SOOS Capability Working Groups
Terms of Reference

SOOS Working Group Title

Acoustic Trends of Antarctic blue and fin whales (Acoustic Trends Working Group; ATWG)

SOOS SSC Sponsor

Dan Costa, and/or Andrew Constable

SOOS Capability Working Group Key Objective(s)

Continue to develop and mature a long term acoustic research program to understand trends in Southern Ocean blue and fin whale distribution, seasonal presence, and population growth through the use of passive acoustic monitoring techniques. Implementation of these objectives will occur via:

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

Terms of Reference

SOOS Capability WGs define their own Terms of References, however there are some standard terms that SOOS encourages WGs to undertake. These can be discussed with the SSC sponsor.

The WG will fulfill the following terms of reference:

1. Provide support to regional working groups in the implementation of observing system components or advances related to the outputs of this proposed capability working group.
2. Establish linkages with existing and emerging programs of relevance to this proposed capability working group.
3. Convene focussed sessions at national and international meetings, and facilitate synthesis products, to increase the awareness of the scientific community to the importance of the activities and outcomes of this working group.
4. Provide support to International Program Office (IPO) by providing annual reports to be available at the SOOS SSC annual meeting, as well as providing content for the IPO website/newsletters on the activities and outcomes of the proposed working group.
5. Develop a funding plan to sustain the Working Group activities.
6. Have products coming out of the WG acknowledge SOOS.
7. Provide practical recommendations to guide and support passive acoustic data collection in Antarctic waters
8. Provide guidance on standardization of passive acoustic data from different areas for accurate and efficient analysis and interpretation

Participants

A minimum 2 co-chairs from different countries is required; however large WGs are encouraged to have an executive committee or structure that can share the administrative burden and help the group to work efficiently. Ideally, there would be representation from a broad number of nations, representatives from related international programs/initiatives, and gender balance.

Name	Affiliation	Nation Represented	Expertise
Susannah Buchan	COPAS Sur-Austral, Department of Oceanography, Universidad de Concepcion, Chile	Chile	
Ken Findlay	Centre for Sustainable Oceans, Cape Peninsula University of Technology, Cape Town, South Africa	South Africa	
Jason Gedamke	National Oceanographic & Atmospheric Administration, Office of Science and Technology- Ocean Acoustics Program, United States of America	USA	
Danielle Harris	Centre for Research into Ecological and Environmental Modelling, University of St Andrews, Scotland, United Kingdom	UK	
Brian Miller	Australian Marine Mammal Centre, Australian Antarctic Division, Hobart, Australia	Australia	
Ilse van Opzeeland	Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven Germany	Germany	
Flore Samaran*	ENSTA Bretagne Lab-STICC UMR CNRS 6285,France	France	
Ana Širović	Scripps Institution of Oceanography, University of California San Diego	USA	
Kathleen Stafford*	Applied Physics Lab University of Washington Seattle WA, United States of America,	USA	
Others TBD		TBD	
* Project coordinators/co-chairs			

Outputs and Outcomes

Outputs

- Guidelines and practical recommendations, and standards for passive acoustic data collection in Antarctic waters (completed in Van Opzeeland et al 2013)
- Guidelines for standardization of analysis of passive acoustic data from different areas for accurate and efficient analysis and interpretation

- Peer reviewed publications on Antarctic blue and fin whale distribution, seasonal presence, and population growth
- Data on Antarctic blue and fin whale distribution, behavior, and abundance for use in ecosystem models

Outcomes

- Increased understanding of Antarctic blue and fin whale distribution, seasonal presence, and population growth
- Improved models of Antarctic ecosystem function that incorporate the above knowledge.
- Increased capacity for passive acoustics in the Southern Ocean including:
    - Increased data collection efforts to acheive circumpolar acoustic coverage of the Southern Ocean Hydrophone Network
    - Engagement with SOOS Regional Working Groups to better utilize platforms of opportunity for passive acoustic research
    - Development of analytical best-practices and guidelines for standardization of Southern Ocean acoustic data
    - Training of PhD and Masters students in bioacoustics analysis

Mode of Operation

Most WG will work remotely and meet virtually and opportunistically at scientific conferences until funding can be arranged for the specific group activities. The SOKI wiki is available for all SOOS Working Groups, to facilitate the delivery of the terms of reference. SOOS also offers the use of GoToMeeting for virtual meetings and WG-specific web pages for sharing of documents and information.

Our working group has been active as part of the Southern Ocean Research Partnership of the International Whaling Commission (IWC-SORP) since 2009. The group has worked remotely, meeting virtually, and opportunistically at scientific conferences. In the past the group has secured funding for in-person meetings, on average once every 2-3 years. We will continue working in this manner and will continue to seek funding for specific in-person meetings as necessary (probably every 2-3 years).

Strategy & Milestones

SOOS encourages all WGs to develop a clear strategy for achieving the objective, built on a realistic timeline of key milestones. All WGs will be reviewed annually by the SOOS SSC for progress, against the work plan defined in this section. SOOS recommends a strawman strategy be developed for the initial approval process. Once full approval has been received, the WG should work together to develop a comprehensive, multi-year plan. Where possible, the strategy should also identify the resources required to achieve milestones and a proposed way forward to access these resources. SOOS can provide input and support in identifying and accessing required resources.

A meeting of the working group of the IWC-SORP Acoustic Trends Project was held from 5-8 May. At this meeting the working group:

- Conducted a brief high-level review of the work on the project that has been completed to date,
- Identified gaps in existing data collection efforts and developed a new plan to expand the data collection of Southern Ocean Hydrophone Network (SOHN),
- Developed a new framework for standardised analysis of long-term Antarctic acoustic recordings,
- Identified a need for additional coupled behavioural and acoustic studies to enable a more robust interpretation of acoustic data with a view towards development of call density and animal abundance estimates,

- Synthesised a forward-looking work plan for the next 2 years for the Acoustic Trends Project implementing the above work

The report of this meeting is included in this proposal as Appendix A, and it provides background and context of the group as well as outlines the current status and strategy for achieving the project objectives. Additionally, The ATWG identified the following priorities required to achieve the projects goal of investigating trends in Antarctic blue and fin whale behaviour, abundance, distribution, and seasonal presence.

Data collection: Expansion of the Southern Ocean Hydrophone Network (SOHN)

1. Build relationships to allow expansion of data collection efforts to areas that have not been sampled previously.
2. Apply for funding for additional instruments to take advantage of opportunities as they arise.
3. Continue to seek opportunites to collect auxiliary data e.g. behavioral studies, source level measurements, etc.

Data analysis

4. Completion of call library to provide common dataset for development and implementation of automated call detectors. This library will also provide the basis of data to be used for case studies to demonstrate the analysis framework described in the analytical methods section.
5. Analysis of subset of data identified by the group, focusing on a season (summer) of data with broad spatial coverage, as well as analysis of three years of data from a single location.
6. Apply the analysis framework to the analyzed data to make robust ecological comparisons across time and space and present them as a case study in a paper outlining the approach.
7. Enable capacity building by securing funding for and hiring post-doctoral researchers and students to conduct the analyses outlined by the framework.

Engagement with SOOS Regional Working Groups is expected to be an important mechanism for exploring opportunities to expand data collection (item 1 above) and for better utilising opportunities to collect auxiliary data that add value to the SOHN (item 3 above). Additionally, involvement as a SOOS Capability Working Group may facilitate capacity building for passive acoustics (item 7 above) by expanding the membership of the CWG, and/or better matching of existing analytical capacity of SOOS Regional Working Groups with datasets held by the Acoustic Trends Project.

Milestones

Guidelines for SOHN data collection published	2014 (see Van Opzeeland et al 2013)
Engagement with/Outreach to SOOS Regional Working Groups to identify opportunities to expand SOHN data collection & collect auxiliary data from ships of opportunity	2017-Q3 – ongoing
Obtain resources to build additional instrumentation for new SOHN recording sites	2018-Q2
New SOHN recording sites active	2019-Q1
Guidelines for standardized circumpolar analysis completed (including case study)	2019-Q3

Appendix A

Working Paper on report of the SORP Antarctic blue and fin whale acoustic trends working group (ATWG) meeting, Bled, 2017

The IWC-SORP acoustic trends steering group: Flore Samaran[1], Kathleen Stafford[2] (Project Coordinators), Susannah Buchan[8], Ken Findlay[3], Jason Gedamke[4], Danielle Harris[5] , Brian Miller[6] and Ilse van Opzeeland[7], and Ana Širović[9]

[1] ENSTA Bretagne Lab-STICC UMR CNRS 6285,France
[2] Applied Physics Lab University of Washington Seattle WA, United States of America
[3] Centre for Sustainable Oceans, Cape Peninsula University of Technology, Cape Town, South Africa
[4] National Oceanographic & Atmospheric Administration, Office of Science and Technology- Ocean Acoustics Program, United States of America
[5] Centre for Research into Ecological and Environmental Modelling, University of St Andrews, Scotland, United Kingdom
[6] Australian Marine Mammal Centre, Australian Antarctic Division, Hobart, Australia
[7] Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven Germany
[8] COPAS Sur-Austral, Department of Oceanography, Universidad de Concepcion, Chile
[9] Scripps Institution of Oceanography, University of California San Diego

Note: Emmanuelle Leroy (PhD Student at University of Brest) was present as an invited participant and Jason Gedamke was not present

Executive Summary

A meeting of the working group of the SORP Acoustic Trends Project was held from 5-8 May. The meeting was funded by IWC-SORP with further funding from IWC, AAD, ENSTA-Bretagne, and Europole Mer. At this meeting the working group:

- Conducted a brief high-level review of the work on the project that has been completed to date,
- Identified gaps in existing data collection efforts and developed a new plan to expand the data collection of Southern Ocean Hydrophone Network (SOHN),
- Developed a new framework for standardised analysis of long-term Antarctic acoustic recordings,
- Identified a need for additional coupled behavioural and acoustic studies to enable a more robust interpretation of acoustic data with a view towards development of call density and animal abundance estimates,
- Synthesised a forward-looking work plan for the next 2 years for the Acoustic Trends Project implementing the above work

The strategic plan developed at the ATWG meeting places the group on track to continue to achieve its goal of investigating trends in acoustic detections of Antarctic blue and fin whales. The analysis framework developed at this meeting represents a substantial breakthrough in analytical methodology and will not only standardize the analysis of diverse data collected by international collaborators, but will also provide for statistically robust comparisons of past, present, and future long-term acoustic data collected all around the Antarctic. At the meeting the group also developed a 2-year work-plan to assemble and develop the analytical tools required for this new framework, and to demonstrate the framework and tools via an abbreviated circumpolar case study. While this group is focusing on Antarctic blue and fin whales, the analysis framework is also able to be extended to other populations and species that produce sounds.

Background and project history

The IWC-SORP Acoustic Trends Project (ATP) was formed in 2009, and the Acoustic Trends Working Group (ATWG) is comprises both the steering and working group for this project (http://www.marinemammals.gov.au/sorp/antarctic-blue-whales-and-fin-whales-acoustic-program).
The overarching focus of the ATP was the implementation of a long term acoustic research program that would examine trends in Antarctic blue and fin whale behaviour, abundance, distribution, and seasonal presence through the use of long-term passive acoustic monitoring techniques. At the start of the meeting, a brief review was conducted to summarise the prior work completed by the ATG.
One of the first products the ATP delivered into IWC-SORP was a preliminary analysis of existing long-term acoustic recordings for the presence of Antarctic blue and fin whale sounds (SORP Acoustic Trends Steering Group 2012a). The results of this preliminary analysis highlighted the potential of long-term acoustic recordings to provide information about spatial and temporal distribution of Antarctic blue and fin whales. However, this report also identified spatial and temporal gaps in extant long term acoustic datasets, and it also identified several challenges of working with large long-term acoustic datasets, and identified that there may be further challenges that arise when attempting to compare results of different studies (SORP Acoustic Trends Steering Group 2012a).
In 2012, the first full meeting of the ATWG was held in Bremerhaven Germany. The strategy developed at this meeting focused on addressing gaps in spatial and temporal coverage, and the proposed solution centred on the development of a circumpolar necklace of acoustic instrumentation that would allow for co-incident acoustic monitoring in each of the IWC Management Areas over a ten-year period. The need for expanded spatial and temporal coverage was identified, and a whitepaper on the proposed Southern Ocean Hydrophone Network (SOHN) was published to not only provide a primer for potential partners, but also to provide guidelines to facilitate standardisation of data collection (Van Opzeeland et al. 2014).

Infrastructure

Metadata

The ATWG identified the need for common metadata formats at the Bremerhaven meeting in 2012, however, each member of the group presently maintains their own metadata storage system (e.g. excel spreadsheets with deployment information). Širović introduced Tethys (tethys.sdsu.edu) as possible metadata repository platform. Tethys is a bioacoustics data management system developed by Marie Roche / San Diego State University which allows the creation of long term data sets, seamless data sharing, data organisation, consistency and standardization and the integration of contextual information (Roche et al. 2016). The ATWG agreed that a workshop on the installation, maintenance, and use of Tethys would facilitate uptake by group members, and could greatly streamline the sharing of metadata, data, and results from acoustic detectors. Funding for such a workshop will be prioritised and sought by the group.

Data collection efforts – past, present and future

At the 2017 meeting, the ATWG synthesised a map of previous and and current long-term acoustic recording sites south of 60° S (Figure 1) and identified spatial gaps within IWC Management Area III, Area I (westwards outside of the Antarctic Peninsula) and Area VI (Table 1). National Antarctic bases in these areas were reviewed to determine potential resupply voyages on which potential access to these areas could be leveraged. Also, Southern Ocean Observing System (SOOS) program was identified as another potential access point and plans were made to approach the group at the upcoming SOOS meeting in Bremerhaven in June 2017.
The group acknowledged that a variety of different instruments are being deployed in different locations and that expansion of survey effort will be dependent on available instrumentation, noting that two

instruments are usually required to service one site in the Antarctic. Lack of dedicated instruments is limiting the group's ability to expand SOHN and take advantage of opportunities for deployment as they arise. The ATWG identified this area as a focus for future funding and collaboration opportunities.

Table 1 - Past present, planned, and the potential for future long-term acoustic data collection for each IWC management area. 'Poor' indicates that data collection sites exist, but are not likely to representative of that Area. 'Fair' indicates that at least two data collection sites exist and are widely distributed of that area. 'Good' indicates that multiple data collection sites exist and are well distributed throughout the area.

Area	Historic (2002 – 2016)	Current (2017)	Planned (2018 – 2023)	Countries/Organisations that operate in area and could be approached by ATWG for expanded future data collection
I (120°W – 60°W)	Fair	None	None	West – Norway, South Korea East – Chile, USA (LTER)
II (60°W- 0°)	Good	Good	Good	Germany, Argentina, UK
III (0° – 70°E)	Poor	Poor	Poor	South Africa
IV (70°E – 130°E)	Fair	Fair	Fair	Australia (AAD)
V (130°E – 160°W)	Poor	Fair	Fair	France (IPEV), USA (NOAA PMEL), Italy
VI (160°W – 120°W)	None	None	None	CCAMLR (Antarctic Toothfish Fishery), Southern Ocean Observing System (SOOS)

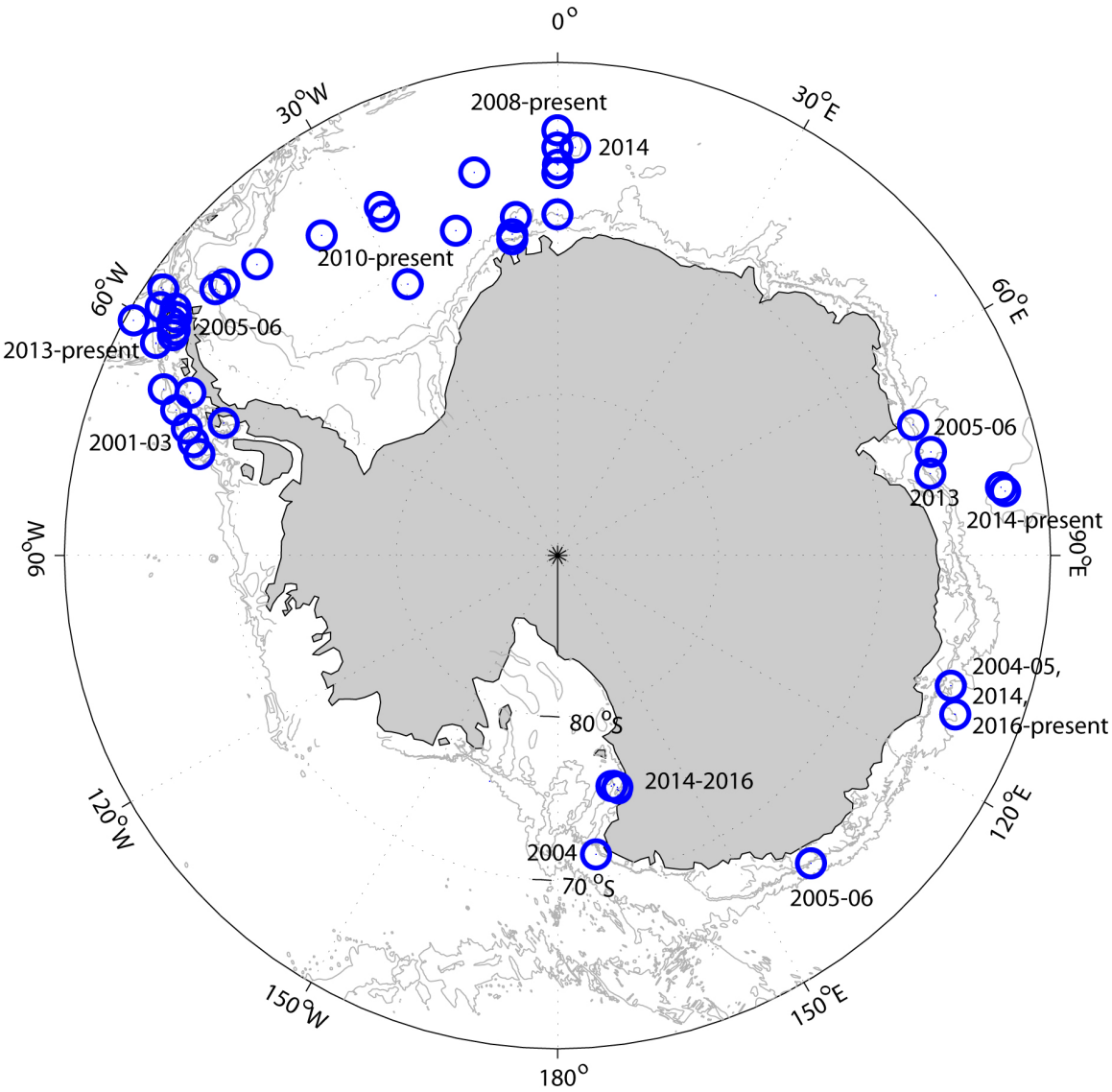

Figure 1 - Map of previous and current locations of long-term acoustic recordings south of 60° S, along with years when acoustic data are available for each location.

Development of analytical methods

At the meeting the ATWG briefly summarised progress since 2012 regarding analytical methods. To address the need to automate the bulk of the analysis of large acoustic datasets, Socheleau and Thomisch, PhD students of ATWG members Samaran and Van Opzeeland, developed novel algorithms to detect vocalisations of Antarctic blue whales present in long-term acoustic recordings in the Southern Hemisphere (Socheleau et al. 2015; Thomisch et al. 2016). Thomisch also investigated effects of different sampling regimes on detection of whale calls (Thomisch et al. 2015), and Van Opzeeland commenced data collection for a new experiment to investigate the effects of hydrophone depth on the number of detections. Leroy and Thomisch each independently applied different automated detection algorithms for Antarctic blue whales to long-term acoustic datasets in the western Indian Ocean and Weddell seas respectively (Leroy et al. 2016; Thomisch et al. 2016). At the end of this review, the group determined that to robustly compare the results of these two studies in a statistically meaningful manner, additional standardisation of results (and further analysis) is required. One way to achieve this standardisation

would be to compare calls per unit area per unit time, and it was suggested that recently popularised techniques for acoustic density estimation might provide such a solution.

Density estimation from acoustic detections

Harris provided an overview of acoustic density/abundance estimation techniques. The conversion of acoustic recordings to densities or abundances of animals in a given area requires a number of step-wise processes including raw call detections within the recordings, the consideration of both false detections and missed detections (as in the "calibrated call counts" work by Tyler Helble on humpback whales), estimation of the survey area from which the calls originate, calculations of the false-call adjusted call densities within that area and conversion of call densities to animals densities through consideration of call production rates assessed through behavioural investigations. Drawing on point-transect methodology of density and abundance estimation, **densities of calls** ($\hat{D}_{\text{call}}$) may be calculated as:

$$\hat{D}_{call} = \frac{n}{\pi w^2 k \hat{P} T}$$

where n = number of detections, w = radius of points, k = number of points and $\hat{P}$ = proportion of calls detected, T = time effort of observations. In the use of automated detectors, it should be noted that an estimate of false positive proportion, $\hat{c}$ is required, while false negatives (in general) are taken care of by $\hat{P}$, so that number of calls per unit time within a given area ($\pi.w^2.k$) estimated by

$$\widehat{N}_{calls} = \frac{n(1-\hat{c})}{\hat{P}}$$

Estimation of the probability of detection $\hat{P}$ can be carried out through a number of well-established methods allowing density and potentially abundance to be estimated (Marques et al. 2013). The ATWG agreed that auxiliary data methods were the most appropriate for existing Antarctic datasets since distances to detections cannot be estimated due to sparse recorder distribution, nor can the same detection be re-identified across most recording sites. Harris then presented a concise outline of the required auxiliary data methods:

1. Run an automated detector on the data
2. Check a subsample of these results for false positives (c)
3. Calculate the analysis effort (T) + (K) (where K is typically 1 for widely spaced SOHN sites)
4. Decide a generous maximum detection radius (w)
5. Estimate $\hat{P}$ using the sonar equation: SL-TL-NL > DT, for which we need to know
    a. Estimate of source level, SL
    b. Measurement of noise level NL
    c. Estimate of TL
    d. Measurement of RL
    e. To check detector results vs SNR (manual check)
    f. Run simulation to generate Average P
6. Combine 1-5 to estimate D_{call} and Variance

For a more direct analysis of probability of detection, additional approaches would have to be used, e.g. distance sampling (Thomas et al. 2002) or mark recapture or spatially explicit capture recapture (Marques et al. 2012). However, these methods would require deployment of acoustic arrays.

Estimates of blue whale Z-call and fin whale 20 Hz calls have been measured previously (Širović et al. 2007; Samaran et al. 2010; Miller et al. 2014), however, estimates for other call types are still needed.

Resulting from Harris's presentation, propagation modelling was identified as a challenge area, largely due to lack of required environmental data (sound speed profile, bathymetry, and seabed acoustic properties) in the Antarctic. Applying the above framework will allow estimation of uncertainties due to transmission loss and enable propagating them through this framework. This approach would still be

informative in that it could reveal knowledge gaps that if addressed would provide the largest improvements.

From call density to animal abundance

To move beyond the above framework for estimating call density to animal abundance, the final component needed is information on the relationship between the number of calls and the number of animals. To obtain this information, we need concurrent observations of behavior and recordings of animals. There are multiple aspects of calling behavior that need to be understood to provide the data for this step, therefore several data collection approaches are needed: visual observations with acoustic localization can link call rates to number of animals in an area; acoustic tagging provides information on the behavior of a calling whale. Ideally, this information would have to be obtained across seasons (time) and at different recording locations, to provide representative coverage and unbiased results.

Work Plan

The ATWG identified the following priorities required to achieve the projects goal of investigating trends in Antarctic blue and fin whale behaviour, abundance, distribution, and seasonal presence.

Data analysis

1. Completion of call library to provide common dataset for development and implementation of automated call detectors. This library will also provide the basis of data to be used for case studies to demonstrate the analysis framework described in the analytical methods section.
2. Analysis of subset of data identified by the group, focusing on a season (summer) of data with broad spatial coverage, as well as analysis of three years of data from a single location.
3. Apply the analysis framework to the analyzed data to make robust ecological comparisons across time and space and present them as a case study in a paper outlining the approach.
4. Enable capacity building by securing funding for and hiring post-doctoral researchers and students to conduct the analyses outlined by the framework.

SOHN data collection

5. Build relationships to allow expansion of data collection efforts to areas that have not been sampled previously.
6. Apply for funding for additional instruments to take advantage of opportunities as they arise.
7. Continue to seek opportunites to collect auxiliary data (e.g. behavioral studies, source level measurements, etc.).

Works Cited

Leroy, E.C. et al., 2016. Seasonal and Diel Vocalization Patterns of Antarctic Blue Whale (Balaenoptera musculus intermedia) in the Southern Indian Ocean : A Multi-Year and Multi-Site Study. , pp.1–20.

Marques, T.A. et al., 2013. Estimating animal population density using passive acoustics. *Biological Reviews*, 88(2), pp.287–309.

Marques, T.A. et al., 2012. Spatially explicit capture–recapture methods to estimate minke whale density from data collected at bottom-mounted hydrophones. *Journal of Ornithology*, 152(2), pp.445–455. Available at: http://link.springer.com/article/10.1007/s10336-010-0535-7 [Accessed October 18, 2013].

Miller, B.S. et al., 2014. Source levels of Antarctic blue whale calls measured during the 2013

Antarctic blue whale voyage: preliminary results. *Submitted to the Scientific Committee 65b of the International Whaling Commission, Bled, Slovenia*, SC/65b/SH1, p.11.
Van Opzeeland, I. et al., 2014. Towards collective circum-Antarctic passive acoustic monitoring: The Southern Ocean Hydrophone Network (SOHN). *Polarforschung*, Submitted.
Roche, M.A. et al., 2016. Management of acoustic metadata for bioacoustics. *Ecological Informatics*, 31, pp.122–136.
Samaran, F. et al., 2010. Source level estimation of two blue whale subspecies in southwestern Indian Ocean. *Journal of the Acoustical Society of America*, 127(6), pp.3800–8. Available at: http://dx.doi.org/10.1121/1.3409479 [Accessed July 19, 2011].
Širović, A., Hildebrand, J.A. & Wiggins, S.M., 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. *Journal of the Acoustical Society of America*, 122(2), pp.1208–15. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17672667 [Accessed July 15, 2011].
Socheleau, F.-X. et al., 2015. Automated detection of Antarctic blue whale calls. *The Journal of the Acoustical Society of America*, 138(5), pp.3105–3117. Available at: http://scitation.aip.org/content/asa/journal/jasa/138/5/10.1121/1.4934271.
SORP Acoustic Trends Steering Group, 2012a. Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the southern ocean. In E. M. Bell, ed. *SC/64/O13 - Annual Report of the Southern Ocean Research Partnership (SORP) 2011/12*. pp. 13–37.
SORP Acoustic Trends Steering Group, 2012b. *SORP Blue and Fin Whale Acoustic Trends Project : Report of 2012 steering committee meeting*, Bremerhaven, Germany. Available at: http://www.marinemammals.gov.au/__data/assets/pdf_file/0019/142714/2012-Steering-Group-Report-SORP-Blue-and-Fin-Whale-Acoustic-Trends-Project.pdf.
Thomas, L. et al., 2002. Distance sampling. In A. H. El-Shaarawi & W. W. Piegorsch, eds. *Encyclopedia of Environmetrics*. Chichester: John Wiley & Sons, Ltd, pp. 544–552.
Thomisch, K. et al., 2015. Effects of subsampling of passive acoustic recordings on acoustic metrics. *The Journal of the Acoustical Society of America*, 138(1), pp.267–278. Available at: http://scitation.aip.org/content/asa/journal/jasa/138/1/10.1121/1.4922703.
Thomisch, K. et al., 2016. Spatio-temporal patterns in acoustic presence and distribution of Antarctic blue whales Balaenoptera musculus intermedia in the Weddell Sea. *Endangered Species Research*, 30, pp.239–253. Available at: http://www.int-res.com/abstracts/esr/v30/p239-253/.