Revised Project outlines for the Southern Ocean Research Partnership

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ABSTRACT

The Southern Ocean Research Partnership (SORP) was proposed to the 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. A framework and set of objectives for SORP were presented to the IWC in 2009 where they were endorsed. Six draft projects were presented to the Scientific Committee in 2010 where they received feedback and review. This paper provides revised project plans based on feedback to these projects received since last Scientific Committee meeting.

KEYWORDS: SOUTHERN OCEAN RESEARCH PARTNERSHIP, IWC, SORP, ANTARCTICA, PROJECTS

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. Many member Governments are now supporting the development of a Southern Ocean Research Partnership (SORP) using non-lethal methods. The aim of SORP is to develop a multi-lateral, non-lethal scientific research program that will improve the coordinated and cooperative delivery of science to the IWC.

In March 2009, the SORP was established to enhance cetacean conservation and the delivery of non-lethal whale research to the International Whaling Commission (IWC). The objectives, research plan, and procedural framework for the partnership were developed through a workshop attended by 50 participants representing 12 countries (Australia, Argentina, Brazil, Chile, Costa Rica, France, Italy, Mexico, New Zealand, South Africa, Uruguay and USA) and several research and environment consortiums. A framework and set of objectives for SORP were presented to the IWC Scientific Committee at its Annual Meeting in June 2009 and where they were endorsed.

Six draft projects were presented to the Scientific Committee in 2010 where they received feedback and review. This paper provides revised project plans based on feedback to these projects received since last Scientific Committee meeting. A summary of progress and achievements of these projects over the 2010/11 period are reported in paper SC/63/O12

PROJECT DESCRIPTIONS

There are six projects that have been proposed for SORP. Short summaries of these projects follow. More detailed descriptions (in the form of IWC research project applications) are attached of the four main research projects (i.e.1-4).

1. *Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean [APPENDIX 1]*

There are three ecotypes of killer whales described from Antarctic waters that comprise at least three separate species. Little is known about these ecotypes and it is important to understand these populations as killer whales play a key role in the Antarctic marine ecosystem. This is especially true with respect to the impacts that they have on prey populations including marine mammals, fish and penguins. This project will investigate the factors relative to the ecosystem impact of three species killer whales that occur in Antarctic and adjacent waters, by focusing on their systematic relationships, abundance, distribution, movement patterns and prey preferences. Collaborators are from USA, Brazil, France and Canada.

2. *Foraging ecology and predator-prey interactions between baleen whales and krill: a multi-scale comparative study across Antarctic regions [APPENDIX 2]*

Little is known about the dynamics of predator-prey interactions and the response of baleen whales to the distribution of their prey in the Antarctic. As a particularly important marine ecosystem (e.g. climate change impacts and international management of marine living resources) research focused on cetacean foraging ecology in the Antarctic represents a critical data gap. We propose to use novel tagging technologies combined with traditional scientific hydro-acoustic methods to quantify the types and frequency of prey consumed and daily consumption rates of poorly understood yet ecologically integral and recovering krill predators in the Antarctic, the humpback and minke whale. Collaborators are from USA and Australia for phase 1 and potentially Brazil, South Africa and Germany for phase 2.

3. *Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean [APPENDIX 3]*

This initiative 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. Current understanding of blue and fin whale life history characteristics, population abundance, and any post-whaling recovery is extremely limited. While obtaining accurate absolute abundance estimates is currently beyond the reach of passive acoustic methods, measures of relative abundance are easily obtainable and can be conducted in a consistent manner. Comparison of relative abundance estimates from individual locations across many years collected by acoustic surveys can provide a precise measure 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. Collaborators are from Australia, France, USA and Germany.

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

An improved understanding of the movements and mixing of humpback whales around Antarctica has been identified as a priority for the IWC. This information is integral to assessing the recovery of depleted populations. A key step in assessing recovery is estimating pre-exploitation size which requires knowledge of stock identity and appropriate allocation of historic catches to correct stocks. 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. Collaborators include New Zealand, Australia, USA, France, Samoa, Tonga and Chile.

5. *Living whales in the Southern Hemisphere*

This project entails the undertaking of a technical conference/workshop to review the strengths and weaknesses of available non-lethal research methods for studies of living whale in the Southern Ocean and their ecological roles in the Southern Hemisphere. The objectives are to advance the synergies of non-lethal methods for investigations addressing four broad themes covering (*i*) molecular techniques, (*ii*) biologging, (*iii*) remote sensing and (*iv*) long term data sets which will each comprise a key note speaker, some detailed case studies, followed by a panel discussion. The Symposium will be followed by four workshops covering (*i*) health assessment of live whales, (*ii*) advances in tagging attachment techniques, (*iii*) non-lethal ageing techniques and, (*iv*) the estimation of diet and consumption rates. A date for this symposium was originally set for September 2011 but due to operational reasons, this date has been changed to March or April 2012, with final dates to be confirmed at Scientific Committee 2011. The venue will be Puerto Varas, 15km from Puerto Montt, in Chile and kindly supported by the Chilean Ministry of Foreign Affairs and Chilean Navy.

6. 2013/14 The SORP Year of the Whale

This is one of the core SORP research projects. Based on discussions at two technical meetings and the SORP Steering Committee Workshop in Paris, this project has been further scoped and developed. The exact focus for this project will be discussed at SC 63 but is likely to include the development of a circumpolar estimate of abundance for Antarctic blue whales. These surveys for Antarctic blue whales are likely to use vocalisations to detect and track calling whales, thereby maximising encounters during surveys. Further information about this project is available in papers SC/63/O13 and SC/63/SH3 and this project will be discussed in detail at Scientific Committee in 2011.

FEEDBACK FROM SCIENTIFIC COMMITTEE

These projects were presented to Scientific Committee in 2010 and considerable feedback and support were received. This feedback has helped the Investigators to revise and improve the project proposals. The revised project proposals are reported here.

APPENDIX 1: SORP Killer whale proposal

SORP RESEARCH PROPOSAL

1. TITLE OF PROJECT

A proposal to study distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in Antarctic and adjacent waters.

2. DETAILS OF NAMED INVESTIGATORS

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Domicile	CANADA

3. DESCRIPTION OF PROJECT

(i) Background to the proposal, underlying rationale and relevance to SORP objectives and IWC needs.

Based on genetic analyses, it was recently suggested that the three ecotypes of killer whales (*Orcinus orca*) that have been described from Antarctic waters (types A, B, and C; Pitman and Ensor 2003) comprise at least three separate species (Morin et al. 2010). Because these types were only recently recognized, almost nothing is known about the abundance, seasonal occurrence, movements, prey preferences or preferred habitats of the different killer whale forms that occur Antarctica. This is important because these factors will contribute in large part to defining the role of killer whales in the Antarctic marine ecosystem, and in the lower latitude areas that they probably migrate to during the southern winter. This is especially true with respect to the impacts that they have on prey populations, which, depending on the type of killer whale, includes either marine mammals or fish, including the commercially valuable toothfish (*Dissostichus* spp.). The significance of killer whale movements and prey choice is also important with respect to depredation problems involving killer whales removing toothfish from longlines, especially near subantarctic islands (Tixier submitted). Killer whales are large, highly mobile and especially numerous in high latitudes; they will likely prove to be a key component within the Antarctic marine ecosystem, and in the waters beyond, and therefore they have been included within the core focus of SORP. Here we propose to study, for the first time, factors relative to the ecosystem impact of three species killer whales that occur in Antarctic and adjacent waters, by focusing on their systematic relationships, abundance, distribution, movement patterns and prey preferences.

<u>Links to Specific IWC Recommendations</u>

The proposed study is directly related to the following IWC recommendations for Southern Ocean research:

Recommendation 1: *It also noted that fisheries observers on longline vessels represent a potential source of data on killer whales in sub-Antarctic waters and* ***recommends*** *that the Secretariat contacts CCAMLR and requests a compilation of data on killer whale occurrence and fisheries interactions from their observer reports and supply those for consideration to the IWC* [SC59, SM, 14.1.1, p. 50]. A significant amount of data on killer whales is collected by observers onboard French Patagonian toothfish longliners operating within the Crozet and Kerguelen EEZs (CCAMLR 58.6 and 58.5.1), and is regularly reported to the CCAMLR scientific committee.

Recommendation 2: *Given the presence of at least three ecotypes in the Antarctic region, and the unresolved questions over the systematics of killer whales in this region, the Committee* ***recommends*** *that additional morphological and genetic studies be carried out on samples from this large area* [SC59, SM, 14.1.2, p. 51]. Regarding this recommendation reports indicate the occurrence of at least 3 distinct ecotypes of killer whales in the Crozet and Kerguelen EEZs. Two of them (types A and B) belong to two of the three types described from Antarctica waters; the third is perhaps an additional type that needs further investigation.

Recommendation 3: *The Committee concluded that this method [estimating age from fatty acids blubber] has important implications for cetacean research and* ***recommends*** *that further effort be made to develop, test and, if appropriate, apply it in demographic studies to other cetacean species, including of large whales* [SC59, SM, 14.1.3, p. 51]. Regarding this recommendation, we have already contacted numerous operators of tourist vessels in the Antarctic Peninsula area and Ross Sea about obtaining photographs of killer whale encounters; from this we have obtained 1000s of images from scores of killer whale encounters, which will help immeasurably in building our photo-ID catalogs for those areas.

Recommendation 4: *(i) The Committee* ***recommends*** *the application of these tools [passive acoustic recorders, satellite tags, sea ice analytical tools] to future cetacean research in the Arctic and Antarctic and* ***encourages*** *researchers to continue the collaborative exchanges initiated at the symposium; (ii) For these reasons, the Committee* ***strongly recommends*** *the integration of cetacean research into these two programmes [ICCED and IPY]; (iii) The Workshop also* ***strongly recommended*** *the continuation (and where necessary, initiation) of long-term studies, both of cetaceans as well as key biotic and abiotic features of the environment; and (iv) The Workshop also* *recognised the difficulties in developing (and measuring) suitable indices both of habitat quality and response in cetaceans. It* ***recommended*** *that further work be undertaken in this regard, particularly with respect to: (1) identifying key features of cetacean habitat; (2) reviewing methods used to assess cetacean nutritive status in both live and dead specimens, with a view to future standardisation of techniques; and (3) developing indices of cetacean response to various stressors* [SC58, E, 12.1, p. 43]. This project can also be linked to the four recommendations listed above from SC58 as satellite tags will be used extensively as well as passive acoustic recorders. Furthermore, the long term killer whale study at Crozet and Kerguelen will be continued and it is our intention to continue indefinitely the studies begun in the Peninsula area during 2008-09.

(ii) Specific objectives.
The aim of this study is to better understand the systematics and ecology of killer whales in Antarctic and surrounding waters. Achieving some of these objectives will require international collaboration with researchers from various land bases and research platforms around Antarctica and in subantarctic waters. The main objectives of the proposed project are:

- to compile a killer whale sightings database from our own research cruises and from other vessels (tour ships, research vessels, etc.) to provide for the first time a detailed, up-to-date distribution map of the different killer whale types in Antarctic and adjacent waters, highlighting areas of concentration.
- to organize photo-ID catalogs for selected areas (e.g., Ross Sea, Antarctic Peninsula, Crozet/Kerguelen Is.) to be used for estimating local populations of killer whales (Durban et al. 2010). This will be based on photographs we have already taken and will be taking (several thousand images collected to date), as well as those that have been (and will be) sent to us on request from other sources.
- to collect projectile biopsy samples to support further phylogenetic studies of Antarctic and subantarctic killer whales (Morin et al. 2010); the same samples will also be used for comparative food habit studies (stable isotopes/fatty acids) and contaminant loads (e.g., Krahn et al. 2008).
- to deploy satellite tags to study local and seasonal movements of killer whales (Andrews et al. 2008) to determine if migration occurs among the different species and what the destinations might be.
- to record, during focal follows, observations of foraging habits and prey preferences of the different killer whale types in Antarctica (e.g., Pitman and Durban submitted a, b).
- to record acoustic vocalizations of the different types of killer whales in Antarctica and the subantarctic for comparative purposes.

(iii) Scientific methodology and approach.
Our research in Antarctica will be conducted primarily from the small (21 m) motor-sailer *Golden Fleece* operating in the Antarctic Peninsula area. Additional data will be collected during the research activities of Projeto Baleias/PROANTAR (Brazilian Antarctic Program) around the Antarctic Peninsula. These activities will be conducted from the Oceanographic and Supply Vessel *Ary Rongel* (75 m) or the Polar Vessel *Almirante Maximiano* (91.6 m) and by launching small inflatable boats. Research around subantarctic islands will be conducted by fishery observers onboard longline fishing vessels and by workers from Alfred Faure Base on Possession Is., and occasionally from Port aux Francais on Kerguelen Is. In addition, we will be collaborating with SORP and other researchers working on platforms operating around the continent to provide a more comprehensive picture of the ecosystem impact of the world's largest apex predator in Antarctic waters.

The following are the questions we want to address and our proposed methods of investigation:

<u>1. Abundance and Distribution</u> – Nothing has been published on the relative abundance and distribution of the Antarctic killer whale ecotypes since three were first described in 2003 (Pitman and Ensor 2003). We are currently compiling a sightings data base which will provide a basis for identifying ecotype distributions and relative abundance and these come from three sources: 1) opportunistic sightings from tour ships, research vessels (including IWC/IDCR/SOWER) and from observers on longline fisheries vessels, 2) our own directed surveys, and 3) reports from research bases around the continent and on other subantarctic islands. We expect to collaborate with other researchers working on SORP vessels so that their sightings data can contribute a better understanding of distribution patterns for the different forms of killer whales. In areas of repeated coverage, we will produce photo catalogs and use mark-

recapture analytical methods to estimate killer whale abundance in those areas using methods outlined in Durban *et al.* (2010). Pitman and Durban currently maintain a photo-identification catalog of over 300 Type B killer whales (seal-eaters) from the Antarctic Peninsula area, already with a high incidence of resightings of some of those animals. Dalla Rosa (Projeto Baleias) maintains a separate catalog of nearly 100 Type B individuals from the Peninsula. We will combine these catalogs and we expect that within the next 2-3 seasons we will be able to estimate the population size for this ecotype in the Peninsula area. From this, we hope to be able to extrapolate the density and predatory impact of this ecotype around the continent. From Crozet, we currently have a catalog of 218 individually identified killer whales with matches between Crozet and Kerguelen suggesting at least some of these whales travel long distances.

<u>2. Systematics</u> – Tissue samples will be routinely collected using a crossbow and free-floating bolts, a method we have used to sample hundreds of killer whales to date from Alaska to Antarctica, and all the tropical oceans. These samples will be used to support phylogenetic research on the different ecotypes (ongoing at the SW Fisheries Science Center) and to identify population structure. We need more extensive sampling than we currently have because nearly all Type B samples come from the Peninsula area, Type Cs are almost all from the McMurdo Sound area, and there are only a handful of Type A samples from different localities. In addition, we will augment our sampling with samples previously collected around the Antarctic continent during IWC IDCR/SOWER cruises and recently acquired by SWFSC. We will use mounted pairs of lasers on our cameras used for photo-ID studies, will allow us to obtain accurate measurements of killer whale ecotypes to compare body sizes and proportions (Durban and Parsons 2006, Pitman *et al.* 2007); this is especially important because there are no extant killer whale specimens from Antarctica and photogrammetry is currently the only available source of morphometric data.

<u>3. Movements and Residency</u> Patterns - We have satellite-tagged over 60 killer whales to date from Alaska and Antarctica using tiny (ca 40 g) Wildlife Computer tags (Andrews *et al*. 2008). Tracked whales provide information only on local movements and habitat use in the short term and on migratory behavior in the longer term. During our January 2009 field season we tracked a group of Type B killer whales as they traveled over 2000 km north of the Antarctic Peninsula to an area north of the Falkland Islands; this represents the first evidence of a directed, high speed, long-distance migration of killer whales anywhere. It also suggests that killer whales in Antarctica may have specific feeding and breeding grounds as has been shown for humpbacks and southern right whales in Antarctica. Currently, we estimate that deployment of 50 satellite tags should provide a suitable sample size for studying movement patterns of types A and B killer whales in the Peninsula area and from the subantarctic islands of Crozet and Possession. We will also be making efforts to participate on other SORP cruises to tag Type C whales in the Ross Sea and elsewhere.

<u>4. Food Habit Studies</u> - From the Peninsula area, we will conduct focal follow studies of mammal-eating killer whales (types A and B). Our recent experiences suggest that we can record several kills per day by following groups during daylight hours (Pitman and Durban submitted a, b). And with satellite-tagged individuals we can quickly relocate groups after losing them due to thick ice or darkness. From these studies we can document prey selectivity as well as the number of individual prey taken. In addition, biopsy samples and remains of prey kills will be analyzed for lipids, stable isotopes, and contaminants; these will be analyzed for seasonal variation in feeding habits and for comparisons among the three killer whale forms (e.g., Krahn et al. 2008).

<u>5. Acoustic repertoire</u> – To date there has been no comparison of the acoustic repertoire of the different Antarctic killer whale ecotypes. Based on research in the North Pacific, there is reason to believe that there are ecotype-specific call types, as well as differences in vocal behavior related to different prey preferences. For example, mammal-eating killer whales are most likely to vocalize only when attacking and feeding, whereas fish-eaters should vocalize most of the time. Cataloging ecotype-specific differences in acoustic repertoires will provide the basis for future surveys using acoustic technology exclusively. Recordings will be made with portable and D-MON hydrophones, and digital recorders.

(iv) Programme or plan of research.

In Antarctica, we propose a 4-5 year project with the first 2 field seasons (2008-09 and 2009-10 seasons) supported largely by BBC Natural History Film Unit; we will be seeking support for the following 2 or 3 seasons (2010-11, 2011-12 and possibly 2012-13), depending on availability of funds. From the subantarctic islands, the photo-identification effort will continue on indefinitely at Possession

Island and aboard longliners near there as part of a depredation study. A proposed time frame for the rest of the work there would be:

- 2010 – photo-ID and behavioural observations of killer whales from longliners near Crozet Islands.
- 2010-11 – photo-ID, biopsy sampling and satellite tag deployment from longliners and from Possession Island.

(v) Requirement for resources sought in this application.
Please see section 5.

(vi) Any wider justification for the project.
None.

4. CURRICULUM VITAE OF NAMED INVESTIGATORS

Available upon request.

5. BUDGET

Annual budget in US$.

Boat charter (Antarctic Peninsula) - $1500/day x 30 days	$45,000
Travel to Falkland Islands - $2000 x 3	$6000
Acoustic data analysis (1 yr)	$73,000
Salary (1 person Crozet x 4.5 months)	$27,000
Sub total	**$151,000**

One-time expenses:

Satellite tags (and Argos time) - 50 x $3000	$150,000
Zoom Telephoto EF 70-200mm f/2.8L – 2 x $2500	$5000
Digital SLR with HD video recording – 2 x $1800	$3600
Canon D50 + 100-400 stabilized lens	$4500
Teleconverter 1.4x	$300
Camera case & Lens Accessories	$300
Portable Flash Field Recorder	$1000
Laptop computer	$3000
Hand-deployed hydrophone	$1200
4 D-MON acoustic hydrophones	$30,000
Lasers - 6 x $100	$600
Tagging equipment (crossbows; bolts) - 2 x $500	$1000
Biopsy sampling equipment	$3000
Subtotal	**$203,500**
Grand Total	**$354,500**

6. OTHER GRANTS HELD FOR THIS OR OTHER RESEARCH, OBTAINED OR SOUGHT WITHIN THE PREVIOUS THREE YEARS

1. National Geographic Society/Waitt Grants Program, 2008, $15,000 - A new living species of whale at Palmyra Island?
2. US Marine Mammal Commission, 2008, $5,000 - A new living species of whale at Palmyra Island?
3. National Geographic Society Committee for Research and Exploration, 2006, $30,000 - Using satellite telemetry to study foraging ecology and movements of Antarctic killer whales
4. National Science Foundation, 2004, $25,000 - Genetic and photogrammetric investigations of three ecotypes of killer whales in the Southern Ross Sea
5. Marine Mammal Commission, 2004, $16,000 - Genetic and photogrammetric investigations of three ecotypes of killer whales in the Southern Ross Sea

7. PERMITS
(i) Do you have the appropriate permits to carry out the field work, including, if NECESSARY, animal welfare considerations?
Yes.

(i*i) Do you have the appropriate permits (e.g. CITES) for the importation of ANY samples.* Give details and enclose copies if appropriate
Yes.

8. SCHEDULE OF WORK, REPORTING AND USE OF RESULTS
(i)) Expected completion of final report
The work is expected to be ongoing and regular reports will be provided to the IWC.

(ii) Will you submit a manuscript on the results to the Journal of Cetacean Research and Management upon completion of the work? (Whilst this is not a pre-requisite of a successful application, it will be taken into account). If not please state your publication plans
Manuscripts will be sent to high quality scientific Journals and reports presented to the Scientific Committee.

(iii) Will you agree to the use of the results of your study, if requested by the IWC Scientific Committee under its Data Availability Agreement that protects first publication rights of the researchers? Note that for fully funded IWC research, the data shall become publicly available after a mutually agreed period.
Our Antarctic killer whale photo-ID catalog will be posted online at the NMFS/SWFSC website; killer whale satellite tracks in near-real time will be posted on the SWFSC website with links to our educational outreach site. Tissue samples will be housed at the NMFS/SWFSC marine mammal tissue archive – the largest, most comprehensive marine mammal tissue archive in the world. These (and all) tissue samples are available to any legitimate researchers and can be accessed by submitting a proposal to the Loan Committee at SWFSC (contact Barbara.Taylor@noaa.gov). Killer whale photo-ID data and samples collected under Projeto Baleias/PROANTAR are stored at FURG (contact person: L. Dalla Rosa; e-mail: orca@ymail.com). Photo-ID data for Crozet and Kerguelen islands will also be available on request (tixier@cebc.cnrs.fr).

APPENDIX 2: SORP Foraging ecology project

SORP RESEARCH PROPOSAL

1. TITLE OF PROJECT

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

2. DETAILS OF NAMED INVESTIGATORS (Principal Investigator first)

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3. DESCRIPTION OF PROJECT

(i) Background to the proposal, underlying rationale and relevance to SORP objectives and IWC needs.

To date, little is known about the dynamics of predator-prey interactions and the response of baleen whales to the distribution of their prey in the Antarctic. From opportunistic observations, Ainley et al. (2006) suggest that baleen whales may deplete prey enough at the fine-scale that other krill predators alter their foraging behavior and switch prey. Brierely et al. (2002) suggest that the aggregating behavior of krill to a zone just inside the sea ice edge may be a response to balance the risk of predation with foraging, yet no behavioral data on cetaceans exists in the Antarctic to test such a hypothesis. In other areas of the world, however, studies using combined visual, tagging, and prey sampling methods are beginning to elucidate details of baleen whale foraging ecology and predator-prey interactions (Croll et al. 1998, Acevedo-Gutiérrez et al. 2002, Friedlaender et al. 2009, Hazen et al. 2009). As a particularly important marine ecosystem (e.g. climate change impacts and international management of marine living resources) similar research focused on cetacean foraging ecology in the Antarctic represents a critical data gap.

Empirical studies focused on baleen whales in the Antarctic have largely been limited to surveys for population assessments (Branch and Butterworth 2001), describing distribution patterns in relation to large scale physical oceanographic features (Uda 1954, Tynan 1998) or coarse surveys of prey across broad spatial scales (Kasamatsu et al. 2000a, Kasamatsu et al. 2000b, Nicol et al. 2000, Reid et al. 2000, Murase et al. 2002). Such relationships between whales, environment, and prey have rarely been assessed at smaller spatial extents (10s of km) (Thiele et al. 2004). High densities of krill, along with baleen whales and other predators, do occur at ice margins or edges (de la Mare 1997), particularly where they coincide with physical features and biological processes (i.e. complex bathymetry, gyres, eddies, shelf edges) that may enhance concentrations of nutrients and prey (Ribic et al. 1991, Murase et al. 2002, Thiele et al. 2004, Friedlaender et al. 2006). Yet contrasting regions around the Antarctic provide vastly different oceanographic systems around which cetaceans rely on a krill-based forage: for example the marginal ice edge zone of East Antarctica and the coastal, largely ice-free nearshore waters of the Western Antarctic Peninsula.

Recently, significant relationships have been demonstrated between the relative abundance of humpback and minke whales, increasing prey abundance, and certain physical features that may aid in prey aggregation off the Western Antarctic Peninsula (Friedlaender et al. 2006, Friedlaender et al. 2008a,b). While many previous studies of predator-prey relationships in the Antarctic rely on data collected over incongruous spatial and temporal scales, these studies used concurrent measurements of both predator and prey abundance. Such measurements of both whales and prey have also yielded insights into inter-specific interactions between krill dependent whale species in the Antarctic. In autumn, humpback whales appear to associate with shallower krill patches than minke whales, partitioning resources vertically in the water column (Friedlaender et al. 2006, Friedlaender et al. 2008a). Evidence also suggests that where the two species do associate with prey at similar depths, the whales target different sized krill patches (Friedlaender et al. 2008a). Friedlaender et al. (in review) provide new insights to suggest that the amount of niche overlap between humpback and minke whales is higher than that between cetaceans and other krill predators (e.g. crabeater seals and Adelie penguins) around Margeurite Bay. Across years, and as environmental conditions and prey availability change, cetaceans appear to be able to maintain continuity in their niches (which are based to a large degree on the distribution of krill) whereas other krill predators more tied to ice or land have difficulty in maintaining such relationships. Schoener (1968) discusses how sympatric predators, such as minke and humpback whales, avoid competition. Sympatric species that have evolved similar ecological niches are less likely to interact competitively as they typically will target different types of the same prey (i.e. different size classes or depths of swarms) and will go to great lengths to avoid competition. Thus, the likelihood of humpback whales and Adelie penguins interacting competitively for limited resources based on their minimal amount of niche overlap is greater than for humpback and minke whales (Friedlaender et al. in review). This hypothesis is supported indirectly by Friedlaender et al. (2008b) who show strong correlation in the relative abundance of humpback whales, krill size targeted by Adelie penguins and penguin foraging success around Anvers Island.

Currently, ecological studies using concurrent tagging and quantitative prey mapping methods are being conducted (May 2009 and May 2010) in the waters in and around the Gerlache Strait, Western Antarctic Peninsula. Preliminary results indicate unprecedented densities of both humpback whales and krill abundance and never before recorded feeding depths (over 370 meters) in several bays (Nowacek et al. in review). In 2009, 11 humpback whales were tagged, collecting over 160 hours of on-animal data and over 350 hours of scientific echosounder prey data were also collected. The successes of this research initiative have been to provide (1) a proof of concept for conducting quantitative ecological studies focused on cetaceans and their prey in the Antarctic, and (2) a baseline of understanding to describe the foraging behavior and ecological interactions between cetaceans and their prey. The framework of this research initiative was developed with the aim of being easily replicated in a manner that allows for direct and quantitative comparisons between cetacean species and geographic locations around Antarctica.

As both habitat quality and prey availability affect the population dynamics of cetaceans, understanding the distribution of cetaceans and their prey may provide insights into effective and proper conservation and management strategies for these predators (Kasamatsu et al. 2000b, Murase et al. 2002). Findings to date, including those being collected currently, demonstrate that basic and important ecological information regarding baleen whale ecology in the Antarctic can be gleaned from concurrent measurements of both predators and prey. However, this information falls substantially short of what is known for other krill predators in the Antarctic Marine Ecosystem.

Links to IWC Recommendations. Our proposed research will provide information critical to achieving the following recommendations of the IWC:

Recommendation 1: *With regard to the Southern Ocean, the Committee endorses a number of specific Workshop recommendations for future work, including: (5) further efforts (e.g.*

telemetric) to examine the movements and feeding ecology of Antarctic minke whales in winter…The Committee recommends emphasis on cetacean studies which allow comparisons between contrasting regions where data on a wide range of ecosystem components are available. Regionally comparative studies on southern right whales and humpback whales from Eastern Antarctica, the Antarctic Peninsula and South Georgia are likely to be particularly informative [SC61, E, 12.1, p. 60-61]. This recommendation comes from the workshop on Cetaceans and Climate Change.

Recommendation 2: *(i) The Committee **recommends** that all tagged whales be individually identified photographically; biopsy sampling of tagged whales would provide an alternative means of individual identification (via genotyping), as well as information on sex and data for genetic and other studies; and (ii) The Committee also **recommends** that the design and dimension of the tags deployed should be included in all reported studies using satellite tagging and that further studies of the short-term impacts and responses of whales to tagging be conducted* [SC60, SH, 10.2.2.2.5, p. 40].

Recommendation 3: *The Committee **recommends** the application of these tools [passive acoustic recorders, satellite tags, sea ice analytical tools] to future cetacean research in the Arctic and Antarctic and **encourages** researchers to continue the collaborative exchanges initiated at the symposium* [SC58, E, 12.1, p. 42].

Recommendation 4: *The Workshop also recognised the difficulties in developing (and measuring) suitable indices both of habitat quality and response in cetaceans. It **recommended** that further work be undertaken in this regard, particularly with respect to: (1) identifying key features of cetacean habitat; (2) reviewing methods used to assess cetacean nutritive status in both live and dead specimens, with a view to future standardisation of techniques; and (3) developing indices of cetacean response to various stressors* [SC58, E, 12.1, p. 43]

Recommendation 5: *The Workshop **recommended** that future work on habitat utilisation could include consideration of both tagging and at sea survey data in order to provide the most complete assessment of habitat utilisation* [SC/61/REP3, 2.3.4.2.1, p. 27]. This is from the joint IWC/CCAMLR workshop on SO Ecosystem Modelling 2008.

Recommendation 6: *In general terms, the Workshop **recommends** emphasis on cetacean studies which allow comparisons between contrasting regions where data on a wide range of ecosystem components are available from ongoing multi-disciplinary projects* [SC/61/REP4, 8.2.2, p. 22]. This is from the Report of the workshop on climate change and whales 2009.

(ii) Specific objectives.

Our research will:
(1) provide direct and quantitative estimates of krill consumption rates by humpback and minke whales and incorporate these into models for the management of krill stocks and the conservation of the Antarctic Marine Ecosystem;
(2) provide information integral to understanding predator-prey ecology and trophic dynamics, i.e., if/how baleen whales affect the distribution and behavior of krill and/or other krill predators;
(3) evaluate the likelihood and amount of niche overlap and competitive interaction between humpback and minke whales;
(4) add significantly to knowledge of the diving behavior and foraging ecology of baleen whales in the Antarctic;
(5) develop new geospatial, visualization, and analytical tools for the construction of multi- trophic level models that account for physical as well as biological data;
(6) provide a portable methodological and analytical framework for conducting analogous studies across Antarctic (and other) regions; and
(7) quantitatively compare the ecological interactions between humpback and minke whales across two distinct geographic regions: the Western Antarctic Peninsula and East Antarctica.

(iii) Scientific methodology and approach.

KRILL SAMPLING

Krill distribution will be monitored with a combination of acoustics and nets. During the SO GLOBEC cruises, Zhou et al. (2004) developed a suite of MATLAB codes for real time ADCP data processing, interpolation and display integrated with the ADCP system on the *LM Gould*. We will conduct current backscattering surveys and MOCNESS tows on targeted aggregations for verifying acoustic measurements from the *LM Gould* prior to tag deployments. After a tag is deployed, we will continue to map targeted krill aggregations and other areas where whales are foraging, and instantaneously provide locations, abundance and movement (integrating with currents) to Zodiac teams for more detailed high- resolution mapping of krill fields. As animals perceive and react to their environment at a range of scales, there is clearly no single scale correct for studying ecological relationships (Levin 1992). We will utilize acoustic systems on both the *LM Gould* and a Zodiac for mapping both the meso- (1-10 km) and fine-scale (100's of meters), respectively, for this project. We will design meso-scale acoustic surveys to adequately and synoptically cover the immediate area surrounding an aggregation of humpback whales in order to determine the relative number, location, and size of krill patches in the study area. Once the DTag has been deployed on a whale, we will follow a more refined and focused small-scale survey.

We will tow a multi-frequency split-beam SIMRAD EK-60 echosounder system on a Zodiac at a short distance behind the tagged whale and in areas surrounding where the whale has just passed. These measurements will be used to investigate the properties of krill swarms that the whales appear to be foraging on, as well as once the whale has left a certain patch. The radius perpendicular to the whale's track to be covered will likely be on the order of 100s of meters. Survey lines will be constructed to achieve the highest possible resolution of krill swarm size, area, and density. To ground-truth the size and species structure of krill swarms we will periodically conduct MOCNESS tows from the *Gould*. Target strength-length equations will be used to convert acoustic backscatter to numeric a) Meso-scale acoustic survey track (black line) superimposed over the track of a tagged whale (green) and krill swarms (red). b) Hypothetical fine-scale acoustic survey track following the path of a tagged whale. c) prey mapping around an individual foraging whale. abundance estimates using echo-integration and MOCNESS sampled krill sizes (Flagg and Smith 1989, Pieper et al. 1990, Greene et al. 1991, Zhou et al. 1994, Ashjian et al. 1994, Chu and Wiebe 2005).

Using continuous acoustic measurements over 3-D krill aggregations, the reconstruction of a 3-D krill aggregation and its evolution can be achieved by applying the Eulerian-Lagrangian objective interpolation method (Zhou 1998). Acoustic data from the EK-60 will be used as the primary instrument to measure krill biomass and distributions at fine scales from the Zodiac following tagged whales, and the ADCPs will be used as the primary instrument to measure currents and krill biomass and distributions at meso-scales from the *LM Gould*. Both instruments will be calibrated and validated using net tow samples from MOCNESS tows (Flagg and Smith 1989, Ashjian et al. 1994, Zhou et al. 1994).

ANALYSIS METHODOLOGY

<u>Prey sampling</u> (Figure 5) - Acoustic echosounder data will be processed using Sonardata Echoview software. This software allows automatic detection of schools for echo- integration and post-processing. We use the mean volume backscatter strength (MVBS, a measure of acoustic density) from each school as well as patch metrics (height, length, depth, area) to examine patch dynamics at both fine and meso-scales (e.g. Hazen et al. 2009). All exported acoustic biomass data including georeferenced 2-dimensional patch metrics, integrated cell biomass (sA, density per 50m), and physical variables are directly imported into a GIS for spatial analysis. Figure 5 shows a sample of how fine-scale prey mapping is conducted around a tagged whale to compare prey densities where whales feed versus non-feeding behavior.

<u>Whale Data</u> – We use a digital suction-cup tag (DTag (Johnson and Tyack 2003) to collect behavioral data from whales. We have successfully deployed this tag on over 100 humpback world-wide. We combine the pitch, roll, heading, and depth data from the DTag (Johnson and Tyack 2003) with the whale's surfacing locations to generate a georeferenced "pseudo- track" of each animal's movements. The pseudo- track can then be incorporated into TrackPlot (Figure 6), a customized visualization software package which allows for examination of temporally sequenced behaviors as spatial patterns (Ware et al. 2006). The program creates a continuous 3D ribbon indicating the direction of travel, body orientation (pitch and roll), depth, and kinematic movements like fluke strokes. To visualize certain behaviors, like rolling, the ribbon incorporates sensor data and twists around the along-track heading highlighting characteristics of interest (Figure 3, Ware et al. 2006).

Using trackplot we can code every surfacing from each tagged whale as a surface feeding, mid-water feeding, bottom feeding, or non-feeding event, and ground truth events using the behavioral observations during focal follows. Using previously calibrated methods (Hazen et al. 2009, Friedlaender et al. 2009), time-linked surfacing observations from the behavioral data and TrackPlot ribbons can be used to define underwater movement patterns that result in a feeding event. These studies used a blind comparison from a subset of data to manually identify surface feeding events using TrackPlot that were validated against behavioral sequencing data and found agreement 97% of the time (n = 100 events). The mean depth of feeding events and total dive duration per feeding event are calculated using TrackPlot and compared to prey distribution. Feeding and non-feeding events can then imported into ArcGIS for spatially-explicit analysis incorporating prey and oceanographic data.

Data sampling and statistics - For prey data, we will use generalized additive models (GAMs) to examine the non-linear relationship between prey density and environmental variables (Table 1). Generalized linear models (GLM) are useful for examining linear effects of environmental variables on prey density but many ecological relationships non-linear. To examine thresholds in predator behavior, a Classification and Regression Tree (CART; Redfern et al. 2006) will be run with whale behavior as the response variable. Optimal recursive partitioning combined with a cross-validation using explained deviance ensures that only the most significant breaks are included in the final model. GAMs can then be constructed to examine the non-linear relationship between CART selected variables and whale foraging behavior and to test for the factors most influencing whale feeding behavior.

Because whales forage at multiple scales (e.g. travel, search, feeding), having multiple sampling scales can help to resolve these processes. Our fine scale approach will examine individual feeding events and prey density dependence at the scale of an individual whale: feeding likelihood ~ f(prey patch metrics + oceanography), but we will rely on the meso-scale data to tease apart aggregative responses, density dependence in foraging: abundance ~ f(prey biomass + oceanography), and the broader scales of foraging behavior such as travel and search. We will use scale-explicit analyses including exploratory geostatistics, spectral analyses, and wavelets to identify key scales at which predator, prey, and oceanography intersect. We can compare the key spatial scales at each trophic linkage and across ecosystems to determine top predator and prey dynamics across marine ecosystems.

By expanding analyses across multiple years of data, we can quantify inter-annual variability of an individual whale and variability in foraging decisions among whales. By combining spatially explicit analyses at a number of temporal scales our research will serve as an important step towards understanding the foraging ecology of whales in both an evolutionary and conservation framework.

Analytic Data Visualization, Data Fusion, and Interactive Analysis- We and colleagues have developed unique tools to augment the analysis of humpback whale behavior as noted above. TrackPlot has been redesigned to support more detailed kinematic analysis of the data coming from tags, such as DTAG (Figure 6). This package has been instrumental in identifying and classifying feeding events, both in the case of surface feeding of humpback whales on sand lance on Stellwagen Bank (Friedlaender et al. 2009) and in the case of deep feeding of humpbacks on krill in bays of the West Antarctic Peninsula (Ware et al. in review).

Successful interactive visualization tools enlist the powerful pattern finding capabilities of the human visual system to enable researchers to gain insights into relationships between heterogeneous data features, although it is critical for the right representation to be used (Ware, 2008). For example, we (Ware et al. 2006) claim more than an order of magnitude gain in the rate at which whale behavior patterns could be identified through TrackPlot software. This ability has been critical in identifying different classes of surface feeding occurring on Stellwagen bank (e.g. Friedlaender et al. 2009). The most successful visualization tools, however, integrate visualization with interactive analytic capabilities.

We will further develop TrackPlot to support the proposed research. We propose three major new developments. Firstly we will develop methods to automatically identify dive features in the kinematic time series record (such as side-rolls, spirals, loops, lunges, etc). A recent new development in TrackPlot is the capability to estimate the animal's speed using flow noise, a variant of the method of Goldbogen et al. (2006). To this we have added the capability to identify lunges automatically using the acoustic signature of a lunge to deep feeding whales in the WAP (Figures 3&5, Ware et al in review).

We believe that automatic feature identification can be enormously useful, because it opens up the possibility of identifying and quantifying the kinematics of many consumption events over long periods. At the moment, most researchers discovering a new behavior only describe a few "representative" examples. We propose to enhance and generalize the automatic feature finding capabilities of TrackPlot so that researchers can use manually scrutinized combinations of features to identify repeated kinematic patterns through a selection of parameters such as turn rate, roll angle, and depth. Identifying a complete record of such events over extended periods will be essential towards analyzing amount of time spent foraging and linking foraging behavior to prey patches and oceanographic fields. Feature identification tools are being developed iteratively with input from cetacean biologists/behaviorists in concert with visualization programmers.

Secondly, to support larger scale analysis we will develop and evaluate string similarity metrics to group dives into classes related to foraging. We will investigate the use of integrated Markov Chain analysis for this purpose (Baum and Petrie 1996) as well as other string similarity metrics such as q-grams (Ukkonen, 1992). Statistical tools will be integrated into TrackPlot so that once a distinctive behavior is identified, other instances can be automatically found and characterized. The idea is to develop a highly interactive analytic tool where interactive visualization and analysis are tightly coupled (Ware, 2008). Once a behavior is classified, the TrackPlot visualization will be automatically updated so that the different behavioral categories can be placed in geospatial context with other data (prey, oceanography).

Thirdly, we will improve the interoperability of Tackplot with other software. This will involve improving georeferencing, using flow noise and creating standard input and output files compatible with other tools (such as GIS packages).

Together we believe that these enhancements can dramatically improve the ability of marine scientists to extract ecological meaning and inference from tag data. Ware's lab is committed to making TrackPlot tools available to other researchers using tag technology (e.g. DTag, Crittercam, Acousonde) to study the behavioral ecology of marine animals. Quantitative estimates of prey consumption- Tag data will be used to estimate prey consumption rates by whales, which has long been a subject of debate and concern. Leaper and Lavigne (2001) reviewed methods used to estimate these rates, finding that for a 40- ton whale, estimates can differ by a factor of ten depending on the parameters chosen. They indicate that direct estimates of prey consumed via behavioral studies would be very useful in refining these models. We will combine three data sets **to generate quantitative estimates of consumption rate**: i) the number and location of feeding events measured by the DTag (Figure 2, Friedlaender et al. 2009, Ware et al. in prep); ii) acoustic estimates of the biomass and density of prey in the patches exploited by the whale (Hazen et al. 2009); and iii) the volume of water engulfed per foraging event. The volume engulfed by gulping feeders, such as humpback whales, has been estimated to be approximately 70% of their body mass (Pivorunas 1979), but we will paramaterize a length-dependent model to more accurately estimate this volume for an individual whale.

As mouth volume is dependent on the whale's overall body size, we will estimate buccal volume for each tagged whale. We used morphometric data collected by Matthews (1937) from 62 Antarctic humpback whales taken commercially to derive relationships between measurable regions of free-swimming whales and total body length. A significant relationship was found between total body length and fluke width ($R2= 0.66$, $p <0.0001$) as well as with snout to blow-hole length ($R2=0.85$, $p<0.0001$). Digital images of these body regions taken in the field will be converted to actual lengths using a photogrammetric process, and converted to total length and gulp volume for each whale.

The occurrence of lunges/gulps can be gleaned visually from TrackPlot ribbons as well as: i) the accelerometers (Figure 1, Calambokidis *et al.* 2003, Goldbogen *et al.* 2006); ii) the acoustic record (Woodward 2006); and iii) the depth record (Croll *et al.* 1998, Goldbogen *et al.* 2006). The DTag logs all of these data, as well as heading, therefore maximizing our ability to measure lunges and minimize the likelihood of false positives. So, through DTag data and photogrammetrically determined body length, we will have the number of lunges executed by an individual whale and the water volume engulfed. The final part of the consumption rate calculation is prey biomass, and our methods for sampling this parameter are described in detail above.

(iv) Programme or plan of research

Dedicated ship time for a successful effort to collect whale foraging information requires at least 30 days of field work. The exact timing of when cruises would take place is regionally dependent on the occurrence of whales. For example, off the Western Antarctic Peninsula we would target March--

-April, while off East Antarctica we would target February---March. There is no reason to believe concurrent research programs could not be conducted simultaneously in spatially discrete regions. We anticipate conducting field work between 2012---2014 depending on the timing of funds and the availability of ship time in each region. We will aim for two field seasons in each geographic location and a year's time for synthesis and analysis, workshops, project report writing, and manuscript preparation. We plan to submit a research proposal for work around the Antarctic Peninsula to the US National Science Foundation in June 2011. Likewise, we anticipate a similar, collaborative proposal to be submitted to the Australian Antarctic Division within the same time period.

(v) Requirement for resources sought in this application

The International Whaling Commission's Southern Ocean Research Partnership fund would be targeted as potential funder for some of the necessary equipment that can be transported between regions for multiple uses. We propose that SORP funds are used to purchase a dual--frequency echo--sounder system and analysis software to be used in both regions by each research team (~$120,000 USD). International member government agencies will be required for research vessel/ship time. Likewise, currently funded multi---disciplinary international research efforts may be a source of ship time and/or research funds (e.g. ICCED). The US lead research team will submit a proposal to the US National Science Foundation's Office of Polar Programs to support the project around the Antarctic Peninsula. Our proposal will be greatly augmented by the political and intellectual support of the IWC, SORP, and other international countries wishing to collaborate and engage in this unique research effort. A similar, collaborative research proposal will be submitted to the Australian Antarctic Division.

(vi) ***Any wider justification for the project***

None.

4. CURRICULUM VITAE OF NAMED INVESTIGATORS

Available upon request

5. BUDGET

The overall budget for the field work and data analysis will vary regionally depending on the amount of instrumentation currently available to each program (e.g. MOCNESS or similar nets, scientific echosounders (38 and 120 kHz)), and the amount of personnel available for field work. By category is an outline of major budget requirements based on our current research model:

Cost/item	**Frequency**	**Cost (USD$)**
Research coordinator (3 months)		18,000
Suction-cup tags (D-Tags) and equipment	Annual	30,000
Satellite linked time depth recorders	Annual	60,000
Paired dual-frequency (38&120 kHz) echo sounders	One off	120,000
Consumable materials and field equipment	Annual	20,000,
Software licences and development	Annual	20,000
Graduate students tuitions and stipends (annually)	Annual	50,000
Field, analysis, writing and model development	Annual	80,000
TOTAL		~400,000
* not including in-kind vessel charter to be supported by international research programmes ** not including indirect institutional costs		

6. OTHER GRANTS HELD FOR THIS OR OTHER RESEARCH, OBTAINED OR SOUGHT WITHIN THE PREVIOUS THREE YEARS

1. The ecological role of a poorly studied Antarctic krill predator: the humpback whale, *Megaptera novaeangliae*. National Science Foundation, Office of Polar Programs ANT-07-39483, $967,165 August 2008-September 2011

7. PERMITS
(i) Do you have the appropriate permits to cary out the field work, including, if NECESSARY, animal welfare considerations?
Yes.

(*ii) Do you have the appropriate permits (e.g. CITES) for the importation of ANY samples.*
N/A.

8. SCHEDULE OF WORK, REPORTING AND USE OF RESULTS
(i)) Expected completion of final report (note that an annual progress report is required)
2012 in the Antarctic Peninsula and further work potentially in the Ross Sea until 2014

(ii) Will you submit a manuscript on the results to the Journal of Cetacean Research and Management upon completion of the work?
Manuscripts will be sent to high quality scientific Journals and reports presented to the Scientific Committee.

(iii) Will you agree to the use of the results of your study, if requested by the IWC Scientific Committee under its Data Availability Agreement that protects first publication rights of the researchers? Note that for fully funded IWC research, the data shall become publicly available after a mutually agreed period.
Data from all of the sponsored research cruises will be available to contributing countries and collaborating researchers. Data sharing agreements will be mandatory for participation in regional projects, and the project Coordinator will be responsible for maintaining and disseminating data.

APPENDIX 3: SORP Acoustics of blue and fin whales

SORP RESEARCH PROPOSAL

1. TITLE OF PROJECT

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

2. DETAILS OF NAMED INVESTIGATORS (Principal Investigator first)

Name	Dr. Flore Samaran (Project Coordinator & Steering Group Member)
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3. DESCRIPTION OF PROJECT (do not exceed 3000 words)
This should explain adequately the following aspects:

(i) Background to the proposal, underlying rationale and relevance to SORP objectives and IWC needs.

This initiative 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. Current understanding of blue and fin whale life history characteristics, population abundance, and any post-whaling recovery is limited. Commercial whaling severely depleted blue (*Balaenoptera musculus*) and fin (*B. physalus*) whale populations to a fraction of their original abundance with over 350,000 and 700,000 whales killed, respectively (Clapham & Baker, 2002). Blue whales are now thought to number approximately 1% of their pre-exploitation abundance, increasing at an annual rate of 7.3%, though the confidence interval on this rate of increase is wide (1.4-11.6%) (Branch *et al.*, 2007). Even less is known about fin whales, with no recently accepted abundance estimates, and no currently accepted estimates of trends in abundance (NMFS, 2006).

Sightings 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 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 through the collection of data that is relatively inexpensive to obtain, and can be collected continuously for years on end, under ice cover, and in any weather conditions or sea-states.

Sounds travel great distances underwater with detection ranges in the order of many tens to hundreds of kilometres for blue and fin whales (Širovic *et al.* 2007; Stafford *et al.* 2007; Samaran *et al.* 2010). Both species also produce repetitive, stereotypic and distant-travelling calls that are among the most commonly recorded baleen whale sounds in the Southern Ocean (Širovic *et al.* 2006; Širovic *et al.* 2007; Gedamke & Robinson, 2010). These regular, far-ranging calls illustrate the vast ability of acoustic techniques to monitor both populations, and highlight the potential to use acoustics to estimate relative population densities (Mellinger *et al.* 2007; Marques *et al.* 2009; Marques *et al.* 2011). While obtaining accurate absolute abundance estimates is currently beyond the reach of passive acoustic methods, measures of relative abundance are easily obtainable and can be conducted in a consistent manner. 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 a measure 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).

Some relevant IWC recommendations are listed below. Often the use of passive acoustics has been recommended but it is important to note that one of the primary goals of this work is to investigate the plausibility of using passive acoustic means to obtain estimates of population growth rates, an essential life history parameter for understanding and managing populations of whales.

1. Addressing the lack of abundance data for fin whales is a key priority due to the high historic abundance of this species and the current lack of data. Surveys for these species on the breeding grounds (which are largely unknown) are unlikely to be feasible. Data from the Southern Ocean, north of 60°S are limited and could be addressed by surveys between 60°S and CCAMLR boundary which could also help generate estimates for other species (particularly sei and right whales). However, surveys in this area are frequently made difficult by weather conditions. Complete new circumpolar surveys are unlikely in the future, so there is a need for a regional focus to detect trends at smaller spatial scales. Surveys to identify regional trends may also help identify variables driving these trends. (SC61)
2. The Committee **welcomes** the presentation of this work [*passive acoustic monitoring*] and **recommends** its continuation. (SC61)
3. With regard to the Southern Ocean, the Committee **endorses** a number of specific Workshop recommendations for future work, including:… (2) further investigation of the use of autonomous bottom mounted acoustic recorders to obtain long-term datasets for fin and blue whales. (SC61)

4. Following on from the Workshop, the Committee again **emphasises** the great value of long-term datasets and **recommends** that funding be provided to ensure their continuation (SC61)
5. The Committee **recommends** the application of these tools [passive acoustic recorders, satellite tags, sea ice analytical tools] to future cetacean research in the Arctic and Antarctic and **encourages** researchers to continue the collaborative exchanges initiated at the symposium. (SC58)
6. Short term Priorities:…Priority 4: Development of survey techniques. Priority Item 6: Development of methods to integrate acoustics with sightings surveys (2007/8 SOWER planning meeting, SC61)
7. The SC agreed that the following species priorities should be assigned in order from highest to lowest: (1) Antarctic minke and blue whales, (2) fin whales, (3) humpback whales, (4) sei and right whales; and (5) sperm whales. (SC58)

(ii) Specific objectives.

Overall objective:
Measure the relative acoustic density of blue whale and fin whale vocalizations at a range of sites around the Southern Ocean and lower latitude locations to examine trends in relative estimates of abundance, distribution, and seasonal presence of blue whales and fin whales.

Sub-Objectives:
Feasibility study-Year 1

- Assess different techniques for annually quantifying relative abundance of vocalizing whales from passive acoustic recordings. A range of technical issues will be addressed including call detection techniques, calculating detection ranges, distinguishing multiple calls of a singing individual from multiple individuals, and determining a ratio of calls detected to a relative density index.
- Determine the most appropriate methodology for using a series of relative abundance estimates to obtain an index of population growth over time, and for comparing between locations and/or instrument types.
- Obtain preliminary rates of population growth or decline from a previously obtained dataset (8 years of continuous Comprehensive Test Ban Treaty Organization (CTBTO) hydro-acoustic data collected off Cape Leeuwin, Western Australia).
- Design and test models to determine how passive acoustic detection data can be used to estimate relative abundance and trend data for Antarctic blue and fin whales.

Design study-Year 2 & 3

- On the basis of the results of the feasibility study, design a two stage acoustic logger deployment strategy around Antarctica taking into account data on historic and present distribution patterns of whales and logistical constraints of shipping routes for deployment and retrieval of equipment.
  - Stage 1: For an initial priority, focus work on a deployment strategy around the Indian Ocean basin.
  - Stage 2: On the basis of the first stage, consider the feasibility of extending the deployments to a circumpolar scale

Implementation—Years 4, 5 and beyond

- Establish framework for continuing this program beyond the initial SORP 5 year timeframe as population growth estimates will become more powerful when studied over longer periods of time.
- Conduct, multi-year deployments of loggers based on the appropriate study design.
- Use comparison of relative abundance indices between years at individual locations to determine a rate of increase over time
- Use comparison of relative abundance indices between locations to assess relative distribution within years, and changes from year to year.
- Use changes in relative abundance indices within a year and between years at individual locations to assess seasonal acoustic presence of whales at each location.

(iii) Scientific methodology and approach

<u>Data Collection</u>
In the first instance, we propose to use an 8-year time series from the CTBTO station at Cape Leeuwin, Australia to see if any trends in Antarctic blue whale abundance are evident from acoustic data. Additionally, any already established listening stations and previously recorded data could be utilized

for the initial feasibility study (Table 1). Additional potential collaborators will also be contacted to assess other existing and continuing datasets that could contribute to the study. Upon the successful completion of the feasibility study, we will begin looking to expand data collection sites further into the Indian Ocean initially, followed by as near a circumpolar deployment of instruments as can be achieved through the network of collaborators.

Table 1: Previously Collected Datasets

Instrument Name	Latitude	Longitude	Start Date	End Date	Instrument type	Depth	Initial Contact
Drake	-60.5	-61.0	Jan-05	Jan-06	HARUphone	~350m	Dziak/Park
Bransfield1	-62.9	-59.5	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Bransfield2	-62.5	-58.9	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Bransfield3	-62.5	-58.0	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Bransfield4	-62.3	-57.9	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Bransfield5	-62.2	-57.1	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Bransfield6	-62.9	-60.2	Jan-05	Jan-07	HARUphone	~350m	Dziak/Park
Scotia1	-57.5	-41.4	Jan-07	Jan-09	HARUphone	~350m	Dziak/Park
Scotia2	-58.9	-37.0	Jan-07	Jan-09	HARUphone	~350m	Dziak/Park
Scotia3	-57.4	-36.6	Jan-07	Jan-09	HARUphone	~350m	Dziak/Park
Scotia4	-56.4	-33.9	Jan-07	Jan-09	HARUphone	~350m	Dziak/Park
WAP1	-62.3	-62.2	Mar-01	Feb-03	ARP	1600 m	Sirovic/Hildebrand
WAP2	-63.8	-67.1	Mar-01	Feb-03	ARP	~3000 m	Sirovic/Hildebrand
WAP3	-65.0	-69.1	Mar-01	Feb-03	ARP	~3000 m	Sirovic/Hildebrand
WAP4	-66.0	-71.1	Mar-01	Feb-03	ARP	~3000 m	Sirovic/Hildebrand
WAP5	-66.6	-72.7	Mar-01	Feb-03	ARP	~3000 m	Sirovic/Hildebrand
WAP6	-67.1	-74.2	Mar-01	Feb-03	ARP	~3000 m	Sirovic/Hildebrand
WAP7	-65.4	-66.1	Mar-01	Feb-03	ARP	450 m	Sirovic/Hildebrand
WAP9	-67.9	-68.4	Mar-01	Feb-03	ARP	870 m	Sirovic/Hildebrand
DGN	-6.3	71.0	Jan-02	Dec-03	CTBT		Stafford
DGS	-7.6	72.5	Jan-02	Dec-03	CTBT		Stafford
DGS	-7.6	72.5	Jan-04	Dec-05	CTBT		Gedamke
CL	-34.9	-114.1	Jan-02	Dec-03	CTBT		Stafford
CL	-34.9	-114.1	Jan-02	Jun-10	CTBT		Gedamke
Crozet	-46.0	51.0	May-03	Apr-04	CTBT	300 m	Samaran
PALAOA	-70.3	-8.1	Dec 05	ongoing	PALAOA (2 hydrophones)	~180m	AWI/van Opzeeland
AWI 230-6	-66.0	0.0	Mar 08	Dec 10	AURAL	200 m	AWI/van Opzeeland
AWI 232-9	-68.0	0.0	Mar 08	Dec 10	AURAL	216 m	AWI/van Opzeeland
MAD	-26.1	58.2	Nov-06	Dec-08	HARUphone	1300 m	Royer/Samaran/Guinet
MAD	-26.1	58.2	Dec-09		UBOphone	1300 m	Royer/Samaran/Guinet
NCRO-1	-41.0	52.8	Dec-09		UBOphone	1100 m	Royer/Samaran/Guinet
NCRO-2	-41.0	53.2	Dec-09		UBOphone	1100 m	Royer/Samaran/Guinet
NCRO-3	-41.2	53.0	Dec-09		UBOphone	1100 m	Royer/Samaran/Guinet
WKER-1	-46.6	60.1	Dec-09		UBOphone	500 m	Royer/Samaran/Guinet
WKER-2	-46.6	60.5	Dec-09		UBOphone	500 m	Royer/Samaran/Guinet
WKER-3	-46.8	60.4	Dec-09		UBOphone	500 m	Royer/Samaran/Guinet
SWAMS	-43.0	75.6	Oct-06	Jan-08	HARUphone	1000 m	Royer/Samaran/Guinet
SWAMS	-43.0	75.6	Feb-10		UBOphone	1000 m	Royer/Samaran/Guinet
NEAMS	-31.6	83.2	Oct-06	Apr-08	HARUphone	1200	Royer/Samaran/Guinet
NEAMS	-31.6	83.2	Feb-10		UBOphone	1200	Royer/Samaran/Guinet
ARPCasey04	-63.8	111.8	Feb-04	Jan-05	ARP	~3000	Gedamke
ARPPrydz05	-62.6	81.3	Jan-05	Feb-06	ARP	~1800m	Gedamke
ARPKerg05	-66.2	74.5	Feb-05	Feb-06	ARP	~2700m	Gedamke
ARPKerg06	-66.2	74.5	Feb-06	Mar-07	ARP	2680m	Gedamke
ARPPrydz06	-62.6	81.3	Feb-06	Mar-07	ARP	1900m	Gedamke
Curtin44S.2006	-44.0	144.7	Mar-06	Jan-07	Curtin Logger	1866m	Gedamke
Curtin65S.2006	-65.6	140.5	Feb-06	Jan-07	Curtin Logger	~1100m	Gedamke
Curtin54S.2006	-53.7	144.8	Dec-05	Oct-06	Curtin Logger	~1600m	Gedamke
Curtin54S.2008	-53.7	141.8	Dec-07	Feb-09	Curtin Logger	2078m	Gedamke
Curtin.Kerg. 2009	-56.1	77.8	Feb-09	Jan-10	Curtin Logger	587m	Gedamke
Curtin.Casey.2010	-64.6	108.3	Dec-09	Dec-10	Curtin Logger	2770m	Gedamke

Long term, moored acoustic recorders will be deployed to collect passive acoustic data. These instruments are designed to sit on the sea floor in depths of up to 6000m and record acoustic signals for a continuous period of 1 year or more. The recorders can be programmed to sample varying frequencies on different programmable schedules, although for blue and fin whales, the lowest frequencies (<200Hz) are of most interest. These units can be deployed and retrieved on relatively short time frames (~3 hours) permitting them to be dropped off or picked up on transit cruises to the Antarctic that are not necessarily dedicated to marine science. For each data collection site, 2 instruments would be ideal so that each year when an instrument is recovered, a new instrument can be deployed simultaneously. During the first year of the project, an analysis of where to deploy instruments based on previous sighting records and regular vessel transit tracks of collaborating nations will be conducted to inform future deployment decisions.

Data Analysis
The initial feasibility study will focus on assessing analysis techniques utilizing several long term datasets that have been previously collected and are currently available. Table 1 lists examples of these long-term and continuing datasets that can be utilized. With large acoustic datasets of a year or more, automated and consistent data analysis methods will be required. The 9+ years of data that have been collected as part of the CTBTO hydroacoustic array off Western Australia are an ideal dataset to begin these initial feasibility tests (Fig. 1) as over 8 years of data are already in hand.

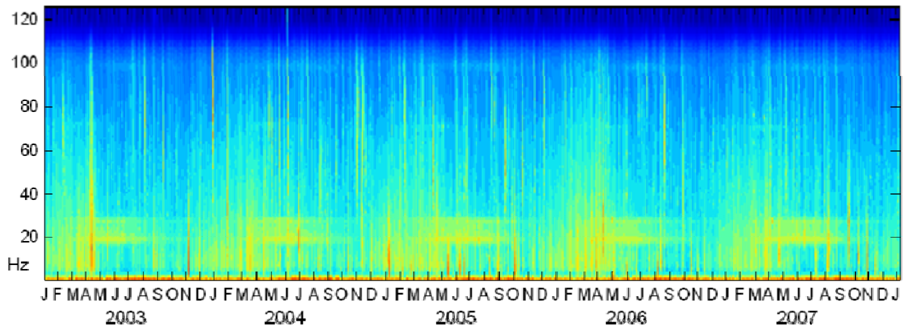

Fig. 1: Spectrogram of 5 years (2003-2007) CTBTO dataset off Cape Leeuwin, Western Australia. Repetitive, seasonal bands of energy at ~20-30Hz, 70Hz, and 100Hz, illustrate Antarctic blue and fin, pygmy blue, and fin whales respectively.

A wide variety of methods are available to either detect individual calls (e.g. spectral correlation, matched filtering, energy summation) or measure the amount of energy at whale calling frequencies (power spectral density) (Mellinger *et al.* 2007). Initial analyses should focus on comparing these methods to assess their 1) ability to detect calling whales and 2) their accuracy and sensitivity to minimizing false positive detections and missed calls.

In order to obtain a relative abundance measure, it will be necessary to approximate the probability of detection over the range where whales may be detectable. This will require measurements of background noise and approximating call detection range using propagation models and the estimated distribution of source levels of the whale call (Samaran *et al*., 2010). Alternatively, a threshold received level could be set that approximately replicates the highest ambient levels encountered throughout the year. The former would provide detection ranges that may vary between measurement periods, while the latter would provide for a much smaller, but consistent, detection range for all measurement periods throughout the year. Finally, a means of distinguishing multiple calls from a single individual versus multiple individuals must be developed. This could involve the use of received level measurement of the calls and the temporal patterning of both blue and fin whale song to distinguish one individual from another, or simple cue-production rates as used in traditional cue-counting surveys (Marques *et al*., 2011; Stafford *et al*., 2007).

For the Cape Leeuwin test data, counts by hour and day of the number of Antarctic blue whale “28 Hz” signals, will be obtained by using the automatic detection method of spectrogram correlation (Mellinger and Clark, 2000; Mellinger, 2001). This involves specifying frequency contours and durations that matched average characteristics of known Antarctic-type blue whale calls. For this study, contours that consist of the following will be used: a 9 s long 27.7 Hz tone, a 1 s long frequency decrease from 28 Hz to 19.5 Hz and a 10 s long tone that decreased to 18.8 Hz. Additionally, we will employ spectrogram noise equalization with a time constant of 40 s to eliminate continuous interfering tones such as those from ships.

Detections will be summed by week. Analysis of variance will be used to compare between-year data for each call type for each region. An additive model using a 52 week seasonal cycle will be used to remove the seasonal component of whale call time series to examine long-term trends in the number of call detections. Student's t-tests will be used to test the hypothesis that the slope of seasonally adjusted data is equal to 0.

(iv) Programme or plan of research.

Please see details provided in Sections 3 (i), 3(ii) and 3(iii).

Time frame for the work: Examination of data analysis techniques can begin simultaneously with the planning for the first deployments of the acoustic moorings. Previous acoustic datasets that have been recorded around the Southern Ocean will be utilized for the initial testing of analysis methods.

2011/12 Begin examination of data analysis techniques utilizing previously collected long-term Southern Ocean acoustic datasets. Begin planning for first round of acoustic mooring deployments by getting commitments from collaborators able to deploy moorings around the Antarctic.
2012/13 First round of acoustic mooring deployments focused on southern Indian Ocean/Southern Ocean deployments
2013/14 Recover/Redeploy acoustic moorings. Analyse data from the first round of deployments. Compare relative abundance at locations around Antarctic within a single season.
2014/15 Recover/Redeploy acoustic moorings. Analyse 2nd year of data from deployments and compare relative abundance at each location between years and to previously collected data.
2015/16 Assess progress and plan future

(v) Requirement for resources sought in this application.

Please see details provided in Section 5.

(vi) Any wider justification for the project.

None.

4. CURRICULUM VITAE OF NAMED INVESTIGATORS

CV's are available upon request.

5. BUDGET

Year 1: Feasibility Study

$50,000 AUD- Personnel (50% time post-doc/researcher)—Project Coordinator's time to conduct analysis of CTBTO data
$12,000 AUD- Steering Group Meeting

Year 2:

$50,000 AUD- Personnel (50% time post-doc/researcher)
$90,000 AUD- 3 Acoustic Loggers (x$30,000 each)
$50,000 AUD- Ship time (4 hours x 3 loggers per year x $100,000/24hrs)

Year 3:

$50,000 AUD- Personnel (50% time post-doc/researcher)
$180,000* AUD- 6 Acoustic Loggers (x$30,000 each)
$100,000* AUD- Ship time (4 hours * 6 loggers per year* $100,000/24hrs)
$12,000 AUD- Steering Group Meeting

Year 4:

$50,000 AUD- Personnel (50% time post-doc/researcher)
$90,000* AUD- 3 Acoustic Loggers (x$30,000 each)
$100,000* AUD- Ship time (4 hours * 6 loggers per year* $100,000/24hrs)

Year 5:

$50,000 AUD- Personnel (50% time post-doc/researcher)
$100,000* AUD- Ship time (4 hours * 6 loggers per year* $100,000/24hrs)

Totals:

$984,000 AUD with no cost reduction included for included in-kind ship time and instrumentation from collaborators.
*$454,000 AUD with cost reduction assuming all ship time and 50% of acoustic recorder costs funded with 'in-kind' contributions from collaborators.

This budget is based upon working up to a total of 6 loggers being simultaneously deployed, with 6 replacements for immediate re-deployment to enable continuous data collection. If more or less loggers were to be deployed, the budget would increase or decrease accordingly.

6. OTHER GRANTS HELD FOR THIS OR OTHER RESEARCH, OBTAINED OR SOUGHT WITHIN THE PREVIOUS THREE YEARS
SOS-BUME : Sound Of the Sea-BRUit de la MEr. Multidisciplinary project application to the French National Research Agency by the University of Western Brittany. A part of this project deals with the analysis of long term acoustic dataset collected by the UBOphone to assess seasonality and distribution of large whale in the Indian Ocean. Answer plans in june 2011

7. PERMITS
(i) Do you have the appropriate permits to carry out the field work, including, if NECESSARY, animal welfare considerations?
No permits are required.

(*ii) Do you have the appropriate permits (e.g. CITES) for the importation of ANY samples*.
N/A

8. SCHEDULE OF WORK, REPORTING AND USE OF RESULTS
(i)) Expected completion of final report (note that an annual progress report is required)
Final report will be submitted at the IWC 67 in June, 2016. This project is meant to be the beginning of a long term Southern Ocean acoustics research and population monitoring program, however, so hopefully the research will continue on for years beyond the completion of the final report.

(ii) Will you submit a manuscript on the results to the Journal of Cetacean Research and Management upon completion of the work? (Whilst this is not a pre-requisite of a successful application, it will be taken into account). If not please state your publication plans
Results of this research will be submitted to a range of journals, including the Journal of Cetacean Research and Management.

(iii) Will you agree to the use of the results of your study, if requested by the IWC Scientific Committee under its Data Availability Agreement that protects first publication rights of the researchers? Note that for fully funded IWC research, the data shall become publicly available after a mutually agreed period.
Yes

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APPENDIX 4: SORP Oceania and Antarctic humpback whale mixing

SORP RESEARCH PROPOSAL

1. TITLE OF PROJECT

What are the migratory destinations and what is the extent of mixing of Southern Hemisphere humpback whales around Antarctica? Phase 1: East Australia and Oceania

2. DETAILS OF NAMED INVESTIGATORS

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3. DESCRIPTION OF PROJECT (do not exceed 3000 words)

(i) Background to the proposal, underlying rationale and relevance to SORP objectives and IWC needs.

The International Whaling Commission recognises seven humpback whale populations in the Southern Hemisphere. These populations, named A to G, are based on the distribution of the known, low-latitude breeding areas. Each year individuals migrate south from these breeding areas to feed in the waters around Antarctica. Our understanding of the migratory routes and the summer distribution of these 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 should be developed in the future.

The initial focus of this project steering group was on data collected during the 2010 joint Australian/New Zealand Antarctic Whale Expedition (AWE) investigating humpback whale ecology between 150°W and 150°E. This expedition covered the putative feeding grounds of IWC breeding stocks E1, 2 & 3 which includes the east Australian humpback whales and the western side of the endangered Oceania humpbacks, both part of the ongoing Comprehensive Assessment of Southern Hemisphere humpback whales (CASH) process. The French IPEV CETA trip (part of a three year project) also collected data from Area V and contributed samples to the AWE dataset (Garrigue *et al*. 2010a - SC/62/SH3). A combination of genetic sampling, satellite tagging and photo-identification has been used in these regions which links well with the techniques used in the AWE. The results of the photo-ID and genetics show strong links between the Balleny Islands (where most data were collected) and east Australia with a single photo-ID match to New Caledonia and a single genetic match to New Zealand (Constantine *et al*. 2011 SC/63/SH16, Steel *et al*. 2011 SC/63/SH10).

These results add support to the possibility that the Oceania E2, E3 and F Breeding stocks may be predominantly feeding in the far east of Area V and in Area IV. Genotype matching of the tissue samples collected during the IDCR-SOWER cruises to Oceania showed connections between one whale from New Caledonia to Area V, one between Tonga and Area VI and two between Tonga and the western edge of Area I (Steel *et al.* 2008 – SC/60/SH13). Robbins *et al*. (2011) also reported the return trip of a humpback whale from American Samoa to Area I and one other whale that was sighted in both places. Previous reports of photo-ID matches between the Balleny Islands and east Australia were based on small sample sizes (Kaufman *et al*. 1990; Rock *et al*. 2006; Franklin *et al*. In Press). The small sample sizes in these studies, whilst valuable, limit any definitive interpretation of whale movements, as does the historical *Discovery* tag work and but the larger sample size from the AWE allows a better understanding of breeding ground linkages to Area V feeding grounds. As other expeditions are undertaken, further research on mixing between humpback feeding and breeding grounds will continue.

With the success of the genotype and photo-ID matching between AWE data and data from west Australia, east Australia, Oceania and the IDCR-SOWER tissue samples and photo-IDs from the Antarctic Humpback Whale Catalogue (AHWC), we propose to focus our efforts on using satellite telemetry to understand the connections between Oceania breeding grounds and feeding grounds. This technology has been successfully used in New Caledonia (Garrigue *et al*. 2010b, 2011), east Australia (Gales *et al*. 2009 - SC61/SH/17) and the Cook Islands (Hauser *et al*. 2010), with interesting results. There are plans for further satellite tagging in New Caledonia and the Cook Islands in 2011, the results of these will be help inform the development of our proposed research.

Recent reports from the Raoul Island (part of the Kermadec Island group, in New Zealand) show October has a high density of whales passing nearby with counts of over 150 humpback whales reported during a single four hour period on 10th October 2010 (Potier 2008, Brown 2009, Brown 2010). Garrigue *et al*. (2010b, 2011) showed that a portion of the tagged whales from New Caledonia migrate past the Kermadec Islands but it is highly unlikely that this population could account for all whales observed. Tonga, Fiji and Vanuatu could account for many of the whales migrating past the Kermadecs with possible contributions from places further east like the Cook Islands (Hauser *et al*. 2010). Raoul Island is also the southernmost location with a high density of whales travelling south to Antarctica; whilst sightings are reported past New Zealand, these are sparse and numbers remain low. 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*. In Press). For these reasons we propose Raoul Island and American Samoa as tentative locations for satellite tagging in 2013, but will consult with researchers interested in this region as we develop this research.

(ii) Specific objectives
With Phase 1 of the project completed (based around the AWE 2010 genetic and photo-ID data) we will focus on the use of satellite tags deployed on whales on their southern migration to determine migratory corridors and links to feeding grounds. The two main questions are:

1. What is the connection between the humpback whales from Area V & VI feeding grounds and their migratory corridors and breeding grounds in Oceania?
2. Do whales from Area V represent a single breeding ground or are they a mix of individuals from several distinct breeding grounds?

Year 1 – Oceania matching
a) We will update the genotype and photo-identification databases that currently exist for Oceania breeding grounds (1991-2005 completed and 2006-2009 remain) and then match to AWE samples. COMPLETED (Constantine *et al*. 2011 SC/63/SH16, Steel *et al*. 2011 SC/63/SH10)
b) We will match AWE and Oceania (updated) to existing IDCR/SOWER (Area IV, V & VI) genotype register. COMPLETED (Constantine *et al*. 2011 SC/63/SH16, Steel *et al*. 2011 SC/63/SH10)

Years 2 & 3 – Genotype matching & planning
a) We will reconcile existing eastern Australia and Oceania (updated) genotype databases and compare to AWE samples (photo-ID ~2,500 individuals for east Australia, ~2,100 individuals for Oceania and genotyped ~1,500 individuals for Oceania) (near completion see Steel *et al*. 2011 SC/63/SH10 for progress).

b) Planning for satellite tagging programme in Oceania, locations to be decided after consultation with interested parties (e.g. South Pacific Whale Research Consortium). The Kermadec Islands and American Samoa have been nominated as priority regions with a strategic focus on breeding grounds and migratory corridors and an emphasis on the unresolved feeding grounds for E2, E3 and F whales. Data will be collected from the Kermadecs and American Samoa in years 2 & 3 and further consultation will be sought to identify individual whales (photo-ID and genotype database holders) and work out the optimal time for tagging whales as they migrate south.

Year 4 – Satellite tagging
a) Deployment of tags on whales. Approximately 60 tags will be deployed at two locations (30 at each location, tentatively Raoul Island and American Samoa). Tissue samples, photo-ID and group composition data will be collected and compared to existing databases.
b) Analysis of data that integrates satellite tag, genotype and photo-ID information.

(iii) Scientific methodology and approach.
Methodology is detailed in (ii) above.

(iv) Programme or plan of research.
Methodology is detailed in (ii) above.

(v) Requirement for resources sought in this application.
These are detailed in the budget below.

(vi) Any wider justification for the project.
None.

4. CURRICULUM VITAE OF NAMED INVESTIGATORS (1 page per investigator)
Available upon request.

5. BUDGET
Overall Project Budget Years 1 – 4. All amounts in Australian dollars.

Year 1 (2010) AWE matching to Oceania genotype & photo-ID database	
Research	
Oregon State University Oceania genotype database	25,000
Opération Cétacés Connectivity database	6,000
University of Auckland Photo-ID matching	10,000
Co-ordination	
Project Assistant	15,000
Steering Committee Meeting	6,000
TOTAL	**$62,000**
Year 2 (2011) Preparation for year 4	
Research	
American Samoa & Kermadec Islands' photo-ID & tissue sampling	15,000
Coordination	
Project Assistant	10,000
Steering Committee Meeting	6,000
TOTAL	**$31,000**
Year 3 (2012) Preparation for year 4	
Research	
American Samoa & Kermadec Islands' photo-ID & tissue sampling	15,000

Coordination	
Project Assistant	10,000
Steering Committee Meeting	6,000
TOTAL	**$31,000**
Year 4 (2013) Satellite tagging & analysis	
Research	
Satellite tags (60)	180,000
Vessel costs	75,000
Travel	10,000
Coordination	10,000
Photo-ID analysis	2,000
Genotyping	10,000
TOTAL	**$287,000**

Shortfalls in budget will be met with contributions from other SORP signatories and external grants.

6. OTHER GRANTS HELD FOR THIS OR OTHER RESEARCH, OBTAINED OR SOUGHT WITHIN THE PREVIOUS THREE YEARS
Available upon request

7. PERMITS
(i) Do you have the appropriate permits to carry out the field work, including, if NECESSARY, animal welfare considerations?
Some permits held, others will be applied for during the coming year.

(i*i) Do you have the appropriate permits (e.g. CITES) for the importation of ANY samples*.
Yes.

8. SCHEDULE OF WORK, REPORTING AND USE OF RESULTS
(i)) Expected completion of final report
2014.

(ii) Will you submit a manuscript on the results to the Journal of Cetacean Research and Management upon completion of the work?
Manuscripts will be sent to high quality scientific Journals and reports presented to the Scientific Committee.

(iii) Will you agree to the use of the results of your study, if requested by the IWC Scientific Committee under its Data Availability Agreement that protects first publication rights of the researchers?
Data from all of the sponsored research cruises will be available to contributing countries and collaborating researchers. Data sharing agreements will be mandatory for participation in regional projects, and the project Coordinator will be responsible for maintaining and disseminating data.

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