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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

The 2016 Antarctic Circumnavigation Expedition (ACE), conducted by the newly created Swiss Polar Institute, will take place from December 2016 – March 2017, aboard the Russian icebreaker RV Akademik Treshnikov. The Australian Antarctic Division and collaborators from the IWC-SORP Acoustic Trends Project and IWC-SORP Antarctic Blue Whale Project have been awarded funding, in-kind contributions of ship time, and in-kind logistical and operational support in order to conduct acoustic monitoring for marine mammals during the ACE voyage. The proposed work, titled *Circumpolar acoustic mapping of endangered Southern Ocean whales* was one of 22 research international projects selected for participation in the ACE voyage, and will be the only cetacean-focused research project. This work will be the first ever circumpolar survey for Antarctic whales to be completed in a single season. Passive acoustic mapping during the ACE voyage will not only focus on the broad-scale circumpolar distribution of marine mammal calls, but will build upon recent methods for long-distance acoustic localisation of blue whales. These data will provide an unprecedented opportunity to compare the circumpolar distribution of aggregations of blue and fin whales with environmental data from satellites, historical whaling catch data, contemporary sighting and acoustic survey data, and acoustic detections from existing long-term underwater listening stations. Such comparisons will help to better understand how and why whales are distributed throughout the Southern Ocean. Additionally, these data may help to independently validate the detection range and spatial coverage of ongoing long-term fixed passive acoustic recordings, and thus facilitate novel efforts for acoustic density estimation of Southern Ocean blue whales. Details of this proposal and a preliminary voyage plan are presented.

KEYWORDS: SOUTHERN OCEAN, PASSIVE ACOUSTICS, SPATIAL DISTRIBUTION, SORP

THE ANTARCTIC CIRCUMNAVIGATION EXPEDITION

The Antarctic Circumnavigation Expedition (ACE) was announced in December 2015 along with an open call for proposals to conduct scientific research during the voyage. This 90-day expedition will take place from December 2016 – March 2017 and will be the inaugural voyage of the recently created Swiss Polar Institute. The ACE will be conducted onboard the Russian flagged icebreaker, the RV Akademik Treshnikov. The tentative voyage plan calls for departure from Cape Town, South Africa in late December with port-calls in Hobart, Australia in January, and in Punta Arenas, Chile in February before returning to Cape Town in March 2017 (Figure 1). In addition to the port-calls, another major component of the voyage will be short stopovers (e.g. 24 – 48 hour) to conduct research on several sub-Antarctic and/or Antarctic Islands on each of the three legs. The voyage plan requires direct transit from the departure-port to islands and on to the next port, maintaining an average speed of 11 knots with little scope to adjust the speed or course.

Over 100 proposals were submitted to ACE, and 22 were selected representing a wide variety of scientific disciplines and international institutions. The Australian Antarctic Division (AAD), in collaboration with scientists from the IWC-SORP Acoustic Trends Project and IWC-SORP Antarctic Blue Whale Project, submitted a successful research proposal to conduct acoustic monitoring for marine mammals during all three legs of the ACE voyage. Our project, titled *Circumpolar acoustic mapping of endangered Southern Ocean whales* has been awarded funding and in-kind contributions of ship time and logistical support to participate in this voyage. Our proposal was the only project selected for the ACE that has a dedicated cetacean research component. Two berths on each of the three legs of the voyage have been awarded to the project. Below we present the details of the proposed project along with preliminary project timeline and work plan.

Figure 1 - Indicative travel plan for the Antarctic Circumnavigation Expedition.

PROJECT OVERVIEW: CIRCUMPOLAR ACOUSTIC MAPPING OF SOUTHERN OCEAN WHALES

Using novel passive acoustic methods we will conduct the first single-season circumpolar survey of endangered Southern Ocean blue and fin whales. The rare and remote nature of these oceanic wandering whales have traditionally made studies costly and challenging. However, recent advances in passive acoustic monitoring, by listening for and tracking their repetitive, long, loud, low-frequency calls, provide new and efficient avenues for their study. By applying these reliable acoustic survey methods we will characterise the circumpolar distribution of blue and fin whales on their summer feeding grounds. Unlike many other techniques that would struggle to yield quality data during direct, non-stop, full-speed transit between ports and islands, our proposed methods for an acoustic survey are well-suited to both the ambitious schedule of the ACE Project and the notoriously harsh conditions commonly encountered in the Southern Ocean.

PROJECT BACKGROUND

Southern Hemisphere blue and fin whales were a primary target of 20th century industrial whaling, and Antarctic blue whales were one of the most heavily exploited of these populations with their numbers reduced to approximately 0.1% of pre-exploitation abundance by 1965 when their take was internationally prohibited. Two subspecies of blue whales have been described in the Southern Hemisphere, namely the Antarctic blue whale and the pygmy blue whale, although pygmy blue whales may include a number of different populations with at least six acoustically and geographically distinctive call types having been identified (McDonald et al. 2006, Brownell et al. 2015). Critically endangered Antarctic blue whales and fin have proven to be challenging to study as the only known aggregations are in the remote Southern Ocean feeding grounds. While some populations of endangered pygmy blue whales form aggregations at known locations (e.g. Gill et al. 2011, Torres 2013, Buchan et al. 2015), their broad-scale distribution remains challenging to elucidate as several populations are believed to inhabit offshore Subantarctic regions of Southern Ocean where there is relatively little vessel traffic and visual surveys are limited by inclement weather (Branch et al. 2007).

Recent developments in passive acoustics now provide robust and reliable means of remotely detecting, tracking and mapping the distribution of vocalising Southern Ocean whales. Application of these methods during recent surveys has revealed novel insights into their behaviour and distribution (Gedamke & Robinson 2010, Double et al. 2015, Miller et al. 2015). This passive acoustic technology involves regularly deploying DIFAR sonobuoys to detect the characteristic low and mid-frequency calls from a variety of Antarctic marine mammal species. For some species, including blue whales, DIFAR sonobuoys can also provide bearings to calling whales from hundreds of kilometres away, and these bearing can be used to more precisely triangulate the location of meso-scale aggregations of calling animals (Miller et al. 2014, 2015). These methods have opened new avenues for remote acoustic monitoring of Southern Ocean whale populations and present new possibilities for testing hypotheses regarding the factors that influence their distribution. If conducted at a circumpolar level, the fine-scale spatial resolution of these types of acoustic surveys may also provide unprecedented precision in identifying population distribution, since geographic variation among calls has been hypothesised to delineate fin whale populations (Gedamke 2009) and blue whale subspecies (McDonald et al. 2006, Brownell et al. 2015).

In addition to recent advances in fine-scale acoustic surveys and long-range in-situ acoustic localisation, there have also been recent advances in long-term acoustic monitoring using autonomous moored recorders. Long-term acoustic monitoring of whales in the Antarctic has occurred in an ad-hoc fashion at various locations and timespans since 2002 (Širović et al. 2004, Gedamke et al. 2007, Samaran et al. 2013). In 2009 the IWC-SORP Acoustic Trends Working Group commenced an international project to coordinate and standardise acoustic monitoring for blue and fin whales in the Antarctic: the SORP Acoustic Trends Project ("SORP Acoustic Trends Project" 2009). More recently the Acoustic Trends Working Group has commenced an ambitious project to deliver a long-term network of circumpolar Antarctic recording stations: the Southern Ocean Hydrophone Network (SOHN: Van Opzeeland et al. 2014). The first SOHN recording stations commenced continuous data collection in 2013 at six recording sites, and the project aims to obtain continuous data acquisition at these and additional sites for the next 5 years. The continuous long-term, coarse-scale data collected by the SOHN are complementary to the short-term, fine-scale data that can be collected from DIFAR sonobuoys deployed during voyages. When combined, these two data streams may offer an unprecedented view of the distribution and behaviour of Southern Hemisphere whales.

PROPOSED METHODS

Data collection and analysis at sea

DIFAR sonobuoys will be deployed using established adaptive survey methods (Gedamke & Robinson 2010, Miller et al. 2015) to efficiently detect and locate aggregations of vocalising whales. The proposed sampling regime requires a minimum of two acousticians on opposing 12-hour shifts. During transit, sonobuoys will be deployed four times per day at approximately 66 nmi intervals (assuming an average speed of 11 knots). For detections close to the vessel (indicated from high-intensity calls and/or high angular variance), sonobuoys may occasionally be deployed more frequently than every 6 hours in order to more precisely determine spatial extent and vocal characteristics. This sampling regime balances the desire for very high spatial resolution with the finite number of sonobuoys available for this study.

Approximately 400 DIFAR & HIDAR sonobuoys have been secured for use during the ACE voyage. Over 300 HIDAR sonobuoys have been purchased from Ultra Electronics Sonar Systems using the bulk of the funding from ACE grant, while the remainder is being supplied from the AAD's stockpiles of DIFAR 53F sonobuoys left-over from the 2015 Antarctic Ecosystems Voyage (Double et al. 2015). Deploying four sonobuoys per day on this 90-day voyage, and accounting for the 10% failure rate encountered on prior voyages suggests that 400 sonobuoys is very close to the minimum number required to achieve this sampling regime. On prior Antarctic voyages the typical limits for radio telemetry from sonobuoys was 12 nautical miles. If our recording system can achieve similar radio telemetry distances on the Akademik Treshnikov, then this would allow a little over one hour of monitoring from each of the 360 planned recording stations for the transits.

The total number of sonobuoys available and short recording durations leaves little, if any, margin for error and/or discretionary deployments, and emphasises the need to extract maximum value from each deployment. Whenever possible, deployments will be scheduled to occur when the ship speed is reduced in order to further increase the quantity and quality of data collected from each sonobuoy. When environmental conditions permit, a helium-filled kite (heli-kite) containing a VHF radio antenna and radio receiver will be flown behind the vessel to extend the range and time over which radio signals from sonobuoys can be received, thus further increasing the value of each sonobuoy. During island stopovers, trial deployments of re-usable sonobuoys will be conducted in order to attempt to maintain continuous acoustic monitoring throughout the stay. Reusable sonobuoys will be recovered before recommencing transit. Islands stopovers may also provide an opportunity to deploy high-frequency (broadband) acoustic recording devices such as SoundTraps, in order to record full bandwidth echolocation and whistles from odontocetes and full-bandwidth vocalisations from pinnipeds. The development of airborne radio systems (heli-kite) and reusable sonobuoys are in accord with IWC-SORP's goal of developing and testing novel and efficient methods for studying rare and remote Antarctic whales.

After each sonobuoy is deployed, acousticians will inspect the incoming acoustic data while logging calls from marine mammals and background noise levels. To ensure data quality, all sonobuoys will be calibrated in real-time using noise from the research vessel (Miller et al. 2016). Additionally, the low-frequency audio will be analysed in real-time to obtain bearings to blue whale calls and detections of other species to ensure the quality of localisation data. This ambitious work-schedule and the fast pace of the voyage leaves little margin for error during data collection and emphasises the need to send acousticians who already have substantial at-sea experience collecting and analysing data from DIFAR sonobuoys.

Calibrated intensity and bearing measurements will be obtained from suitable calls (e.g. tonal and frequency-modulated calls of baleen whales and pinnipeds), and the circular distribution of bearings to calls from each species on each sonobuoy will be used to identify vocal aggregations (Miller et al. 2015). Further analysis will be conducted on calls that are believed to travel over long distances (e.g. blue whale song). For such calls, bearings from different sonobuoys that appear to originate from the same location (i.e. meso-scale area) will be used to define a vocal aggregation and to triangulate its position, extent, and measure its acoustic characteristics (see sub-sections below).

Post-voyage analysis

Circumpolar distribution

The circumpolar distribution of whale calls recorded during the ACE voyage will be compared to the historic distribution of catches during industrial whaling (1904-1986), as well as the historic distribution of visual sightings and acoustic detections of whales during the International Decade of Cetacean Research and Southern Ocean Whale and Ecosystem Research (IDCR-SOWER) voyages (1978-2009), which include recordings from some 705 acoustic stations. The location of acoustic detections from the ACE voyage will be used to investigate relationships among the distribution of calling whales and the environment, namely, remotely sensed data such as bathymetry, water properties, oceanographic fronts, and ice.

Detection range, source levels, and clustering

Additional analysis will be conducted for aggregations where locations could be triangulated and characterised. The calibrated intensity measurements and estimates of distance and spatial extent of aggregations will be used along with models of acoustic propagation to investigate the variation in the source level of each type of call recorded within and among aggregations. Acoustic propagation models will make use of any *in-situ* measurements of the sound-speed-profile made during the voyage (e.g. from CTD/XBT deployments). Knowledge of source level can be essential for passive acoustic density estimation (Marques et al. 2013) and may also prove useful for testing the hypothesis that the source level of blue whale song is inversely correlated with population density (McDonald et al. 2009).

Additionally, the spatial extent and distances between vocal aggregations will be compared with uniform and clustered models of distribution as well as simulations of group dynamic movements (e.g. Peel et al., 2014) to investigate the spatio-temporal stability of aggregations and to test hypotheses regarding movements of individuals among aggregations.

Towards acoustic density estimation

Special attention will be given to vocal aggregations located near long-term recording stations of the SOHN (Van Opzeeland et al. 2014) since these data will be highly complementary to those collected during the ACE voyage. Simultaneous recording of vocal aggregations by ACE and SOHN instruments present a rare opportunity to obtain empirical validation of the detection distances and acoustic propagation losses encountered by SOHN hydrophones. Additionally, the long-term time series recorded before and after the ACE data may provide novel insight into the spatiotemporal stability of these vocal aggregations, which may directly influence the interpretation of ACE data. For example, if SOHN data reveal a circumpolar change in detected call type or rates throughout the season, this could be used to disambiguate trends in the ACE data that may be spatiotemporally confounded, and *vice versa*.

The knowledge of the source level of the calls of whales, the detection range and propagation effects experienced by SOHN recording stations, and the circumpolar spatial distribution of vocal aggregations of whales would not only allow for a novel understanding of how these rare and remote animals use the Antarctic environment, but will also pave the way for efficient future studies (e.g. density/abundance estimation) using autonomous passive acoustic systems and targeted vessel-based surveys (i.e. SORP Acoustic Trends & ABW Projects). While the scope of this project is ambitious, a successful outcome may decrease the cost of assessing the putative recovery of Southern Ocean whales and provide novel insights into their demographics and life-history.

EXPECTED RESULTS

This work will comprise the first single-season circumpolar survey for Southern Ocean whales and provide the most precise and up-to-date synoptic view of the summer distribution of Southern Hemisphere blue and fin whales. Circumpolar acoustic recordings will also be used to investigate the geographic variation among calls, as this has been hypothesised to delineate Southern Ocean fin whale populations and blue whale subspecies (McDonald et al. 2006, Brownell et al. 2015).

Long-distance acoustic triangulation will reveal the location and characteristics of meso-scale aggregations of vocalising blue and fin whales in order to quantify their circumpolar distribution. Characteristics of aggregations will not only include the number and type of calls detected, but also quantification of the spatial extent and degree of clustering (e.g. Peel et al., 2014) of aggregations. The spatial distribution of vocal aggregations of blue and fin whales will allow comparison with historic 20th century whale distributions, remotely sensed environmental data, and in-situ observations to understand relationships among whale populations and the Antarctic, sub-Antarctic, and sub-tropical environments.

In addition to endangered blue and fin whales, this acoustic survey will also yield information on the circumpolar distribution and vocal repertoire of other Antarctic and sub-Antarctic whale species that are encountered including humpback, southern right, sei, and sperm whales. The results of this survey will play an important role in refining future studies to ascertain whether these animals, many of which are still endangered, are recovering after their near extirpation during industrial whaling.

Links to existing research programmes

The unprecedented fine-scale circumpolar acoustic coverage achieved during this voyage may be transformative for analysing the decades-long time series of acoustic data collected and curated by the IWC-SORP Acoustic Trends Project (http://www.marinemammals.gov.au/sorp/antarctic-blue-whales-and-fin-whales-acoustic-program). Data collected during this voyage would be highly complementary to that collected by the Southern Ocean Hydrophone Network, an international collaboration of widely dispersed long-term Antarctic monitoring stations for efficient, but broad-scale, monitoring of Antarctic marine mammals. Furthermore, the location of vocal aggregations of Antarctic blue whales may directly influence voyage planning for the IWC-SORP Antarctic Blue Whale Project (http://www.marinemammals.gov.au/sorp/antarctic-blue-whale-project), a flagship research project of IWC-SORP. The data would also augment those collected on the AAD-led IWC-SORP Blue Whale Voyage (2013) and the joint New Zealand-Australia Antarctic Ecosystems Voyage (2015) and lead to a number of high-impact, peer-reviewed publications.

The research will be carried out by an international, multi-disciplinary team composed of leading experts in their field dedicated to the development of sophisticated, novel, non-lethal whale research techniques in support of the international contention that whales do not need to be killed in order to study them (IWC-SORP; http://www.marinemammals.gov.au/sorp). Results will be presented at future Scientific Committee meetings of the IWC. It is hoped that these results will play an influential role in the management and conservation of whales and Antarctic marine living resources such as krill, the main prey of Antarctic baleen whales.

Outreach

Our technological developments, data, results, images and footage will be openly and broadly disseminated to a wide range of audiences including international management and conservation agencies, academics, and the general public via: internationally accessible data portals; blogs; live streaming (e.g. real time acoustic data); websites; live uplinks with schools and universities and teaching materials; tourist vessel lectures and; potentially citizen science projects e.g., confirming acoustic detections and classifications.

PROJECT TIMELINE

late Jun 2016	ACE Voyage planning meeting for project PIs (Lausanne, Switzerland)
Jul 2016	Confirm supply of sonobuoys. Procurement of heli-kite.
Aug 2016	Testing of airborne radio systems and reusable sonobuoys
Oct 2016	Freight of sonobuoys to mobilization port(s)
late Nov 2016	Trials of acoustic instrumentation in port (before departure of leg 0).

late Dec 2016	Mobilization: setup & tuning of acoustic instruments
Dec 2016 – Jan 2017	ACE leg 1: Cape Town – Hobart
Jan – Feb 2017	ACE Leg 2: Hobart – Punta Arenas
Feb – March 2017	ACE Leg 3: Punta Arenas – Cape Town
Late Mar 2017	Demobilization: breakdown & freight of instruments. Post-voyage debrief
Mar 2017	Preliminary voyage report
Apr 2017	SOHN annual data retrieved
Oct 2017	Preliminary results and progress report
Jan 2018	Peer reviewed publications: *Distribution of ABW Aggregations on ACE*
Apr 2018	SOHN multi-year data retrieved.
Mar 2019	Final report: Peer reviewed publications: *ACE and SOHN Acoustics*

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