SORP Blue and Fin Whale Acoustic Trends Project: Report of 2012 steering committee meeting

Alfred Wegener Institute, Bremerhaven, Germany, October 2013

Acoustic Trends Steering Group

Flore Samaran (Project Coordinator)– Centre de Recherche sur les Mammifères Marins UMS 3462-CNRS, University of La Rochelle, France

Kate Stafford (Project Coordinator)– Applied Physics Laboratory, University of Washington, USA

Ken Findlay – Mammal Research Institute Whale Unit, University of Pretoria, South Africa

Jason Gedamke – National Oceanographic & Atmospheric Administration, Office of Science and Technology-Ocean Acoustics Program, USA

Brian Miller – Australian Marine Mammal Centre, Australian Antarctic Division, Australia

Ilse van Opzeeland – Ocean Acoustics Lab, Alfred Wegener Institute, Germany

Contents

Overall agenda

1) Review of prior SORP Acoustics work and achievements
2) Review and discussion of links to other projects
3) Discussion of ongoing work for 2012/13
4) Review of methods to analyse long-term acoustic data sets
5) Review of past, present, and future instrumentation to collect long-term acoustic data
6) Discussion of data storage
7) Development of a strategic plan/vision for the project for 2013-2018

Project background

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

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 with 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 on 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, techniques to do this are developing rapidly (Thomas and Marques 2012, Marques *et al.* in press) with easily obtainable measures of relative abundance that 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).

The purpose of the 2012 meeting of the SORP Acoustics steering group was to review ongoing work on Southern Hemisphere blue and fin whale acoustics, discuss current and future data collection and analysis efforts, and to refine the vision of the project into a strategic plan that can be used to guide research efforts over the next five years.

Review of ongoing work

Summary of previous report (Flore Samaran)

A report of ongoing work on the SORP Blue and Fin Whale Acoustic Trends Project up to 2012 was presented to the 64th Scientific Committee of the International Whaling Commision as an annex of work conducted under the SORP banner (Samaran *et al.* 2012). Samaran presented this report as a starting point for discussion of ongoing work. In short, during the past decade, there have been about 44 different sites in the Southern Hemisphere where from a minimum of 12 months to 9 years of passive acoustic recordings were collected. However, these recordings have been made by many different groups using various instruments and analysis methods, and furthermore there has not been much emphasis on consistency in spatial and temporal sampling. The result is a patchwork of recording sites spread out over a large space and long-time. In 2012 Samaran and Stafford led efforts to conduct preliminary analysis on existing data with a circumpolar, Southern Ocean focus as well as a focus on multi-year records (CTBTO Cape Leeuwin station; Samaran *et al.* 2012).

South Atlantic (Ilse van Opzeeland)

Van Opzeeland presented an overview of her group's data collection efforts in the Southern Ocean South of the Atlantic. Initially data was collected using MARUs and Aurals, however in 2009 a collaboration began between Alfred Wegener Institute (AWI) and company Develogic to develop SonoVault long-term passive acoustic recording devices. The SonoVaults are presently configured to record continuously at 5333 Hz 24-bit depth for a duration of 3 years. AWI has deployed 9 SonoVaults and 2 Aurals in 2010. In January 2013, AWI will recover and exchange the 11 acoustic moorings that were deployed in 2010, and will deploy 17 devices (13 moorings two of which will have three devices each) between 60°W and 0°. Additionally, AWI has continuous recordings dating from late 2005 from PALAOA, an acoustic observatory with hydrophones moored through the Antarctic ice shelf (70.3°S, 8.1°W). The PALAOA recordings contain acoustic signatures of four ice-breeding pinniped species and also various cetacean species, among which Antarctic blue and fin whale calls. Van Opzeeland presented preliminary analysis of long-term data from the PALAOA observatory and the MARU and AURAL recorders that showed a decreasing frequency trend in the 28 Hz calls. Additionally, blue whales were still acoustically detected when there was significant ice-cover, though it was suspected that this might be related to increased detection ranges due to decreased ambient noise levels during periods with ice cover. The typical blue whale acoustic signature in the PALAOA and Aural recordings is a virtually continuous band around 28 Hz, representing a chorus of simultaneously singing individuals. Single calls are relatively rare in these recordings, but occur more often in the MARU recordings. Distinguishing single calls to determine call rates, is often not reliably possible when the chorus is present. However, the intensity of the chorus itself might provide an alternative measure for the number of vocally active animals within a given area. Exploring how information on local blue whale densities can be derived from the chorus signature was defined as one of the objectives of the Passive Acoustics working group.

Indian and Southern Ocean (Flore Samaran)

Samaran presented a summary of recent analysis she and colleagues had conducted using of acoustic data from moored recording devices in the subantarctic part of the Indian Ocean (26°S to 42°S). Devices recorded pygmy and Antarctic blue whale calls, as well as fin whale calls. Geographic, seasonal and diel variation in calling rates was presented, as well as statistical automated methods for determining the minimum number of individual Antarctic blue whales calling in an acoustic recording based on the intercall interval.

Southeast Indian to Southwest Pacific (Brian Miller)

Miller presented a review of instruments used to collect long-term acoustic data (Table 1) as well as work on developing a new self-contained acoustic mooring and long-term acoustic recorder electronics (work that was originally started in 2009 by J. Gedamke when at the Australian Antarctic Division). The prototype stand-alone acoustic mooring was successfully deployed and recovered in 800 m of water over a 3 day trial period in March

2012. The mooring was designed to be quickly and easily deployed and recovered from Antarctic supply vessels. The basic mooring design includes 2 glass floatation spheres and 1 glass instrument housing mounted into a titanium frame. The titanium frame is attached via a 10 m nylon strap to a pair of EdgeTech PORT LF acoustic releases, which are in turn connected via a 10 m nylon strap to 200 kg anchor. The recorder electronics sample at 12 kHz 16-bit depth and storage includes up to 64 SD cards with an expected battery life in excess of 15 months of continuous recording (Figure 1). Material costs for the mooring were approximately $8,500 AUD, while material costs for the recorder electronics, hydrophone, and recovery aids were approximately $5,000 AUD. The tandem acoustic releases comprised the bulk of the material costs at approximately $16,000 AUD. The relatively low cost of materials and logistically straightforward deployment prompted discussion of avenues for procuring additional instrumentation. Ideas included requesting IWC funding for instruments, directly approaching governments for funding, or a hybrid where countries can "buy-in" to the project at the cost of an instrument so that each country has an instrument to use.

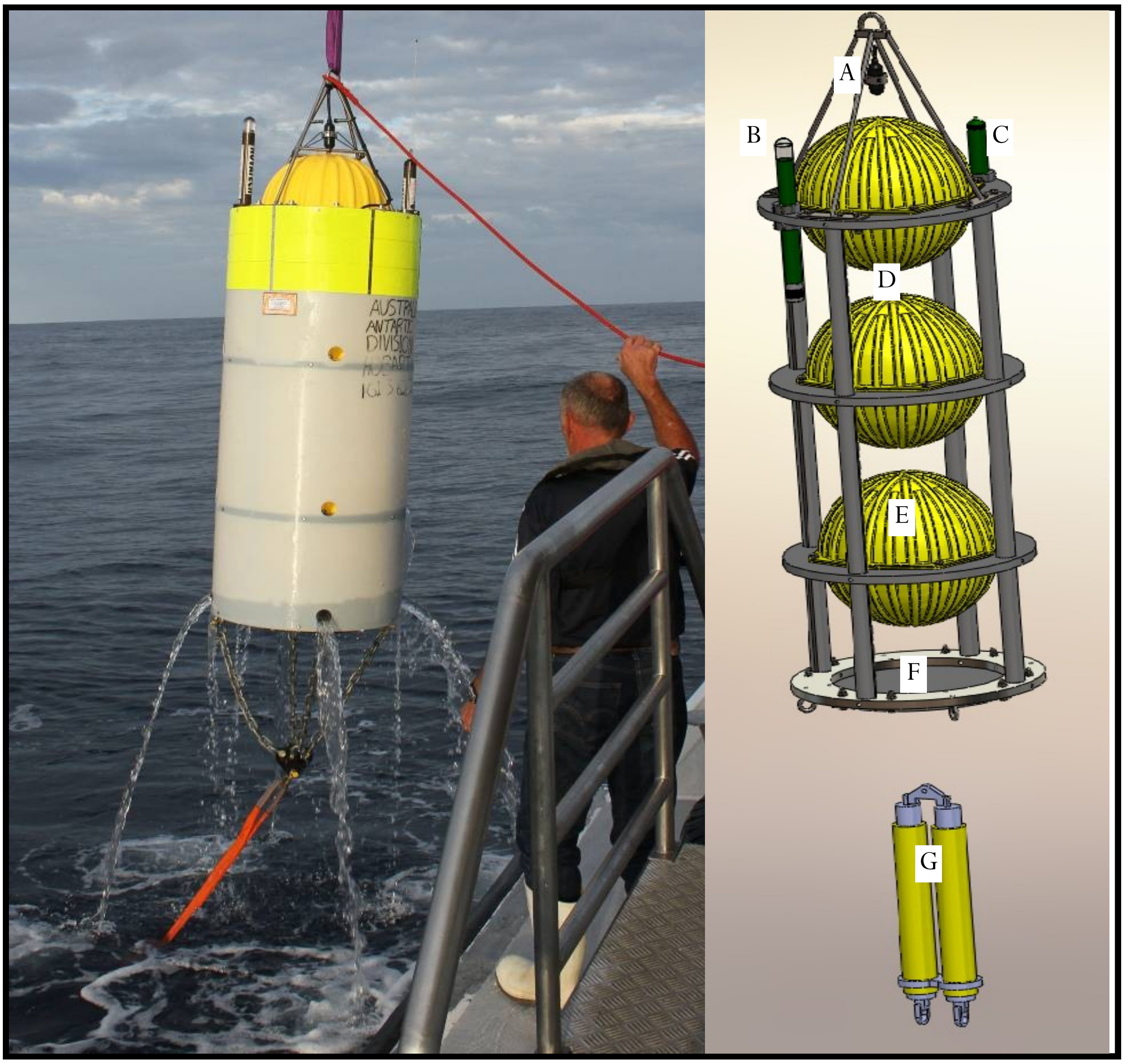

Figure 1 – Photograph and schematic of a moored acoustic recorder developed at the Australian Antarctic Division. A) Hydrophone. B) Recovery flashing light. C) Recovery radio beacon. D) Glass floatation spheres. E) Electronics housing. F). Baseplate and ballast. G). Acoustically activated release.

Link to other research projects

South African Blue Whale Project (Ken Findlay)

Findlay presented a summary of plans for the South African Blue Whale Project (SABWP). This project would potentially use South Africa's new research vessel, *SA Agulhas II*, to conduct focussed research on Antarctic blue whales as well as to deploy long-term acoustic moorings to investigate long-term trends in abundance. Findlay reviewed previous work conducted South of South Africa from 0 - 20°E where many photographic identifications and tissue samples of blue whales were made during Southern Ocean Whale Ecosystem Research (SOWER) voyages. Proposals for the SABWP include deployment of long-term acoustic recorders off the coast of South Africa and at high latitudes, off the Antarctic continent. Such recorders may reveal insight into the bi-modal peak in the seasonality of catches recorded at Saldanha, and Walvis Bay, yet only a single peak is found off Angola. In the short term, the project proposes to deploy at least two AURAL recorders during the austral winter off the west coasts of South Africa (off Saldanha Bay) and Namibia (off Walvis Bay), before moving these to the Antarctic in the region of the Maud Rise (2°E) and Astrid Ridge (11°E) and possibly further east (at approximately 18°E). In the longer term, relatively shallow islands and sea mounts may be targeted as further sites for acoustic moorings (eg. Bouvet Island, Tristan de Cunha, Marion Island, Discovery Sea Mount). Furthermore, the *SA Agulhas II* travels along the oceanographic Good Hope Line each year, so there are several sites that may be visited annually to service moorings with acoustic recorders.

Because there is currently a lack of acoustic mooring expertise on the project, Meredith Thornton, of the Mammal Research Institute's Whale Unit, University of Pretoria, was invited to participate on a University of Washington mooring cruise off Greenland in September 2012 to learn the basics of deploying and recovering moorings and programming Aural instruments. Her travel to participate on this cruise was funded by SORP. In addition to deploying passive acoustic moorings, the SABWP also has applied for 14 days ship time in the 2013/14 season to "ground truth" the abundance of animals in the area near high-latitude acoustic moorings. Some discussion was held on the design of a relatively short term voyage to achieve this objective, including the use of DIFAR sonobuoy tracking to increase blue whale encounters. As the SABWP is still in the early stages, there was some discussion regarding the best ways to integrate the SABWP with both the SORP Blue and Fin Whale Acoustic Trends Project, which focuses largely on long-term acoustic recordings, as well as the complimentary SORP Antarctic Blue Whale Project, which focuses on blue whale abundance, population structure and *in-situ* observations of behaviour. Further discussion of linkages between the SORP projects ensued.

SORP Antarctic Blue Whale Project (Brian Miller)

Miller presented a synopsis of two short voyages conducted in 2012 as part of the SORP Antarctic Blue Whale Project (ABWP) (Miller *et al.* 2012). The ABWP and the Blue and Fin Whale Acoustic Trends Project are complimentary in nature. While the Acoustics project uses passive acoustics to infer relative changes in abundance and seasonality, the ABWP is tasked with generating a precise estimate of abundance for Antarctic blue whales, as well as characterising whale behaviour, and population structure. Abundance, whale behaviour, and population structure will be measured via a series of voyages and the main methodologies used will be photographic and genetic mark-recapture techniques as well as behavioural observations. In order to maximise the number of whales encountered, these voyages will make use of DIFAR sonobuoys for real-time acoustic tracking of whales (Miller 2012). Precise measurements of abundance can provide a "ground truth" for relative abundance estimates made via long-term acoustic recordings. Similarly, simultaneous visual and acoustic observations of Antarctic blue whale behaviour collected on ABWP voyages add significant value to the interpretation of long-term acoustic recordings, and provide an essential link between the acoustic behaviour and number of individuals present. Additionally, information regarding population structure will also add significant value to interpretation of long-term acoustic recordings. There was concise discussion regarding opportunities to collect behavioural data during the 2013 ABWP voyage, and the steering group recommended that effort should be made on the ABWP voyage to record the following behavioural information simultaneously with acoustic recording: distance, bearing, number of whales, general surface behaviour, time of surface interval, dive time. As a result, the ABWP voyage will make use of video cameras to get precise bearings and distances to whales as well as record surface behaviours (ie. Leaper and Gordon 2001), while simultaneously making acoustic recordings, at least for the first hour upon approaching a group of whales.Effort will also be made to simultaneously collect acoustic recordings and genetic samples to better investigate links between population structure and whale vocalisations.

IWC Southern Ocean Whale Ecosystem Research (SOWER) Sonobuoy Recordings (Ken Findlay)

In proposing an investigation of the acoustic data from hundreds of sonobuoys that were deployed during the latter part of the IWC SOWER surveys, Findlay enquired whether there had been any systematic analysis of these recordings and whether these recordings represented an untapped source of acoustic data. It was noted that the highest value in such data were at times when there were simultaneous recordings and sightings, and that this would likely be only a handful of the numerous recordings where blue and fin whales were audible. It was agreed that SOWER sonobuoy data might represent a good avenue to train a South African student in analysis methods, but that the data were not likely to answer many scientific questions of interest to the Blue and Fin Whale Acoustic Trends Project. Technical advice and limited support for analysis of sonobuoy data based on existing software used by the SORP ABWP might be provided to such a student by the AAD.

Strategies

Collection of data

There was considerable discussion regarding future data collection efforts. Topics of discussion ranged from sampling rates of individual instruments, to long-term cycles of biotic and abiotic processes in the Antarctic ecosystem.

Spatial Coverage

It was generally acknowledged that ideal spatial-temporal coverage (ie. complete circumpolar coverage recording continuously for decades), was not possible and logistics dictated that multi-year data sets could only be collected along supply routes for Antarctic stations and oceanographic moorings that are serviced regularly. It was recommended that having circumpolar coverage was important in order to provide an indicator of changes in circumpolar distribution that may otherwise be confounded with changes in population. The group concluded that it would be a realistic goal to attempt to have at least one instrument in each of the six IWC management areas. After the meeting a list of previous, present, and planned deployments was complied. The resulting map (Figure 2) reveals that AWI has excellent coverage of Area II. The largest part of the AWI's passive acoustic recorders form part of the HAFOS mooring array that crosses the Weddell Sea. The anticipated end date of the HAFOS project is 2014/15. After this period, passive acoustic recorders are aimed to be integrated in AWI's remaining and/or new long-term oceanographic moorings. The University of Brest in collaboration with the UMS 3462-CNRS (Centre de Recherche sur les Mammifères Marins) had good coverage in the Indian/Subantarctic Ocean (between Areas III and IV). Planned deployments by the Australian Antarctic Division will provide coverage of area IV in 2013/14, while collaboration between the UMS 3462-CNRS (Centre de Recherche sur les Mammifères Marins) and the Australian Antarctic Divsion would provide coverage to Area V. The steering group also recommended that a series of acoustic moorings be maintained between 0 and 20°E (the study area for the SABWP) to improve coverage of Area III. Areas I and VI were identified as areas in need of attention with few historical recordings (especially Area VI) and no planned data collection in either area in the near term. It was recognized that additional collaborators would likely be required to effectively sample these areas in order to achieve circumpolar coverage. Olaf Boebel (Ocean Acoustics Lab, AWI) included this request in the presentation he gave at the SOOS meeting in Hobart in November 2012. There was general interest from the

SOOS community to support the SORP project and where possible combine efforts to deploy and service recorders with ongoing oceanographic research, not only for Areas I and VI, but generally. Further concrete collaboration possibilities are to be discussed. At present, the British Antarctic survey has put in a proposal for internal funding to deploy instrumentation near the South Orkney and South Shetland Islands. If this proposal is successful then the combined efforts of Germany, South Africa and the United Kingdom will provide excellent, unprecedented coverage of the South Atlantic sector of the Antarctic.

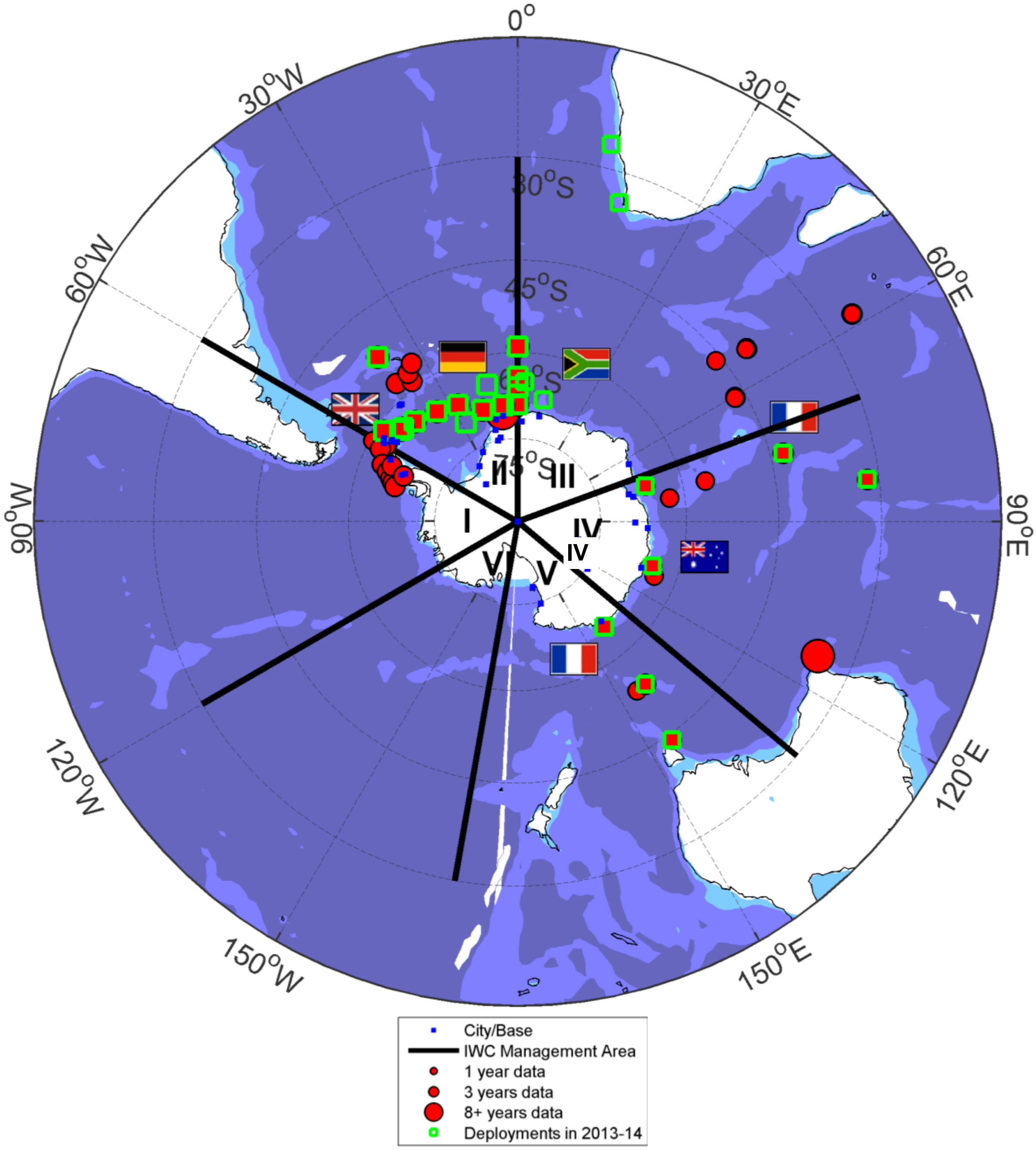

Figure 2 – Previous (solid red circles) and planned (green circles) deployment locations for long-term acoustic recorders. The size of the symbol is proportional to the duration of the data collection. Blue squares indicate cities or Antarctic stations. Light blue shading indicates areas shallower than 300 m. Light purple indicates areas between 300 and 3000 m depth. Dark purple indicates areas deeper than 3000 m.

Temporal Coverage

Consistency of data collection over a long time period was identified as a top priority to be addressed by the project. It was recommended that initially sites for data collection would remain in continuous operation for the first six years in order to include at least one El Niño/southern oscillation event. Furthermore, data collection of long periods increases the chances of temporal overlap of data collected at different sites. A review of trends after the first six years of data collection would then determine the future requirements for data collection (eg. every other year, or every fourth year). It was suggested that instruments should record continuously, rather than on a duty cycle, in order to facilitate comparison of inter-call intervals within and among sites. To measure acoustic trends over the suggested time period, changes over this time must be greater than the baseline inter-annual variation. However, presently there is not sufficient understanding of baseline inter-annual variation, and thus multi-year data collection in sufficient sites must first occur before this can be investigated further.

Storage of data and metadata

A need to have a central and standardized location for recording metadata with links to actual data was identified as important in order to facilitate analysis of trends among different sites and over different time scales. It was generally agreed that metadata must be located in a central repository (ie. database/website), but that due to the large size of data files and different embargo requirements from different institutions that partners should be able to choose where to host actual data and the nature of access restrictions. The group agreed that it would be best not to re-invent the wheel, and metadata storage should leverage existing infrastructure available to partners of the project. Suggestions for metadata storage then included the data catalogue for the International Whaling Commission, the PANGAEA information system (http://www.pangaea.de/about/), the Australian Antarctic Data Centre (http://data.aad.gov.au/), and the Australian Ocean Data Network (http://portal.aodn.org.au/webportal/). Further investigation of the possibility to store large acoustic data sets and metadata with each of these systems was recommended.

Analysis of data

There was considerable discussion of methods to analyse long-term acoustic data. Given the simplicity of implementation and ease of interpretation, long-term spectral averages (LTSA) were proposed as a first step in exploration of data from a single site. Inspection of LTSA allows a quick diagnostic test for the presence of blue and fin whales via the presence of tight bands of energy around 28 Hz (Antarctic blue), 24-28 Hz (fin), and 70 Hz or 35 Hz or 70 Hz(pygmy blue populations). For fin whales, higher frequency bands of energy at 89 and 99 Hz have also both been associated with Southern Ocean fin whale pulse calls. It has been hypothesized that the separate 89 and 99 Hz components may be indicative of different populations of fin whales. Despite the utility of LTSA for data exploration, LTSA alone does not provide a quantitative method of comparing blue and fin whale acoustics among locations or over multiple years in a single location. LTSA was viewed as a suitable method for initial exploration of long-term passive acoustic data, although less precise than measuring the number of days with detected calls. Daily time slices were recommended for LTSAs, though a confounding factor, that many previous recordings had a duty cycle on the order of a few minutes every few hours, was acknowledged.

Given the volume of acoustic data collected, investigation of individual whale vocalisations is greatly facilitated by automated detection algorithms. Stereotyped calls, such as fin whale pulse and blue whale ‘z’ calls can be detected with reasonable success using spectrogram correlation (ie, template detection) techniques (XBAT, Ishmael). However, it was noted that such techniques must account for changes that occur in vocalisations over time (eg. decreasing tonal frequency of blue whale ‘song’ calls). Given rapid development of automated detection algorithms, the steering group felt it was not yet appropriate to recommend a particular algorithm. Rather it would be more useful to recommend guidelines for choosing parameters and templates. Furthermore it was recommended that researchers using automated detectors manually verify a subset of their data (eg. 10%). A comparison of the results of automated detectors and these manually verified data can ideally be presented graphically as a receiver-operator characteristic curve (ROC curve). The subset of data that is manually verified should ideally cover not just a range of detection thresholds, but also a range of signal to noise ratios. While detection of individual whale calls is much more complex than LTSA, it yields a quantitative result that is directly comparable within and among sites. Furthermore, individual calls can be considered cues, and estimates of cue rates can be used to directly count the number of whales calling at any one time at a particular location, thus directly yielding the stated objective of the project: a relative estimate of abundance. A preliminary investigation of the CTBTO dataset from Cape Leeuwin was recommended to see if the percentage of hours/days with more than one whale calling had a trend with time that might be correlated with changes in abundance.

It was agreed that the steering committee should provide a 'blueprint' paper on automated analyses methods best suitable for Antarctic blue and fin whale acoustic signatures as this is urgently required in order to standardize detection methods and hence allow comparisons of acoustic data between different recorders and areas. This 'blueprint' paper is a high-priority deliverable expected in 2013.

There was a review of the long-term analysis technique conducted by Nieukirk et al (2012) referred to as the 'fin index'. This technique looks at the power in the fin whale band compared to that of a control band that is believed to contain noise. This technique appears to achieve a middle ground between the simplicity of LTSA, and the time consuming nature of counting individual calls, while still providing a quantitative measure of whale sound that may be correlated with relative abundance of whales. It was suggested that similar methods could be applied to create an 'Antarctic blue index.' However, it was recommended that further investigation be conducted on existing long-term data sets in order to quantify measurement error and inter-annual variation before making any conclusions regarding the suitability of the 'fin index' for determining acoustic trends of blue and fin whales in the Southern Ocean.

Capability development

The need for additional international collaboration was identified during discussion of data collection. The steering group discussed a number of measures that could address this need. In order to increase data collection capabilities, the group recommended finding additional funding to buy new moored acoustic recorders. Potential funding sources included IWC and also directly approaching partner nations by asking them to "buy-in" to the project for the cost of a moored acoustic recorder.

In addition to increasing the ability to collect data, it was also recognised that the project could benefit from having additional collaborators. It was recommended that the project cast a wide net for additional collaborators, and that the project maintain an open and inclusive attitude towards potential collaborators. In order to achieve this, the steering group discussed ways to emphasize the benefits of collaboration and lower the barrier to participation. The benefits of collaboration included:

- logistical support of polar programs,
- access to expertise of the steering group and other collaborators,
- support for training and deployment of instruments,
- political benefit through involvement with a high-profile international project.

Recommendations to lower the barrier to participation included:

- making it as easy as possible for potential collaborators to justify long-term acoustic monitoring to their funding institutions (ie. promoting the use of long-term PAM),
- collecting and maintaining a list of PDFs and citations of useful papers on the SORP website,
- making available reference designs for long-term passive acoustic recorders and moorings
- providing support for training and deployment of instruments,
- providing a central data base where collaborators can store their passive acoustic data and meta data
- providing support for acoustic analyses (ie. Paper or report that can be used as standard reference for choosing parameters and templates)

- encouraging in-kind contributions of instruments, ship-time, studentships, capability development and matching these contributions to the needs of collaborators

Conclusions

The meeting of the steering group of the SORP Blue and Fin Whale Acoustic Trends Project was very productive with the wide-ranging content of this report reflecting the breadth and depth of discussions held in Bremerhaven. The project is still in its early stages, and as the recommendations indicate, there is substantial need for additional collaborators, particularly in regard to circumpolar data collection. The project has much to offer potential collaborators, and at present, the project has good support from the Australian, French, and German polar programs, with future support from the South African Antarctic program under consideration. Despite the long-term focus of the project, it is expected that there will be a substantial number of outputs in the form of peer-reviewed publications as well as guidelines and recommendations from the steering group.

Acknowledgements

The Steering Group is indebted to the Alfred Wegener Institute for Polar and Marine Research for hosting the meeting. Thanks to Olaf Boebel and Lars Kindermann for tours of AWI warehouse and virtual tour of PALAOA. Funding for travel and accommodation was in part provided by the Souther Ocean Research Partnership.

References

Branch, T. A., K. M. Stafford, D. M. Palacios, C. Allison, J. L. Bannister, C. L. K. Burton, E. Cabrera, C. A. Carlson, B. Galletti Vernazzani, P. C. Gill, R. Hucke-Gaete, K. C. S. Jenner, M. N. M. Jenner, K. Matsuoka, Y. A. Mikhalev, T. Miyashita, M. G. Morrice, S. Nishiwaki, V. J. Sturrock, D. Tormosov, R. C. Anderson, A. N. Baker, P. B. Best, P. Borsa, R. L. Brownell Jr, S. Childerhouse, K. P. Findlay, T. Gerrodette, A. D. Ilangakoon, M. Joergensen, B. Kahn, D. K. Ljungblad, B. Maughan, R. D. McCauley, S. McKay, T. F. Norris, S. Rankin, F. Samaran, D. Thiele, K. Van Waerebeek and R. M. Warneke (2007). "Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean." Mammal Review **37**: 116-175.

Clapham PJ, Baker CS (2002) Modern whaling. In: *Encyclopedia of Marine Mammals* (eds Perrin WF, Würsig B, Thewissen JGM), pp. 1328–1332. Academic Press, New York.

Gedamke, J., Robinson, S.M. (2010**).** Acoustic survey for marine mammal occurrence and distribution off East Antarctica (30-80°E) in January-February 2006. Deep Sea Research II 57(9-10):968-981.

Gillespie, D., (1997). An acoustic survey for sperm whales in the Southern Ocean Sanctuary conducted from the RSV Aurora Australis. Report of the International Whaling Commission 47: 897-906.

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

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

Marques, T.A., Thomas, L., Ward, J., DiMarzio, N., and Tyack, P.L. (2009). Estimating cetacean population density using fixed passive acoustic sensors: An example with Blainville's beaked whales. J. Acoust. Soc. Am 125(4):1982-1994.

Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Jarvis, S., Morrissey, R. P., Ciminello, C., DiMarzio, N. (2011) Spatially explicit capture recapture methods to estimate minke whale abundance from data collected at bottom mounted hydrophones. Journal of Ornithology.

Marques, T.A., L. Thomas, S. Martin, D. Mellinger, J. Ward, D. Moretti, D. Harris and P. Tyack. In press. Estimating animal population density using passive acoustics. Biological Reviews. Article in online-early form at publisher's web site: doi:10.1111/j.1748-7692.2011.00561.x

Mellinger, D.K., K.M. Stafford, S.E. Moore, R.P. Dziak, and H. Matsumoto (2007): An overview of fixed passive acoustic observation methods for cetaceans. Oceanography, 20(4), 37–45.

Miller, B. S., N. Kelly, M. C. Double, S. J. Childerhouse, S. Laverick, and N. Gales. Cruise report on SORP 2012 blue whale voyages: Development of acoustic methods. Paper SC/64/SH11 presented to the IWC Scientific Committee, Panama City. 16pp. Unpublished.

Miller, B.S. 2012. Real-time tracking of blue whales using DIFAR sonobuoys. Proceedings of Acoustics 2012. Fremantle, Western Australia.

National Marine Fisheries Service. 2006. Draft recovery plan for the fin whale (*Balaenoptera physalus*). National Marine Fisheries Service, Silver Spring, MD. **http://www.nmfs.noaa.gov/pr/pdfs/recovery/draft_finwhale.pdf**

Nieukirk, S.L. D. K. Mellinger, S. E. Moore, K. Klinck, R. P. Dziak, and Goslin, Jean, 2012. Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean , 1999 – 2009. *J. Acoust. Soc. Am.* 131(2). pp.1102–1112.

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

Thomas, J.A., Fisher, S.R., Ferm, L.M. and Holt, R.S. (1986). Acoustic detection of cetaceans using a towed array of hydrophones. Report of the International Whaling Commission (Special issue 8): 139-148.

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

Samaran F, Adam O, Guinet C. 2010. Detection range modelling of blue whale calls in southwestern Indian Ocean. Applied Acoustics 71: 1099-1106.

Samaran, F., K. Stafford, J. Gedamke, I. Van Opzeeland, B. Miller, A. Olivier, M. Baumgartner, S. Mussoline, and P. Guillaume. Report on the use of passive acoustic data to study distribution, seasonal presence, and population trends of blue and fin whales in the Southern Ocean. In: Annual Report of the Southern Ocean Research Partnership (SORP) 2011/12. Editor: E. Bell. Report to the 64th Scientific Committee of the International Whaling Commission. SC64/O13. pp. 13-37.

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

Širovic, A., Hildebrand, J.A., Thiele, D., (2006). Baleen whales in the Scotia Sea during January and February 2003. Journal of Cetacean Research and Management 8 (2), 161-171.

Širovic, 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), 1208-1215.

Stafford, K.M., Citta, J.J., Moore, S.E., Daher, M.A. and George, J. 2009. Environmental correlates of blue and fin whale call detections in the North Pacific Ocean, 1997-2002. Marine Ecology Progress Series 395:37-53.

Tables

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

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

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

Appendix: Intended Agenda

	1 October	
Morning	1)	Review of 2011/2012 work and achievements
		a) 2012 Study for the IWC report (Flore and Kate)
		b) Trial deployment of AAD moored acoustic recorder in March 2012 (Brian)
		c) AWI data collection, PALALOA SonoVault, Aural (Ilse)
Afternoon	2)	Possible links with other projects
		a) South African blue whale project (Ken)
		b) SORP Antarctic blue whale project (Brian)
Late Afternoon	3)	Ongoing work for 2012/2013 (all)
	4)	Write first draft of Strategic Plan 2012-2017
	2 October	
Morning	5)	Visit of the PALOA Observatory and meeting with Lars Kindermann
Afternoon	6)	Ongoing work - 2012/13
		a) Analysis methods (Flore) - Detection - Estimation density
		b) Instrumentation – AAD moored acoustic recorders (Brian) - Mooring design and deployment details - Recorder availability - Locations and strategies deploying moorings (Voyages that could deploy/recover a moored recorder) - Sample rate, duty cycle, filtration - Freely available database of metadata and data from this project
Late Afternoon	7)	Work plan for 2012/2013 (All)
	3 October	
Morning	8)	Finalize work planned for 2012/13 and review of draft Strategic Plan including work for 2012/13 – second draft (All)
		a) strategies for data analysis
		b) strategies for instrumentation
		c) strategies for fundings
Afternoon	9)	Further discussion (All)
		a) Potential publications
		b) Write first draft of Strategic Plan 2012-2017