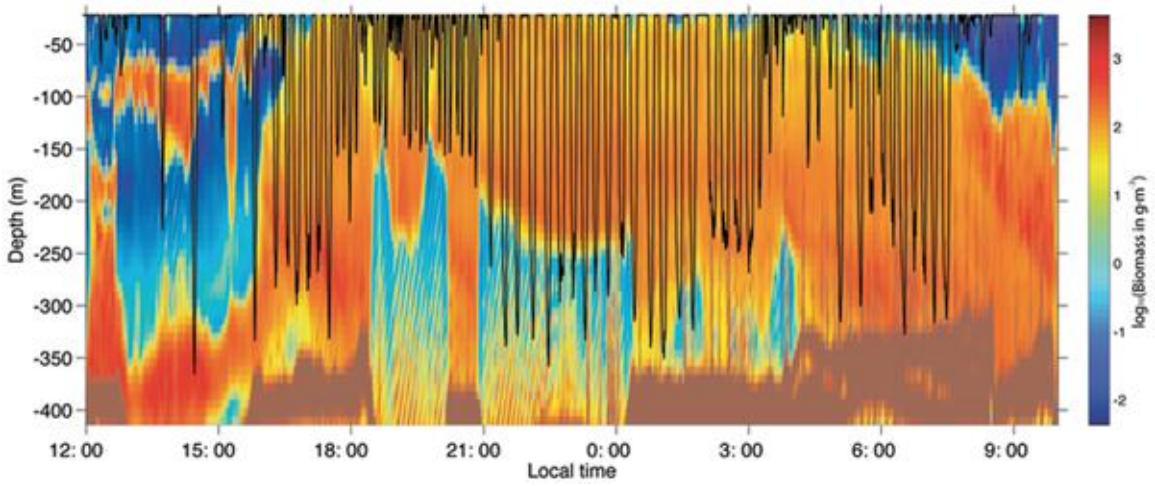


Figure 2. Humpback whale dive profile and krill biomass. Daytime resting behavior is indicated by the lack of dives. The exploratory deep dive at ~1430 h local to 370 m is the deepest recorded dive for a humpback. The whale's diving behavior as measured by the DTag tracked the vertical movement of krill at night. Krill density was measured within 100 s of meters from the tagged whale (confirmed by surface observations and radio tracking). doi:10.1371/journal.pone.0019173.g002

Table 1. Estimated consumption of Antarctic krill by the 306 humpback whales we counted in Wilhelmina Bay, WAP during the 54-day change in the timing of sea ice advance described by Stammerjohn *et al*. (2008) and using the daily consumption rate estimates from Reilly *et al*. (2004). doi:10.1371/journal.pone.0019173.t001

daily consumption (kg)	total krill (kg)	tons consumed	model	Krill Abundance (tons)	% of total consumed by whales
390.34	6.45E+06	3225	Innes et al.	2.0E+06	0.161
497.23	8.22E+06	4108	Innes et al. revised	2.0E+06	0.205
694.38	1.15E+07	5737	2% max	2.0E+06	0.287
785.95	1.30E+07	6494	2.5% max	2.0E+06	0.325
874.33	1.44E+07	7224	3% max	2.0E+06	0.361

We used humpback whale abundance estimates from line transect surveys described in our results.
doi:10.1371/journal.pone.0019173.t001

Espinasse B, Zhou M, Shu Y, Hazen E, Friedlaender AS, Nowacek D, Chu D, Carlotti F (2012) Austral fall-winter transition of mesozooplankton assemblages and krill aggregations in an embayment west of the Antarctic Peninsula. Marine Ecology Progress Series 452:63-80.

Abstract

To assess krill aggregations and humpback whale, *Megaptera novaeangliae*, foraging behavior, spatial and temporal relationships between Antarctic krill, *Euphausia superba*, and zooplankton taxonomic groups were studied during an interdisciplinary cruise conducted in May and June 2009 within Wilhelmina Bay on the western side of the Antarctic Peninsula. A vessel-mounted acoustic Doppler current profiler (ADCP) and a calibrated EK-60 echo sounder were used to assess circulation patterns and krill distributions in the bay, and a multiple opening and closing net (with 333 μm mesh) and environmental sensing system (MOCNESS) was used to collect live samples of mesozooplankton and krill for taxonomic composition analysis.

The results from this field study complement a previous one that examined an anticyclonic bay-scale circulation of Antarctic krill. This super-aggregation of krill covered ~100 km^2, had a concentration of 1000s of individuals m^{-2} and was associated with more than 306 humpback whales present in Wilhelmina Bay. Results from the

mesozooplankton study revealed that krill continuously conducted diel vertical migrations and formed aggregations in the inner bay, while the chlorophyll concentration at the surface decreased from 2.2 to 0.6 g C m^{-2} due to the decrease of daylight, and zooplankton concentrations increased from 0.5 to 1.5 g C m^{-2} probably from advective influx. Most zooplankton were distributed below 200 m while krill fed in the upper 150 m. The spatial and temporal correlations between krill and small- to medium-sized mesozooplankton imply that krill may become omnivorous when there is a lack of phytoplankton in the late austral fall. Although both phytoplankton and zooplankton biomasses contributed only small fractions of the daily ration needed for krill metabolism in Wilhelmina Bay, it is not clear what caused krill to aggregate on such a large scale, as this led to high mortality as a result of starvation and predation by whales and other top predators.

Johnston D, Friedlaender AS, Read AJ, Nowacek DP (2012) Initial density estimates of humpback whales in the inshore waters of the western Antarctic Peninsula during late autumn. Endangered Species Research 18:63-71.

Abstract

In the Southern Ocean, humpback whales, *Megaptera novaeangliae*, were depleted by commercial whaling operations during the 20th century, but many populations now appear to be recovering. Previous surveys of whale distribution along the western Antarctic Peninsula (WAP) suggested that humpbacks feed on krill swarms over the continental shelf during the summer, but little is known about their movements and densities during autumn, when krill begin to seek inshore refugia for overwintering. Here we present estimates of humpback whale densities in some inshore regions of the WAP during the late autumn. We surveyed 653.9 km of track line in the Gerlache Strait and adjacent bays during 26 April to 1 June 2009. We detected 371 groups of humpback whales in a distance sampling framework that allowed us to calculate estimates of whale density along track lines in open and enclosed habitats within our study area. Density estimates along track lines ranged from 0.02 to 1.75 whales km^{-2}; the highest densities were found along track lines in the enclosed regions of Wilhelmina Bay, the Errera Channel, and Andvord Bay. These results provide preliminary insight into the density and distribution of WAP humpbacks and indicate that large numbers of whales remain in Antarctic feeding grounds late into autumn. This study also provides details on the difficulties in estimating density of whales in the inshore regions of the WAP using traditional line transect/distance sampling methods, and provides direction for future studies including the use of model-based approaches to estimating whale densities in this region.

Table 1. Survey effort and density estimates of humpback whales in the Gerlache Strait and nearby channels and bays during the autumn of 2009.

Stratum	Habitat type	Effort (km)	Track lines	Sightings	Encounter rate (km^{-1})	%CV	Density (no. ind. km^{-2})	%CV
Dallman Bay (East)	Open	34	1	2	0.59	100.00	0.02	100.90
Gerlache/Bismarck Strait	Open	270	11	72	0.27	16.70	0.09	20.60
Open overall	Open	304	12	74	na	na	0.08	20.00
Andvord Bay	Enclosed	80	6	58	0.72	18.60	0.68	19.28
Charlotte Bay	Enclosed	19	1	2	0.11	100.00	0.10	100.10
Errera Channel	Enclosed	15	2	27	1.75	27.20	1.64	27.70
Neumeyer Channel	Enclosed	36	2	1	0.03	141.40	0.03	141.50
Paradise Bay (North)	Enclosed	12	1	5	0.43	63.30	0.46	63.50
Schollaert Channel	Enclosed	38	2	6	0.15	63.30	0.15	58.00
Wilhelmina Bay	Enclosed	134	19	251	1.87	8.93	1.75	10.30
Enclosed overall	Enclosed	333	33	350	na	na	1.00	9.20

Ware C, Friedlaender AS, Nowacek DP (2010) Shallow and deep lunge feeding of humpback whales in fiords of the West Antarctic Peninsula. Marine Mammal Science DOI: 10.1111/j.1748-7692.2010.00427.x

Abstract

Humpback whales (*Megaptera novaeangliae*) belong to the class of marine mammals known as rorquals that feed through extraordinarily energetic lunges during which they engulf large volumes of water equal to as much as 70% of their body mass. To understand the kinematics of humpback lunge feeding, we attached high-resolution digital recording tags incorporating accelerometers, magnetometers, pressure and sound recording to whales feeding on euphausiids in fjords of the West Antarctic Peninsula. Instances of near vertical lunges gave us the unique opportunity to use the signal from the accelerometer to obtain a fine scale record of the body accelerations involved in lunging. We found that lunges contain extreme accelerations reaching 2.5 ms^{-1} in certain instances, which are then followed by decelerations. When animals are intensively feeding the inter-lunge interval is similar for both deep and shallow lunges suggesting a biomechanical constraint on lunges. However, the number of lunges per dive varies from one for shallow feeding (<25 m) to a median of six for deeper dives. Different feeding patterns were evident in the kinematic record, for deep and shallow feeding bouts with the much greater mean turn rates occurring in shallow feeding.

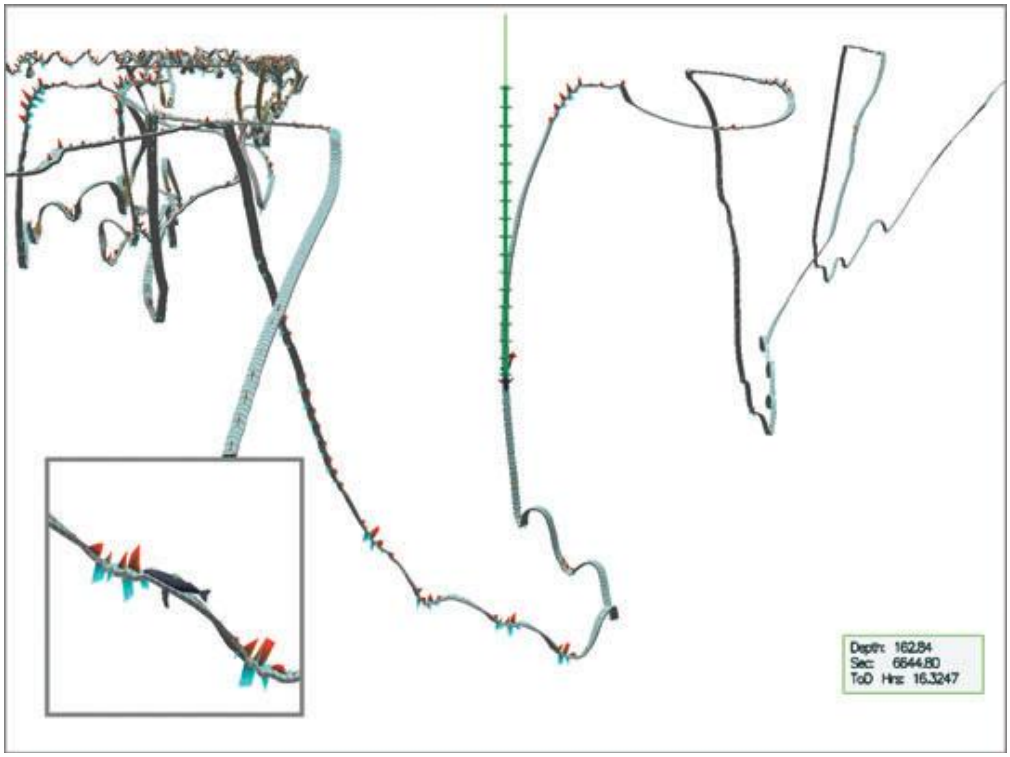


Figure 1. A representation of a deep foraging dive in TrackPlot. The sawtooth patterns on the track are derived from angular accelerations around a lateral axis and indicators of fluking behavior.

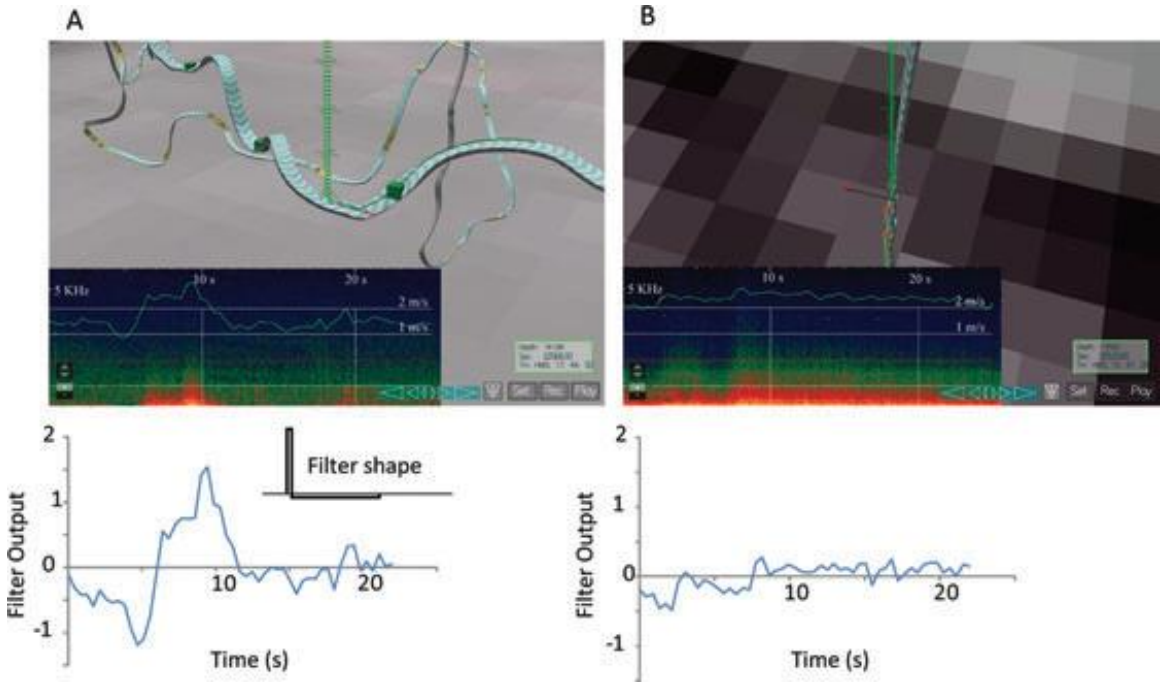


Figure 6. The application of the automatic lunge filter. Each plot shows a section of track together with the acoustic spectrogram for that section. The green plot overlaid on the spectrogram indicates the speed estimated from flow noise. The output of the lunge filter is shown beneath. (A) A clearly defined lunge. The peak of the filter signal defines the location. (B) For comparison, a section of track where the animal ceased fluking strongly. There is no rapid decrease in speed and the lunge filter does not give a signal.

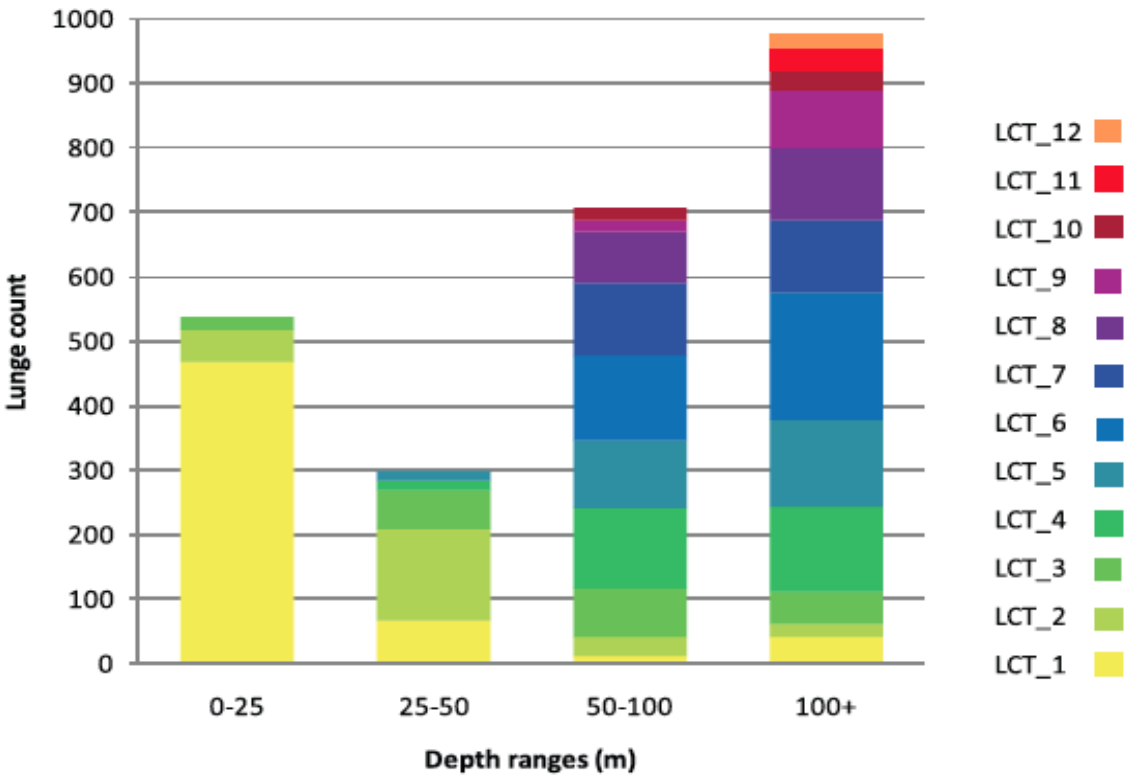


Figure 7. Stacked histogram showing the relationship between the number of lunges per dive (LCT) and the maximum dive depth.

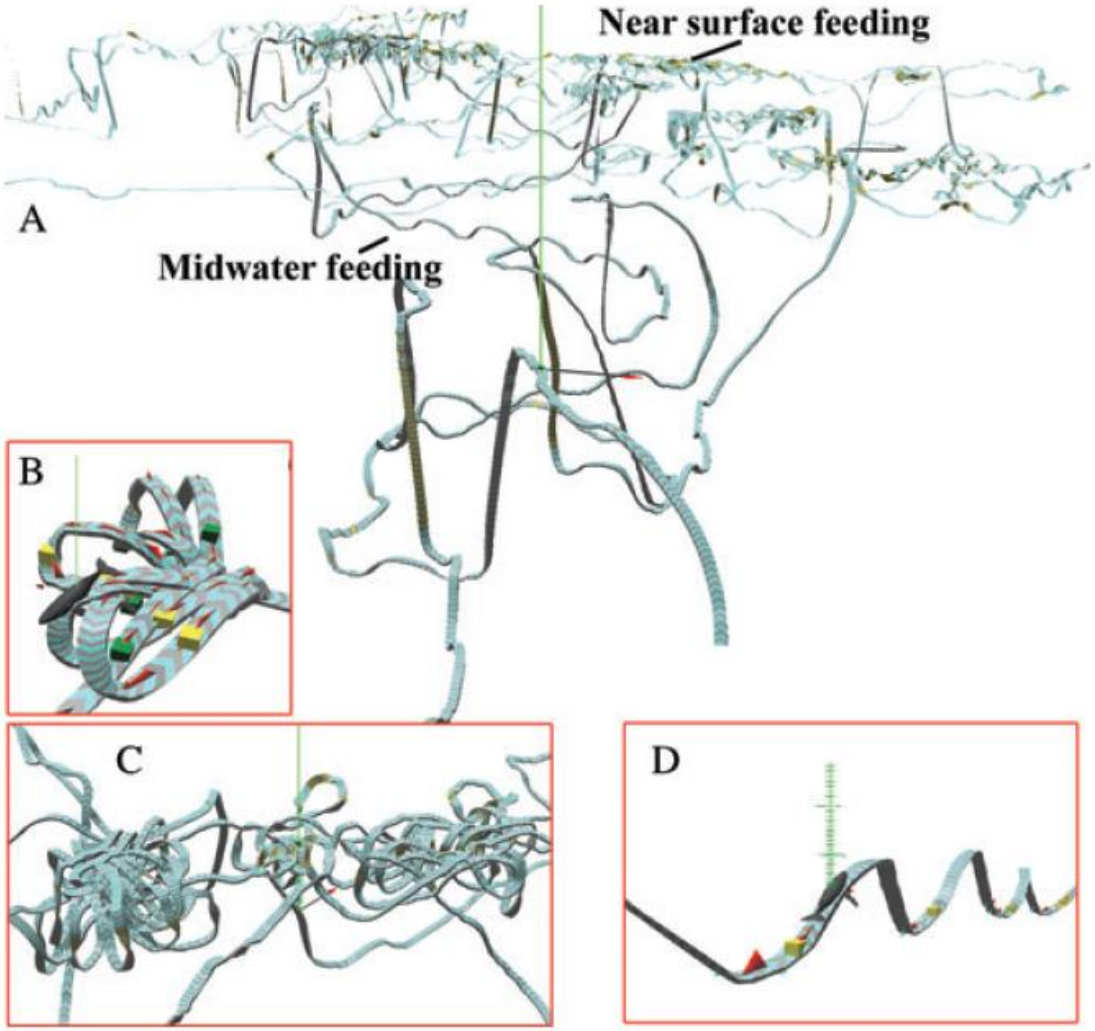


Figure 10. (A) Both surface and deeper feeding episodes are evident in this track that shows several hours of foraging. (B and C) Detailed examples of surface feeding, in (B) individual lunges are marked. (D) A typical deep feeding pattern. The colored cubes in (B) and (D) represent the locations of peak speed in feeding lunges, green representing a stronger lunge than yellow. The red triangles shown in (B) and (D) represent fluking as in Figure 2.

Friedlaender AS, Tyson R, Stimpert A, Read, A, Nowacek D (In Review) Extreme Diel variation in the diving behavior of humpback whales along the Western Antarctic Peninsula. Marine Ecology Progress Series.

Abstract

Humpback whales (*Megaptera novaeangliae)* partition their time between high latitude, prey-rich feeding, and low latitude, prey-deficient breeding/calving regions. On feeding grounds whales must acquire enough energy to sustain them for the entire year, and thus feed as efficiently as possible. We deployed multi-sensor archival tags on whales along the Western Antarctic Peninsula in autumn to describe and quantify feeding behavior for the first time. Based on the presence feeding lunges, tag data were used to determine behavioral state: feeding, resting, traveling or exploring. Our results show a clear diel pattern, in which whales feed exclusively and continuously at night, including significant changes in feeding depths over time consistent with diel vertical prey movement. The majority of shallow feeding dives included a single lunge, a strategy that increases feeding efficiency through proximity to the surface, reducing the energetic costs of diving. Whales appear to maximize their energetic intake through the timing of behavioral state changes and feeding at times when energetic costs of diving are minimized. The inactivity of whales during daylight hours may indicate prey is too deep to allow for efficient foraging. Our results add to the paucity of data describing how baleen whales (the largest animals on the planet) optimize their behavior, specifically in relation to the distribution and movement of prey, to fuel their extraordinary energetic requirements necessary for growth, migration, and reproduction. Our results also provide the first quantitative description of feeding behavior by humpback whales in Antarctica.

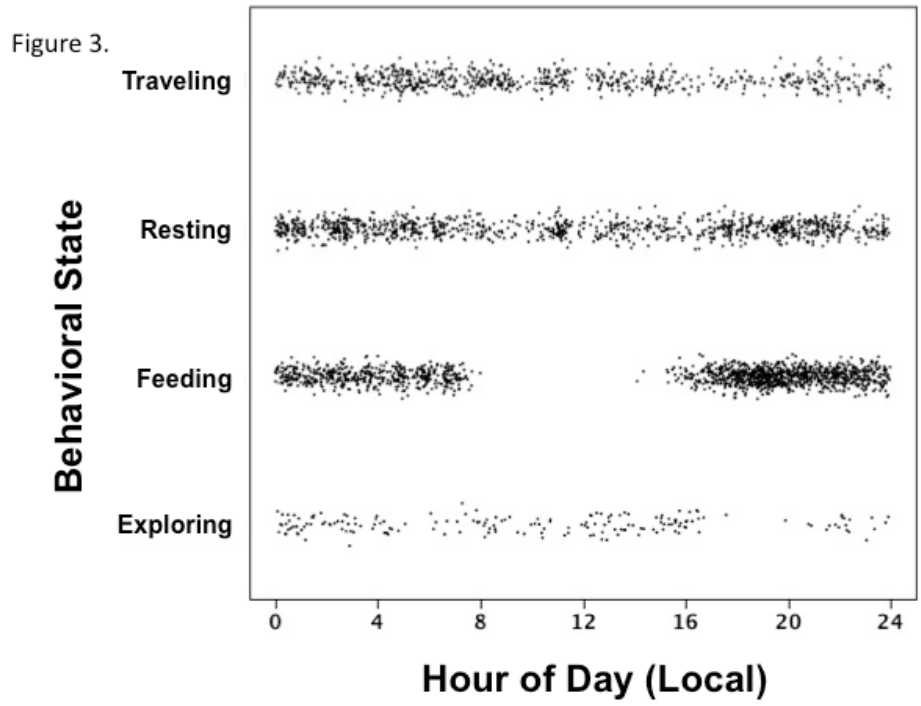


Figure 3. Frequency and temporal distribution of all dives categorized by behavioral states for all tagged whales from 2009-2010.

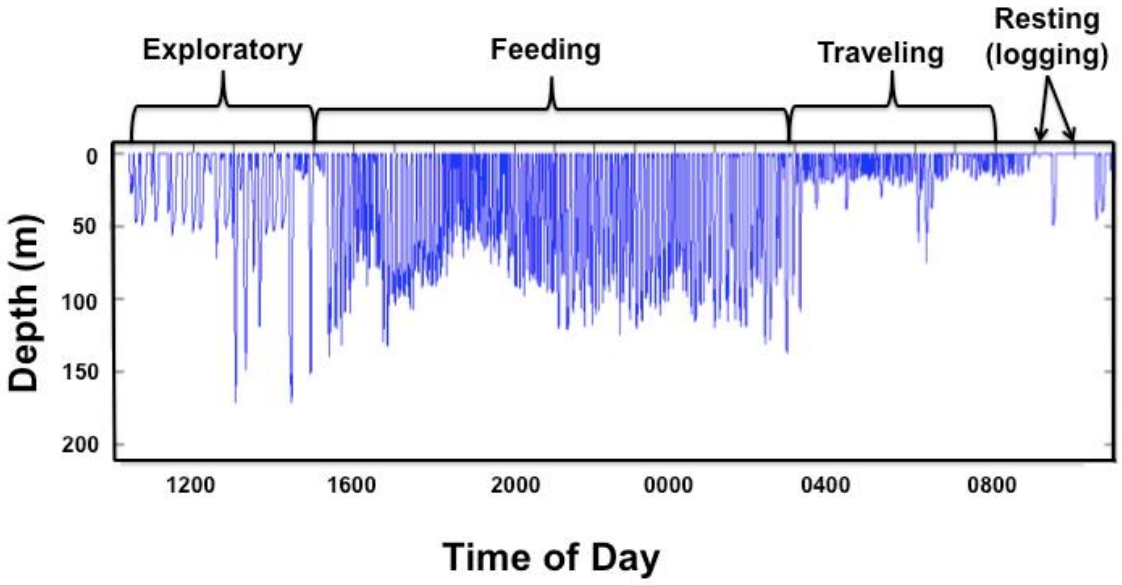


Figure 5. Representative dive profile for a humpback whale tagged in Wilhelmina Bay. Behavioral states are marked including an extended feeding bout during afternoon and night, traveling in the early morning, extended surface/logging periods during daylight hours, and exploratory dives in early afternoon prior to deeding.

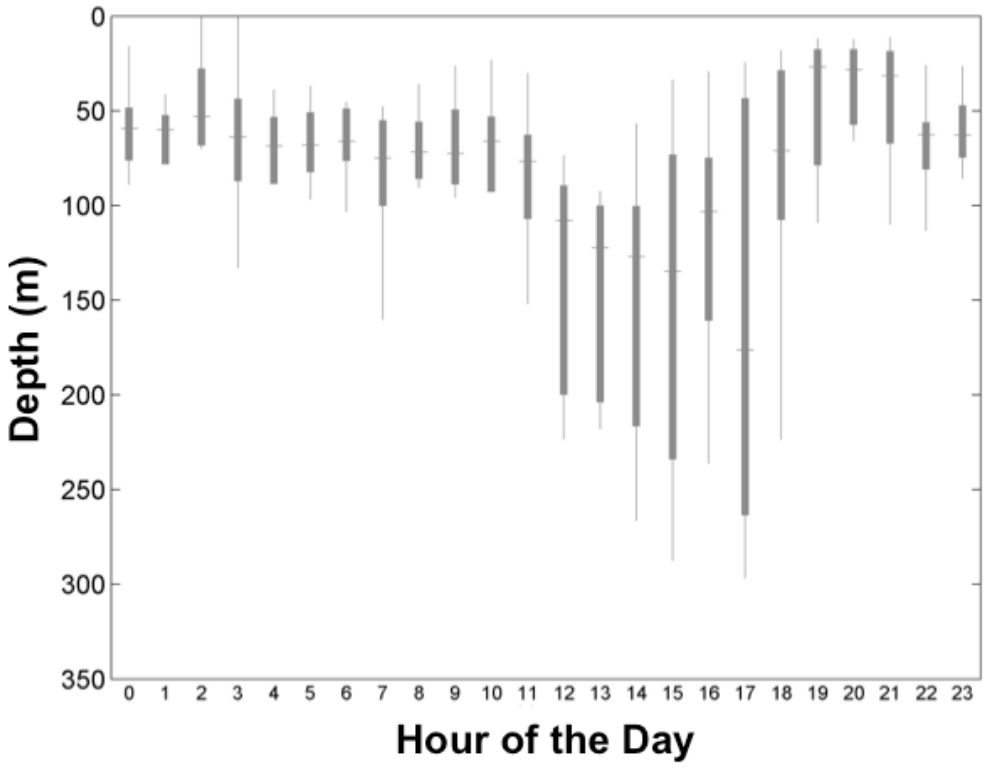


Figure 7. Hourly mean, range, and standard error in humpback whale depth of feeding dives in Wilhelmina Bay.

Friedlaender AS, Johnston DW, Tyson R, Kaltenberg A, Stimpert A, Curtice C, Hazen E, Halpin P, Read A, Nowacek, D (Submitted) The optimal diving machine: foraging strategies of humpback whales in Antarctic waters. Ecology Letters.

Abstract

Optimal foraging theory is predicated on the notion that species have evolved optimal strategies to search for and maximize net energy gain with respect to the myriad costs associated with acquiring energy. We test the following ecological hypotheses regarding humpback whales and their prey: 1) at the population-level, the timing and depth of feeding will relate to increased prey density and availability in the water column; 2) at the individual whale level, as feeding depth increases, so too does the density of prey targeted. During periods of time that whales were feeding, the density of krill was significantly lower ($p=0.001$) the depth of krill patches was significantly shallower ($p=0.001$) and the percent of water column containing krill was significantly greater ($p=0.001$). At the sampled-population level, the linear regression model predicting whale feeding events in relation to krill density, patch depth and percent water column containing krill was significant ($P= 0.0002$) and robust ($R^2 = 0.91$). At the individual whale level, we collected concurrent measurements of krill patch density spatio-temporally linked with 36 feeding lunges in 2009 and 243 feeding lunges in 2010. In both 2009 ($p<0.0001$, $R^2 = 0.25$) and 2010 ($p<0.0001$, $R^2 = 0.33$), we found a significant positive relationship between whale feeding depth and increasing krill density. Humpback whale feeding behaviour follows optimal foraging theory predictions, even when accounting for spatio-temporal dynamics of their prey. In the Antarctic, humpback whales feed at night on shallow, dispersed krill patches, but increase the density of prey targeted with increased feeding depth. This strategy allows the whales to minimize the energetic costs associated with diving and searching for smaller, dense krill patches, while at the same time increasing foraging rates. This information is important when considering the functional role and ecological relationships between predators and prey across marine ecosystems, specifically for those that include increasing baleen whale populations.

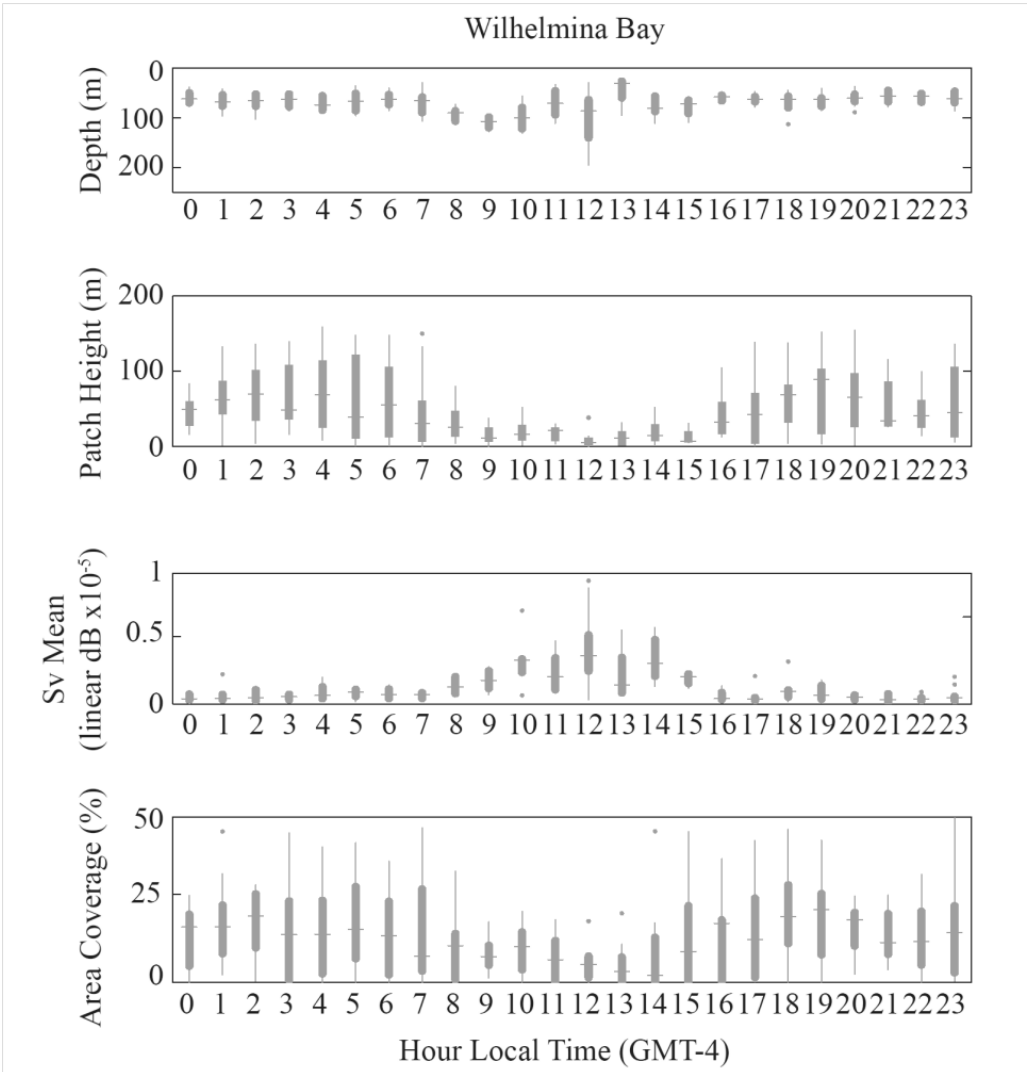


Figure 2. Hourly distributions of depth of krill patches (to midpoint of patch), patch height, mean Sv, and percent area covered by krill in Wilhelmina Bay.

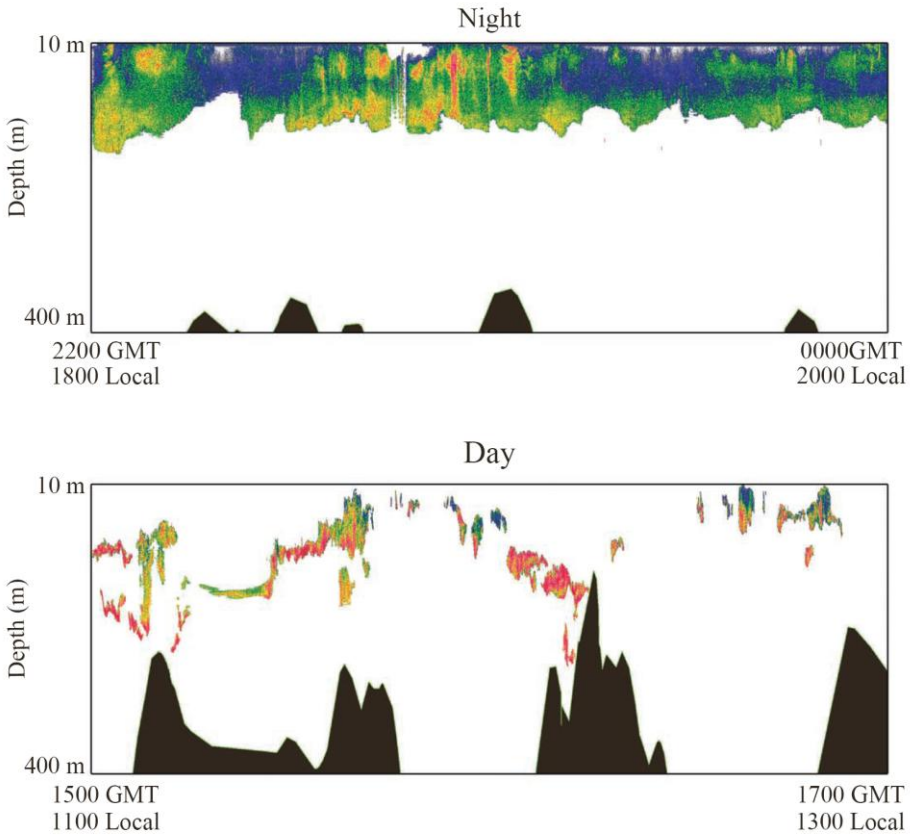


Figure 3. Night (top) and day (bottom) echograms of krill patches collected over 2 hours by a 120 kHz echosounder on May 13, 2010 in Wilhelmina Bay. Daytime patches were significantly deeper and denser, while covering a smaller portion of the water column than nighttime patches.

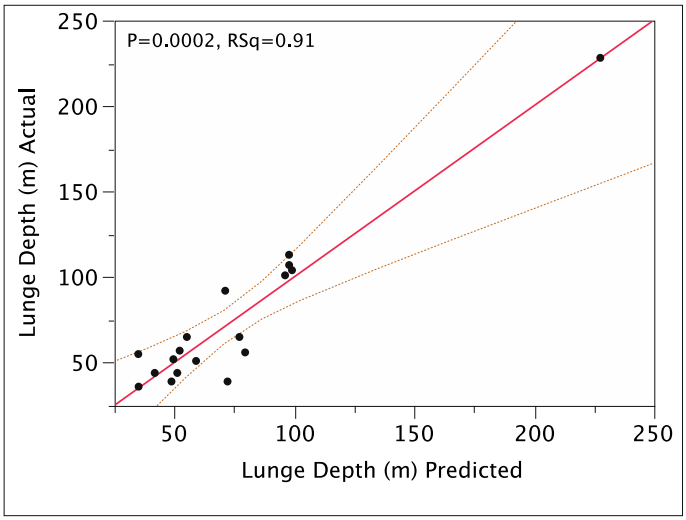


Figure 5. Least-squares regression model predicting the depth of whale feeding based on krill patch metrics.

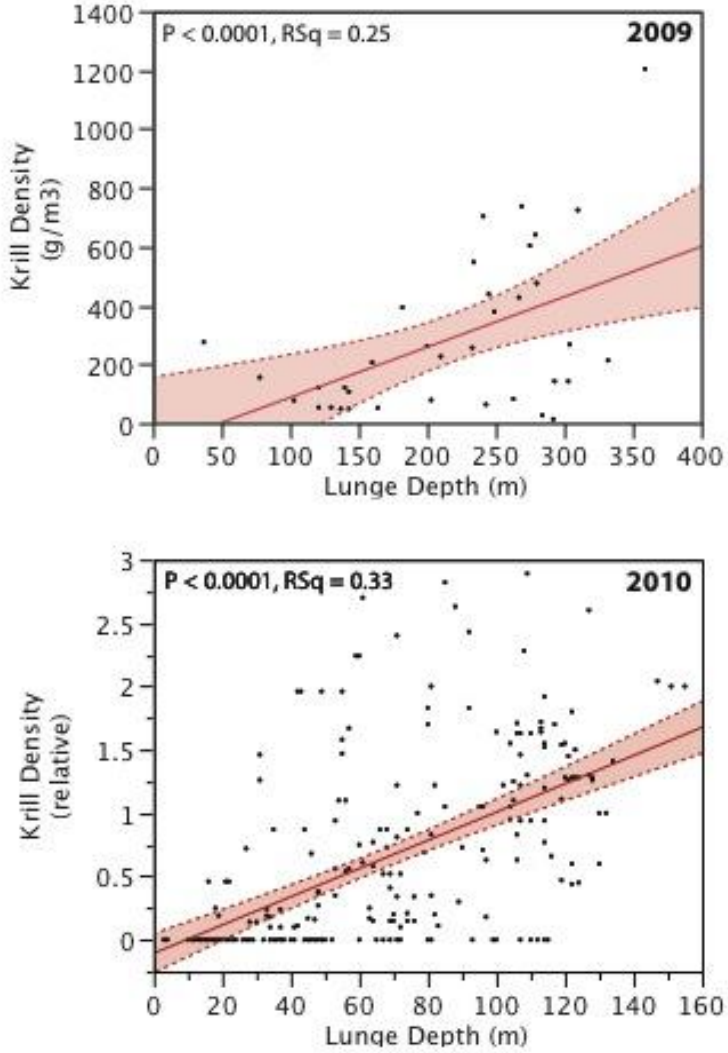


Figure 6. Least-squares regression relating the depth of whale feeding lunges with concurrent krill density. Absolute krill densities are used in 2009 and relative densities are used for 2010. Both years indicate a significant relationship between increased whale feeding depth and increased krill density.

Ongoing Research on the Foraging Behavior and Movement Patterns of Humpback and Minke Whales around the Antarctic Peninsula.

In February 2013, a National Science Foundation supported research cruise took place on the *R/V Point Sur* in collaboration with the US Antarctic Program and the Australian Antarctic Division. The goals of this research were to deploy both long-term satellite tags, and short-term multi-sensor suction cup tags on both humpback and minke whales while concurrently mapping the distribution, abundance, and behavior of Antarctic krill. Over a two-week span, we deployed 19 Argos-linked satellite tags on humpback whales and 13 on Antarctic minke whales. We also deployed 4 multi-sensor suction cup tags on humpback whales and 2 on Antarctic minke whales. The deployments of both types of tags on minke whales represent the first successful efforts for either tag on the species. At the time of this report, 5 humpback and 2 minke tags are still functioning, generating substantial data on the movement patterns of both species.

The following figures are representative of the data that are being collected from Argos-linked satellite tags. Currently, we are generating kernal home range estimates for individual whales using a moving window average of 7 days. This information will allow us to compare the size, movement, and amount of overlap between humpback and minke whales in the region, and determine if and how these home ranges change throughout the course of the feeding season. The data that are shown in these figures are from Argos-linked satellite tags that were deployed by Ari Friedlaender in 2012 during a National Science Foundation research cruise as part of the Palmer Long-Term Ecological Research (LTER) study.

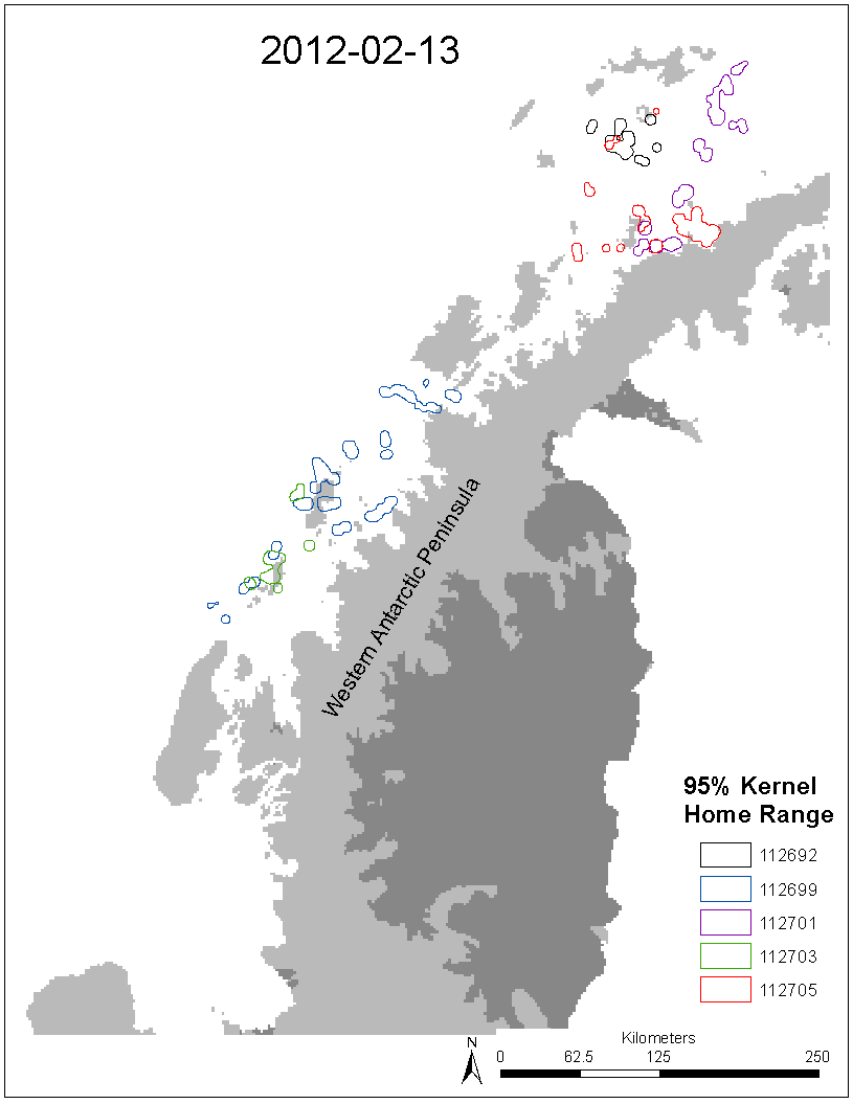


Figure 1. Weekly 95% kernel home range estimates for 5 humpback whales tagged with Argos-linked satellite transmitting tags.

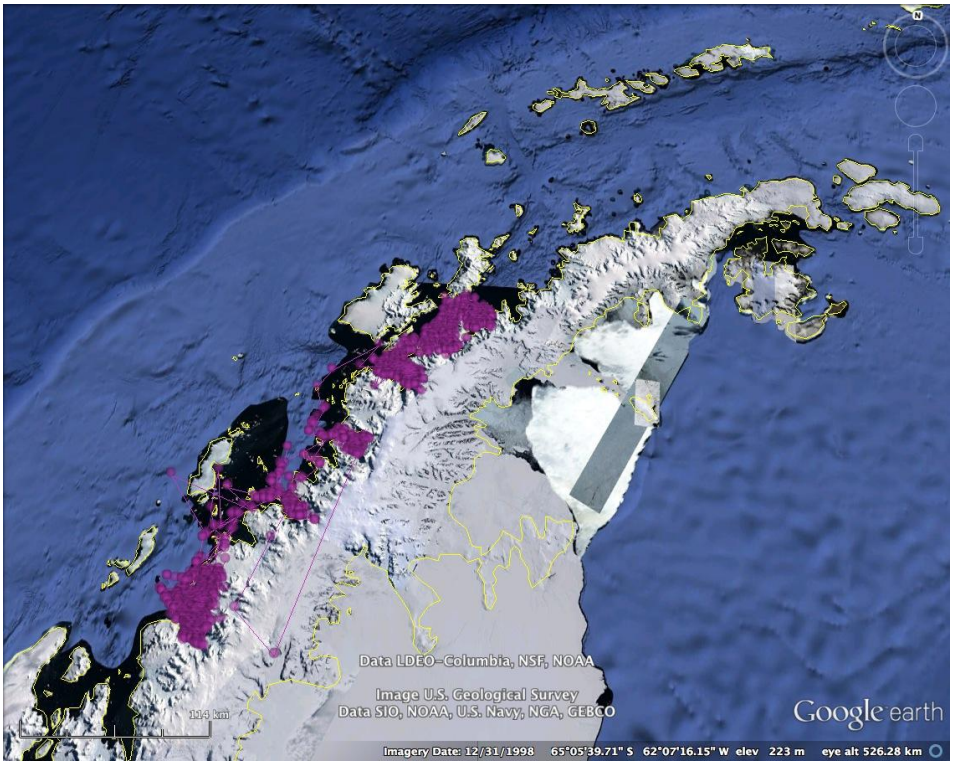


Figure 2. Satellite track of Antarctic minke whale from 8 February-13 May 2013, Antarctic Peninsula.

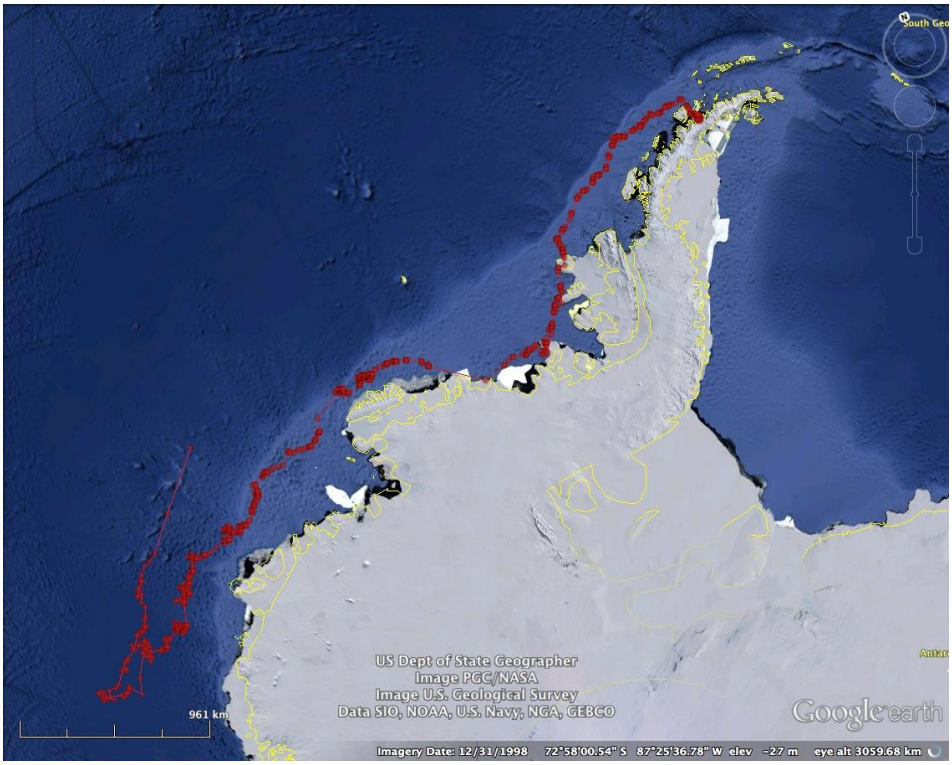


Figure 3. Satellite track of Antarctic minke whale, 8 February – 28 April 2013, showing movement from initial tag deployment in the Gerlache Strait across the Belingshausen Sea towards the Ross Sea.

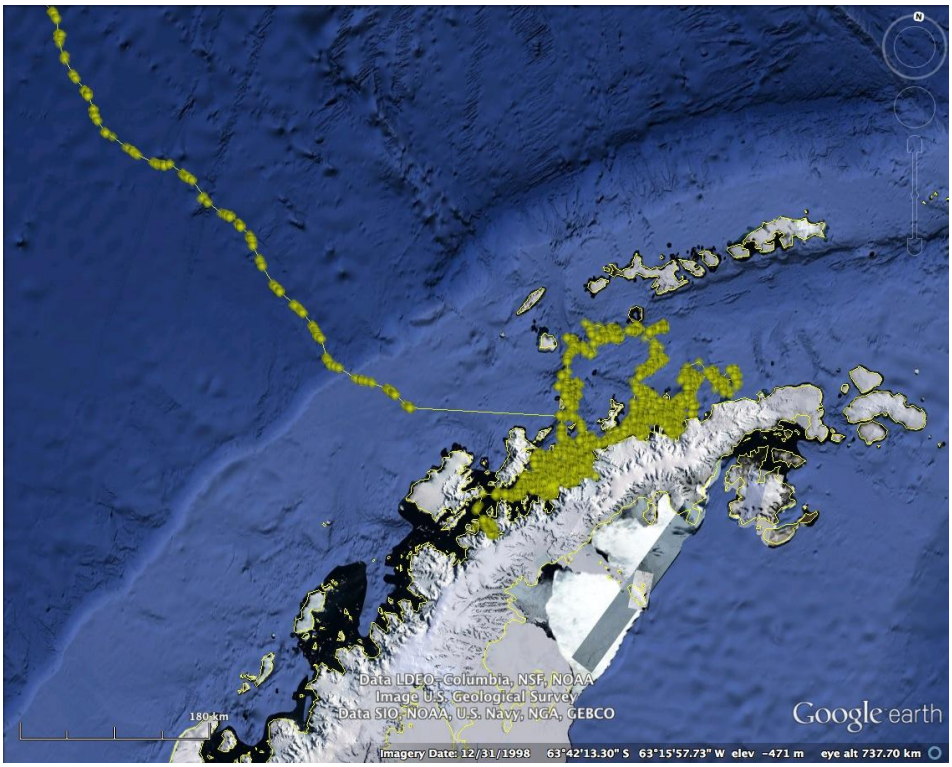


Figure 4. Humpback whale satellite track from 6 February – 13 May 2013 showing foraging behavior around the Gerlache and Bransfield Straits, Antarctic Peninsula before beginning migration along the western side of South America.

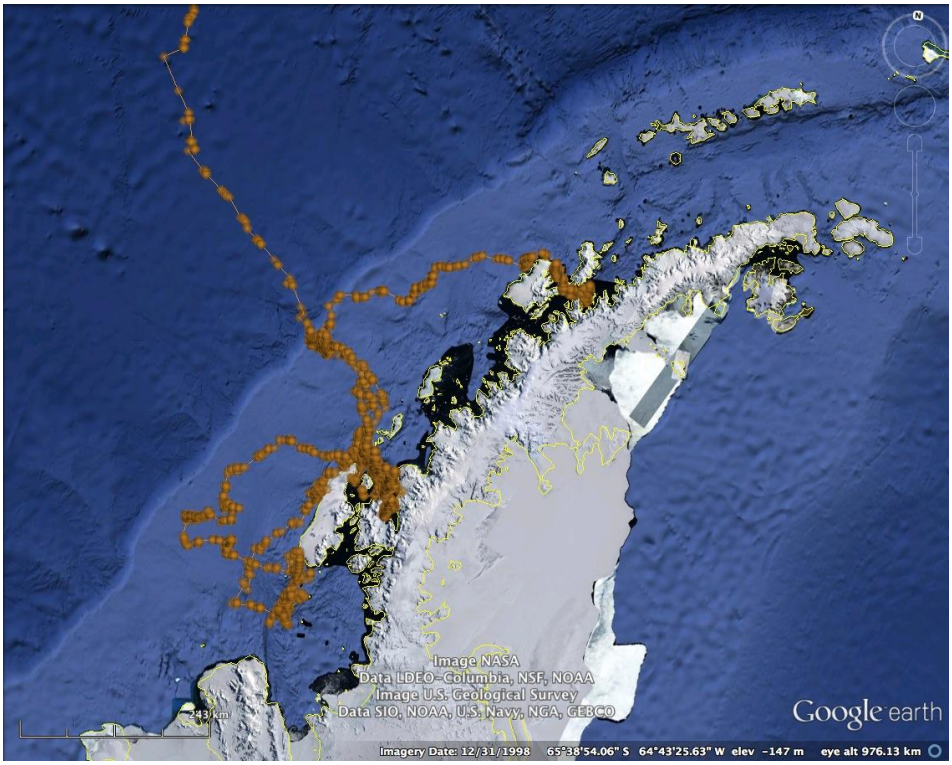


Figure 5. Satellite track of humpback whale from 6 February – 13 May 2013. The whale was tagged in the Gerlachce Strait and foraged over a broad area including Marguerite Bay before beginning migration along the west side of South America.

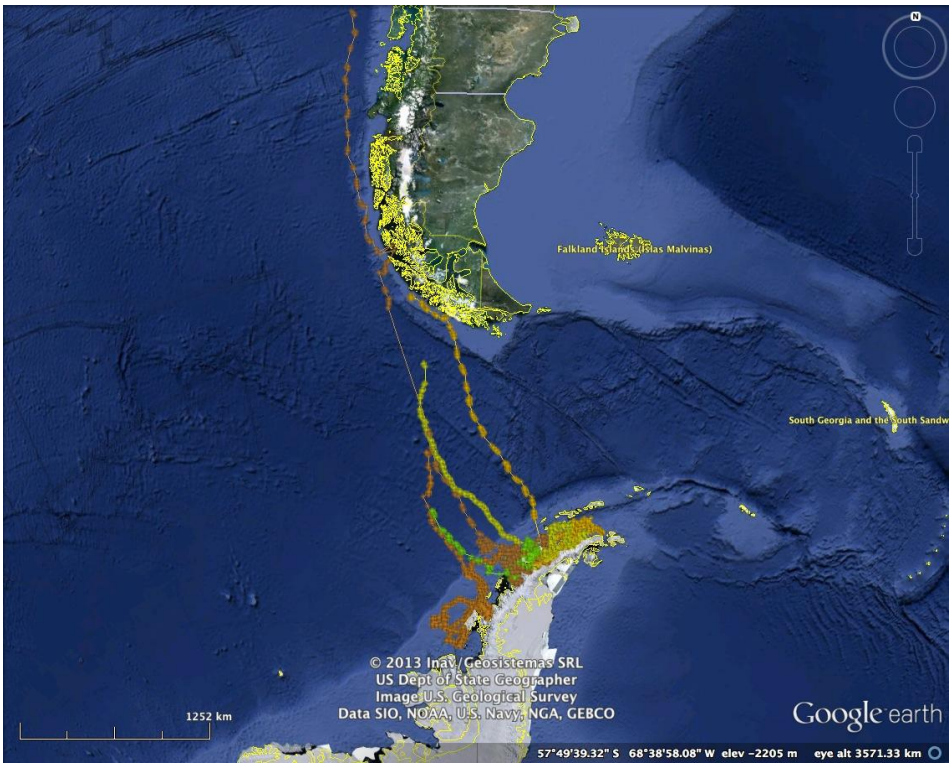


Figure 6. Satellite tracks of 5 humpback whales tagged in the Gerlache Strait, Antarctic Peninsula. The tracks all show foraging behavior around the Antarctic Peninsula before beginning migration across the Drake Passage and along the western side of South America. All tags were deployed in early February 2013 and are currently transmitting as of 13 May 2013.

Friedlaender AS, Goldbogen J, Nowacek D, Read A, Tyson R, Bowers M, Johnston D, Gales N. (Submitted) Breaking the ice: the foraging behavior and kinematic patterns of Antarctic minke whales. Biology Letters.

Abstract

Minke whales are among the most abundant and widely distributed balaenopterid cetaceans, yet we know little of their underwater behavior. For example, the diving, foraging, and kinematic patterns of Antarctic minke whales (*Balaenoptera bonaerensis*) are completely unknown. To understand these aspects of their biology, we deployed multi-sensor suction cup tags on two Antarctic minke whales in Wilhelmina Bay, Western Antarctica Peninsula, in February 2013. These whales fed almost constantly and at an average depth of 19 meters (max. = 106) on 1.5-minute dives (max = 9.4). Water filtered per unit time was 219 m3/hr, 18x less than a blue whale feeding at a similar depth. Average lunge rate was 112/hour, four times higher than reported for baleen whales, including 40 dives with >15 lunges (max = 24). A significant relationship existed between feeding depth and lunge frequency overall, but k-means clustering suggests that several dive types exist, with differing combinations of depth, duration, and feeding rates. Feeding rate increased with depth in only the shallowest and shortest feeding dives. Our results provide the first direct observations of the subsurface behavior of Antarctic minke whales, including feeding under sea ice. These observations allow comparisons with other balaenopterid whales with respect to anatomical scaling and the energetic costs of lunge feeding. With these data in hand, we can begin to examine ecological relationships among krill predators in this region and determine how these species partition resources. This knowledge is important given the rapid warming and diminishing sea ice conditions driving ecological change around the Antarctic Peninsula. Future efforts combining fine-scale kinematic information with broad-scale information from satellite-linked dive recording tags will provide a greater understanding of the movement patterns and ecology of these whales, and inform efforts to manage their populations around Antarctica, while minimizing the need for lethal sampling.

**This abstract has also been submitted for the 20th Biennial Conference on the Biology of Marine Mammals, December 2013, Dunedin, New Zealand.

Image 1. Multi-sensor archival suction-cup tag (Acousonde) deployed on an Antarctic minke whale, Wilhelmina Bay, Antarctic Peninsula, February 2013. Tag sensors include pressure, temperature, 3-axis accelerometers and magnetometers, hydrophone, and VHF.

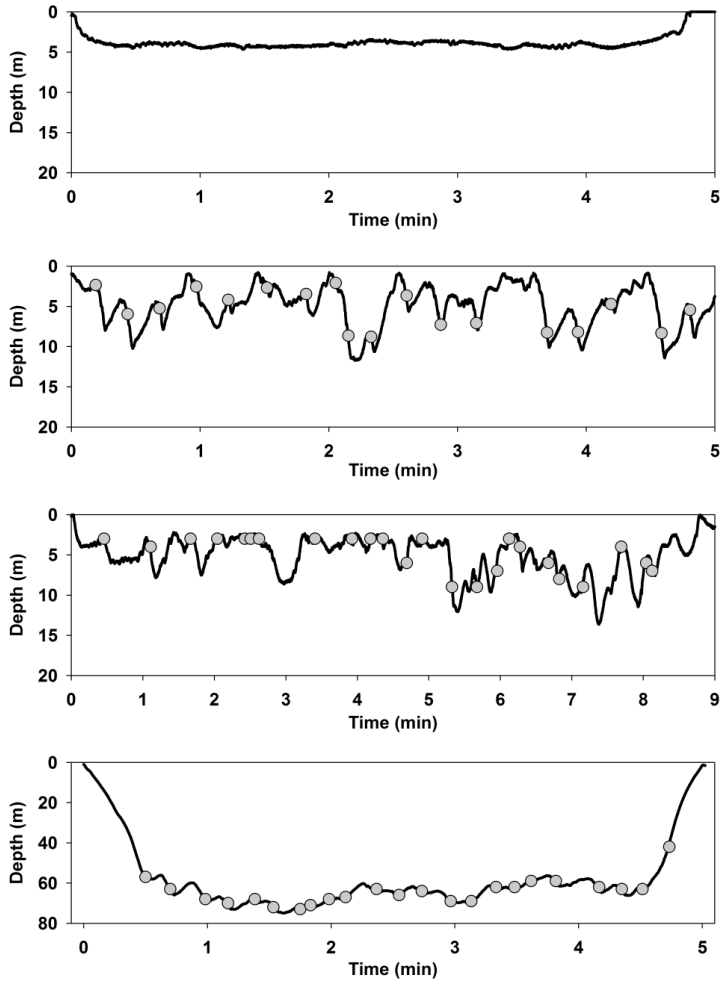


Figure 1. Dive profiles of Antarctic minke whales. From top, a shallow traveling dive with no feeding, a shallow feeding dive with feeding lunges (grey circles), a shallow feeding dive with extraordinary feeding rates (n=24 feeding lunges), a deep feeding dive.

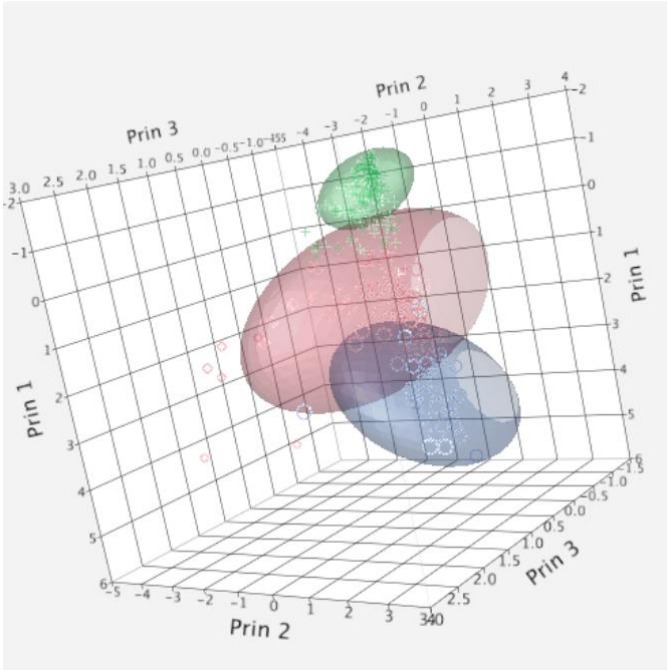
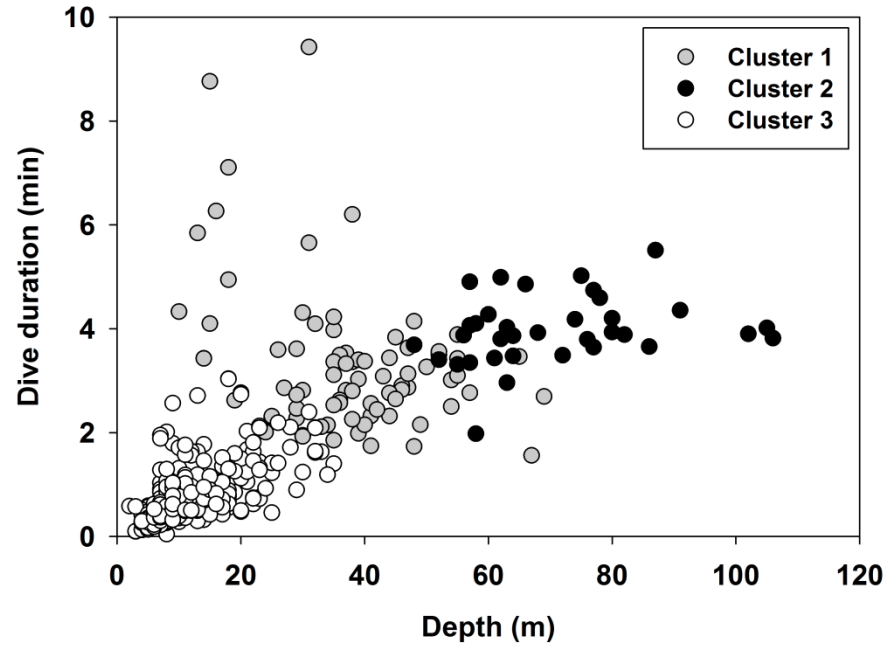


Figure 2. K-means clustering of Antarctic minke whale feeding dives showing three distinct clusters based on a combination of dive time, dive depth, and number of lunges per dive.



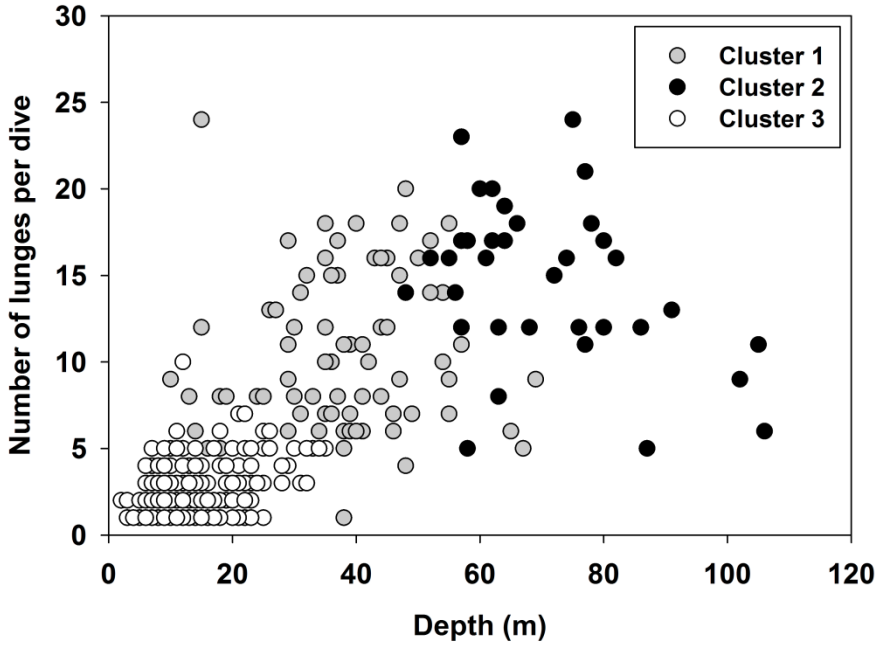


Figure 3. Antarctic minke whale foraging dives grouped into clusters based on dive duration, depth, and lunge frequency. The top panel shows the relationship between dive duration and dive depth for all dive clusters, while the bottom panel shows the relationship between the number of lunges per dive and dive depth for each cluster of dive types.

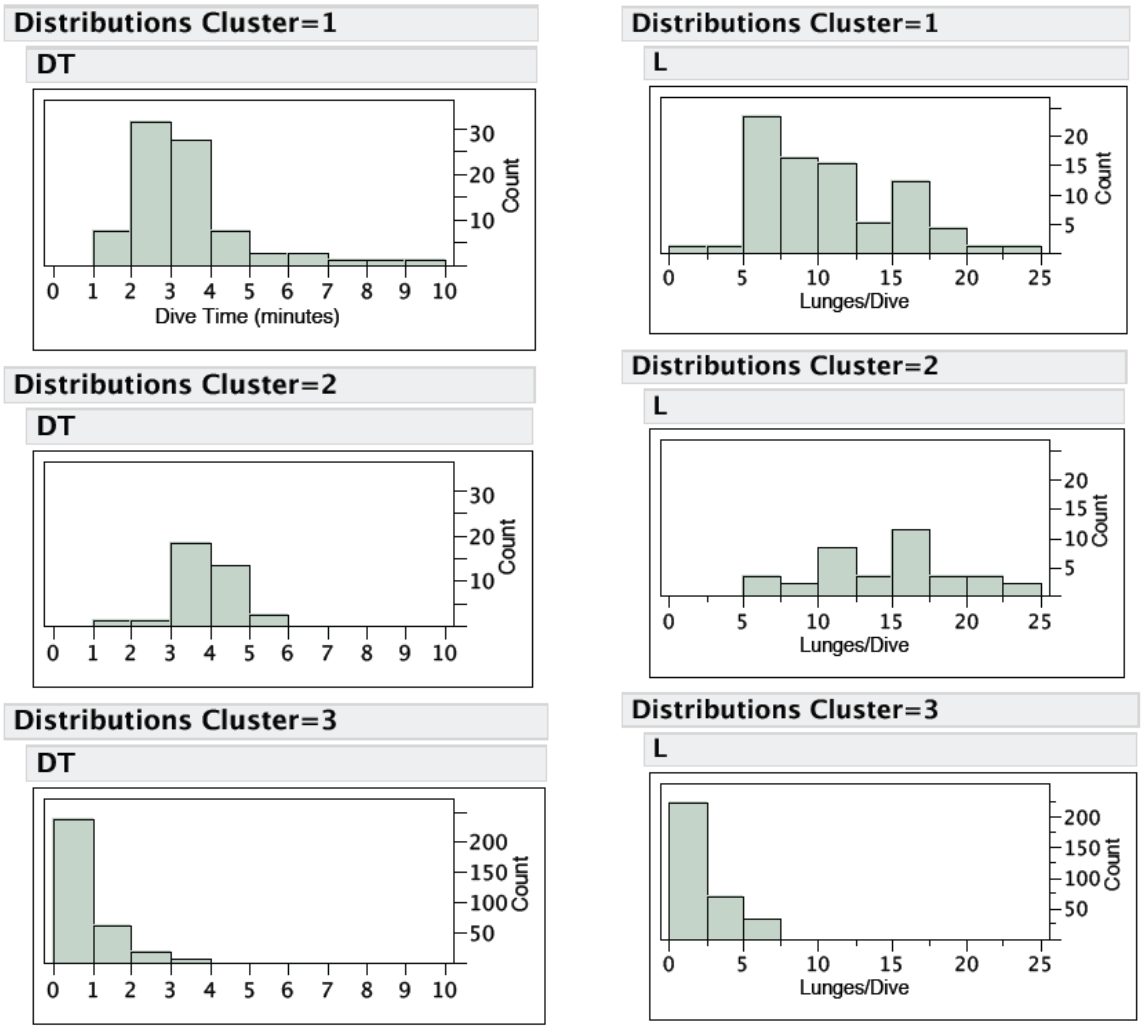


Figure 4. Histograms showing the frequency of distributions of dive time (left) and number of lunges per dive (right) for three types of Antarctic minke whale feeding dives.