Investigating the ecology and behavior of blue whales (*Balaenoptera musculus*) in the Gulf of Corcovado, Chile
Technical Report 2017

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Technical Report

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The data presented in this report is preliminary.
Please contact the authors if you would like to use any figures.

Front Cover Figure Caption:
A blue whale surfaces in the calm seas of the Gulf of Corcovado. Photograph taken by Gloria Howes under Chilean research permit: Ministerio de Economia, Fomento y Turismo, Subsecreteria de Pesca y Acuicultura, MERI 488-FEB-2017 Ballena Azul, Golfo Corcovado.

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INTRODUCTION

Blue whales are known principally by two contrasting accolades, firstly, as being the largest animal to have ever lived on Earth, and secondly, as having been hunted to near extinction during twentieth century whaling. During the whaling era over four thousand animals were caught in Chilean waters alone (Williams et al. 2011). The species has been slow to recover from almost total decimation and hence a valuable discovery was made in 1993, when a small blue whale population of 232 individuals was found in the Gulf of Corcovado (GoC) in the Chiloense Ecoregion of Southern Chile (Hucke-Gaete et al. 2004). Genetic, acoustic and morphometric studies indicate that these blue whales are part of a wider Southeast Pacific population that is distinct from both the Antarctic (*B. musculus intermedia*) and "pygmy" (*B. musculus brevicauda*) blue whale subspecies (Branch et al. 2007, Buchan et al. 2014, Torres-Florez et al. 2014). Further investigations are required to establish the degree of isolation of the population and the health and viability of the individuals within it. Such knowledge is vitally important and will aid Chilean policy makers in generating informed management decisions regarding the conservation of this population.

In 2014 some encountered animals were observed in poor body condition, appearing emaciated. This led to a collaboration with Dr. Michael Moore WHOI) and Dr. John Durban (NOAA) in 2015 to measure and assess blue whale body condition using photogrammetry and an unmanned hexacopter (Durban et al. 2016). To further address this issue, collaborations with Dr. Joseph Warren (Stony Brook University) and Dr. Paolo Segre (Stanford University) were sought to investigate both prey availability and the energetics of blue whale foraging in the GoC.

As this study has evolved, new questions and concerns relating to the GoC blue whale population have arisen. Diving data from DTAG's indicate a diurnal shift in behaviour, with animals foraging for prolonged periods in surface waters during the night. Such behaviour exposes the animals to an increased risk of ship strike incidents, when ships are unable able to see and thus potentially avoid whales. Existing and new collaborations (e.g. with Dr. Daniel Zitterbart, WHOI) are using new tools to address such issues during the 2017 research cruise.

LONG-TERM GOALS

The principle goal of this project was to continue the investigation into the ecology, foraging and acoustic behavior of blue whales in the GoC, Chile, which began in 2014 with the support of the Melimoyu Ecosystem Research Institute (MERI).

OBJECTIVES

This investigation had six principle objectives, (1) to obtain data on the diving, foraging and vocal rates of individual blue whales in and around the GoC (Fig. 1), through the deployment of suction cup attached digital acoustic tags (DTAGs), (2) to collect biopsy samples from encountered blue whales, (3) to conduct prey mapping and prey sampling trawls in the vicinity of foraging whales, (4) deploy a suction cup attached video and movement recording (CATS) tag in conjunction with aerial photogrammetry to study body kinematics and foraging strategies, (5)

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deploy a bottom mounted hydrophone array for passive acoustic monitoring of blue whales in the Gulf of Ancud (GoA).

DTAG Study

This investigation aimed to acquire data on the ecology, foraging and acoustic behavior of individual blue whales in and around the GoC, Chile (Fig. 1). This was undertaken via the deployment of suction cup attached digital acoustic tags (DTAGs; Fig. 2). DTAGs are miniature sound and orientation recording tags developed at WHOI (Johnson and Tyack 2003). These tags contain a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. DTAGs record sound at the whale, as well as depth, and 3-dimensional acceleration and magnetometer information, and thus provide data on vocal, movement and dive behavior. The tag is attached with four suction cups using a hand-held 8 m carbon fiber pole (Fig. 2), and can be programmed to release after durations of up to 30 hours.

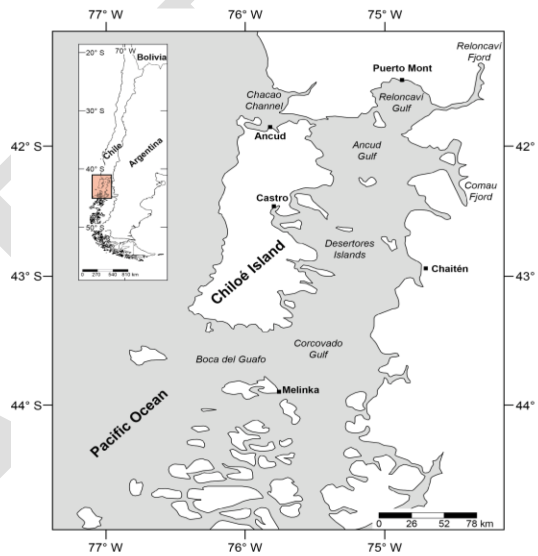

Figure 1. Maps indicating the location of the study region on the coast of Chile (inset) and the principle study area, the Gulf of Corcovado.

Biopsy Sampling

To further our knowledge of the genetic stock from which the blue whales of the GoC originate and to investigate the health and contaminant levels of these whales, remote biopsy sampling was conducted opportunistically. As with samples collected in previous years, those collected in 2017 are contributing to a global stock assessment of blue whales being conducted by NOAA SWFSC, La Jolla, USA. Equally, these samples are contributing to a broad ecosystem health study of the GoC being led by Gustavo Chiang and Paulina Bahamonde.

Prey Mapping and Sampling

To further investigate foraging and habitat use, prey mapping surveys and qualitative zooplankton samples were taken at the locations of feeding whales. Prey sampling net trawls were used to collect prey in order to characterize food sources. These datasets contribute directly to the food web modeling, stable isotope analysis and contaminant biomagnification investigations being undertaken by Fundación MERI in the region.

Kinematics Study

To compliment the DTAG study, a video and movement recording tag built by Customized Animal Tracking Solutions (CATS) were employed (Fig. 6). These CATS tags enable scientists to investigate the mechanics of motion and the forces required to generate motion. This study will employ them to investigate the kinematics of blue whales foraging in the GoC, facilitating

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Figure 2. The DTAG (bottom left) and the attachment method via hand-held pole (top left); images on the right show the tag attached to a blue whale with its four suction cups and the tag's small size relative to the animal's size.

studies of body condition and the energetic requirements of these animals. As a pilot study in 2017, the team from Stanford attempted to collect aerial photogrammetry images of tagged whales using drone technology, further enhancing their methods to assess kinematics and energetic requirements of GoC blue whales.

Passive Acoustic Monitoring (PAM) in the Gulf of Ancud

The passive acoustics project had two main aims:

1) Estimate the acoustic detection function for blue whale Southeast Pacific (SEP) and down sweep calls in the GoA and GoC. Estimate habitat use within the GoA and GoC over the deployment time of the bottom mounted array.

The months of February and March were chosen to conduct the field effort, based on historical blue whale sightings, acoustic detections and weather data.

Project Personnel and Research Vessel

Cruise personnel included Gustavo Chiang (MERI) who acted as the chief scientist and geneticist responsible for processing genetic samples, Alessandro Bocconcelli (WHOI) who was in charge of field operations, Leigh Hickmott (Open Ocean Consulting and the University of St. Andrews) was responsible for tag deployments, biopsy sampling and data collection. Joseph Warren (Stony Brook University) led the prey mapping and sampling research, Paolo Segre (Stanford University) headed the kinematic study and tag analysis, and Daniel Zitterbart (WHOI) developed and managed the acoustic mooring detection experiment. Gloria Howes (MERI) collected photo-identification images and assisted with field logistics. Laela Sayigh (WHOI) acted as the whale vocalization lead analyst.

The RV *Khronos* was employed as the principle survey vessel (Fig. 3).

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FIELD METHODS

Each day, weather and sea-state permitting, visual search efforts to detect marine mammals began at sunrise on the main vessel. All cetacean sightings were recorded in LOGGER (see Tracking and Visual Data Collection below and Appendix I), and where possible photo-identification images were collected. Once blue whales were detected, the possibility for tagging and or photogrammetry was assessed and if conditions were suitable tagging or photogrammetry commenced.

Tracking, visual data collection and photo-identification

To visually search for study animals, and to observe the behavior of the animals during tagging and tracking, a marine mammal observer platform was installed on the deck of the flying bridge of the RV *Khronos*. Observers scanned with the naked eye and 7 X 50 binoculars. This platform was equipped with a computer running the behavior logging program LOGGER (recording data such as species, group size, behavior, latitude/longitude; see Appendix I) and a VHF digital direction finder system for tracking the tag. Video and/or digital photographs to record species and any identifying marks were collected whenever possible.

Tagging

The tagging boat was deployed with a driver (Bocconcelli), photographer (Howes) and tagger (Hickmott or Segre) to deliver the DTAG or CATS tags using the hand-pole. Attempts were made to tag each whale in a group when whales appeared to be coordinated and were likely to remain together, thus minimizing the risk of tag loss.

Figure 3. The RV *Khronos*.

Visual observers on the main vessel helped direct the tag boat towards animals, monitored tagging approaches, and ensured tagging permit compliance. Data sheets and computer data logs were kept on the main vessel and tag boat, detailing each tagging approach. If tagging was unsuccessful after several approaches, tagging efforts were suspended. During tagging efforts video and/or 35mm digital photographs were collected whenever possible, as were sloughed skin samples (see Genetic samples below).

Once a whale was successfully tagged and all relevant data collected by the tag team, the zodiac returned to the main vessel. The main vessel was then used to track and maintain visual and photo-identification efforts for the duration of tracking and behavioral observations (except for night hours). Tagging attempts continued during daylight hours and a day was only considered complete when all tags were recovered and there was no longer enough daylight to attempt further tagging. Tags were recovered with a dip net from the main vessel. Tag data were offloaded onboard, and the tags were recharged and sterilized for subsequent use.

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Genetic Samples

Biopsy Sampling - To collect skin and blubber samples from free ranging blue whales, a 150lb draw weight Barnett Wildcat crossbow was used to deploy biopsy bolts fitted with a sterile stainless steel cutting tip (50 or 25mm X 5mm)(Fig. 4). Collected biopsy samples were processed and stored in RNAlater (a stabilization and storage liquid), in preparation for laboratory analysis.

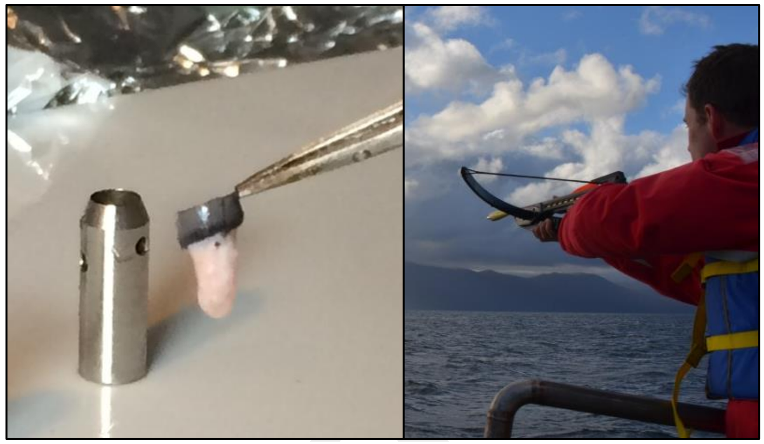

Figure 4. Stainless steel biopsy tips were used to collect skin and blubber samples. Biopsy bolts were deployed using a crossbow.

Sloughed Skin - Sloughed skin samples were opportunistically collected from the DTAG's suction cups, catalogued and stored in RNAlater.

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Prey Mapping

A two-frequency (38 and 200 kHz) scientific echosounder was used to map the distribution and abundance of fish and zooplankton during the study. The system was mounted on the port side of the RV Khronos at a depth of 1m (Fig. 5) and collected data from ~ 2m depth to the bottom of the water column with a vertical resolution of approximately 10 cm.

Figure 5. The scientific echosounder system was pole mounted on the port side of the RV Khronos for underway data collection (left) and could be raised for rapid transit (middle, the orange object is the transducer). The data collection and storage system were located on the bridge of the vessel (right, the pig is a lab mascot).

Prey Sampling

A 250 µm mesh, 50 cm diameter and 3 m long zooplankton net was towed horizontally from the RV Khronos at 2 knots for 20-30 minutes. Once the trawl was complete the net was hauled to the surface, where the accumulated plankton was separated by size and species, labelled and stored at -20 °C in preparation for analysis.

All genetic and prey sampling specimens will contribute to analysis being conducted by Dr. Gustavo Chiang (University of Concepcion, Chile) as part of a wider study: ‘Biomagnification and potential effects of Persistent Organic Pollutants (POPs) and trace metals in the aquatic food webs of the Antarctic Peninsula and Patagonia’.

CATS Tagging & Aerial Photogrammetry

The CATS tag is capable of recording video, fine-scale three dimensional movement data, pressure and GPS location data (Fig. 6). The tag attaches with suction cups and is deployed using a hand pole. The video and movement data recorded by the tag provide unique data to assess the kinematics and foraging stratagies of feeding blue whales.

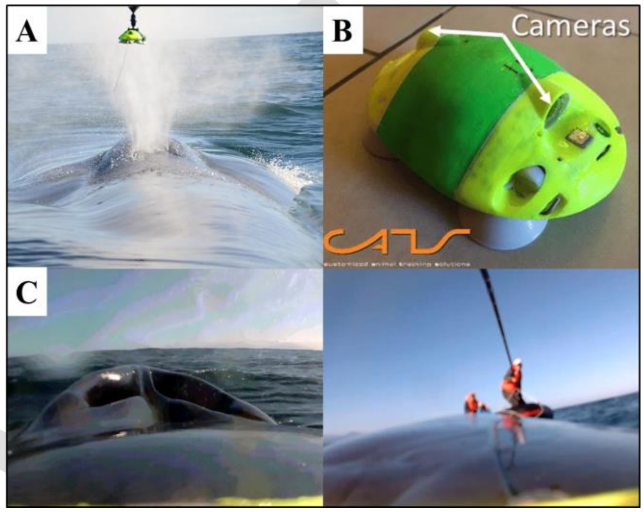

Figure 6. The CATS tag. (A) Tag about to be deployed, (B) the tag with forward and rear facing cameras, (C) front and rear images from the tag as it is deployed.

Passive Acoustic Monitoring

To achieve the PAM goals, an acoustic array consisting of spatially separated SoundTrap300 autonomous recorders was deployed (Fig. 7). Sampling frequency was set to 48kHz, gain to high with continuous sampling. The hydrophones were spaces between 2.5 and 3.5 miles apart. The spacing was chosen to allow time-difference of arrival and back propagation methods to be employed for localization purposes. The locations were chosen to focus the listening capacity of the array towards GoA, while staying in shallow waters of less than 150m depth (Table 6).

Time synchronization is achieved by clapping close to all sensors before deployment and after retrieving (Fig. 19).

CTD Casts

To better understand the physical oceanography and habitats within the GoC, conductivity, temperature and depth (CTD) measurements will be made throughout the cruise. CTD data is used to create both chemical and physical attribute profiles of the water column. These data provide insight into biological systems, including where blue whale prey may aggregate or occur in high abundance.

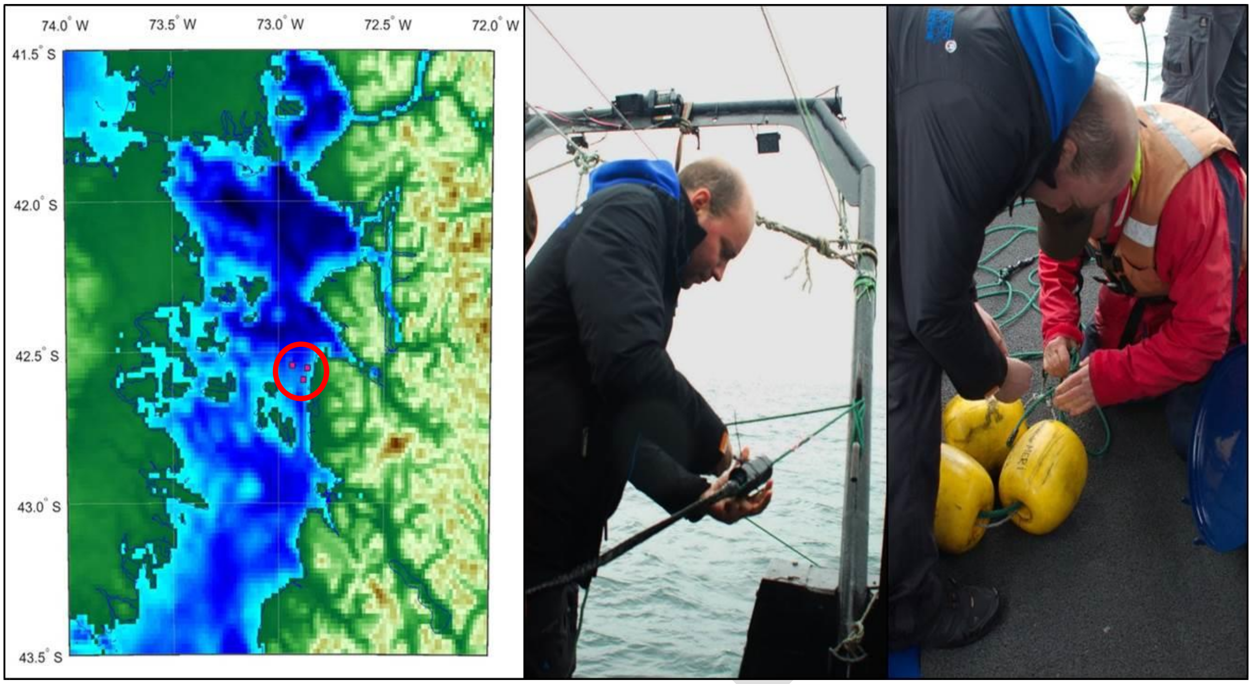

Figure 7. Location map of the PAM array in the Gulf of Ancud and preparation of a SoundTrap shallow water mooring.

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RESULTS

Field Effort

A 15 day cruise was completed (19th February to 5th March 2017), departing from the port of Dalcahue, Chiloé Island, Chile. Based on survey results from the previous three years, search effort aimed to focus within the north eastern region of the GoC (Chaitén, Islote Nihuel and Chumilden) and eastern side of the Gulf of Ancud. Historic blue whale habitat use areas (Melinka, Melimoyu and Tic Toc), would be surveyed if whales were absent in the northern areas. Over the 15 survey days the vessel travelled 1121 nm, during 195 hours of 'on effort' surveying (Fig. 8).

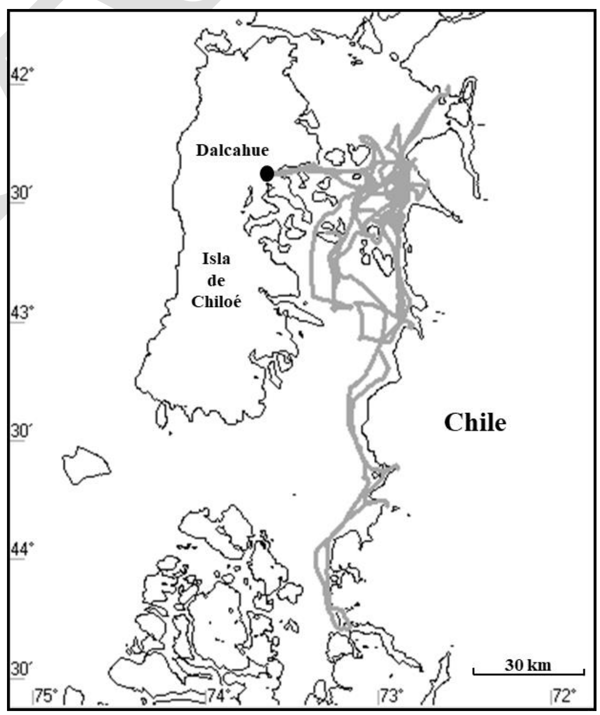

Figure 8. The study area and grey vessel track of the RV Khronos, indicating where the research effort was conducted.

The cruise was hampered by unseasonal bad weather. Unlike previous years, thick fog was repeatedly encountered, preventing effective visual searching for animals. Efforts were made to co-ordinate with other vessels and operators using the GoC to find blue whales during the cruise. A combination of foggy conditions and apparent lack of whales using the GoC at the time of the cruise, resulted in far less blue whale encounters and thus research opportunities than the team has experienced in past cruises.

The survey effort resulted in 282 sightings of seven mammal species, with sightings being made on each of the 15 survey days (Table 1). 86 % (n = 241) of all sighting were of two otariid species, the South American fur seal (*Arctocephalus australis*) and the South American sea lion (*Otaria flavescens*)(Table 1).

Five different cetacean species were recorded, with blue whales comprising 51 % of the 42 cetacean sightings (Table 1). Killer whales (*Orcinus orca*) were recorded and photo documented for the first time during the 2017 cruise, having been briefly observed but not photographed in 2014.

Scientific Name	Common Name (Spanish)	Common Name (English)	Number of Sightings	Mean Group Size, SD (Range)
Arctocephalus australis	Lobo fino	South American fur seal	122	1.6, 1 (1 – 7)
Balaenoptera musculus	Ballena azul	Blue whale	21	1.1, 0.3 (1 – 2)
Lagenorhynchus australis	Delfín austral	Peale´s dolphin	11	3.4, 2 (1 – 8)
Megaptera novaeanglinae	Ballena Jorobada	Humpback whale	3	1.3, 0.6 (1 – 2)
Otaria flavescens	Lobo marino	South American sea lion	119	3.5, 19.2 (1 – 200)
Orcinus orca	Orca	Killer whale	3	3, 0 (3)
Phocoena spinipinnis	Marsopa espinosa	Burmeister's porpoise	3	1.3, 0.6 (1 – 2)

Table 1. Table of mammal species recorded, with the number of sightings per species, mean group size, standard deviation and ranges.

Photo-identification

1876 photo-identification images were taken of three cetacean species during 13 encounters (Table 2). Nine blue whale groups containing either one or two individuals were photo documented between the 20th February and 04th March (Tables 2 and 3)(Appendix I). Eight individual blue whales were photo-identified, six of which were new whales (Table 3). Two blue whales were resights from previous years, one (Bm012) was first identified in 2015 and one animal, Bm003 has previously been observed in 2014 and 2015 (Appendix I). Two of the 2017 photo-identified whales (Bm071 and Bm074), were observed on two different survey days, the

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remaining six were only seen once.

Scientific Name	Common Name	Number of Photo-ID Encounters
Balaenoptera musculus	Blue whale	9
Megaptera novaeanglinae	Humpback whale	3
Orcinus orca	Killer whale	1

Table 2. Marine mammal species documented using photo-identification, with the number of encounters per species.

Two different humpback whales were encountered on three separate occasions, twice as single individuals and once as a pair together. Both animals were new individuals, increasing the MERI humpback whale photo-ID catalogue to 14 individuals (Appendix II).

Date	EncSeq	Latitude	Longitude	Time (local)	Group Size	ID's	Age Class
20-Feb-17	1	-42.42238	-72.80046	7:29	1	Bm071	Adult
25-Feb-17	1	-42.45093	-73.10140	11:48	1	Bm072	Adult
26-Feb-17	1	-42.86340	-73.26015	17:52	1	Bm073	Adult
27-Feb-17	2	-42.43974	-73.10854	18:10	1	Bm071(B)	Adult
27-Feb-17	3	-42.37240	-73.08643	20:42	1	Bm003	Adult
01-Mar-17	1	-42.46190	-72.94819	13:04	2	Bm012(T) Bm074	Adult Adult
02-Mar-17	1	-42.47896	-72.92226	16:52	1	Bm075	Adult
03-Mar-17	1	-42.40131	-72.82657	13:25	2	Bm012 Bm076	Adult Adult
04-Mar-17	1	-42.32797	-72.86086	7:35	1	Bm074(T)(B)	Adult

Table 3. Blue whale encounter and photo-identification summaries. (T) = tagged with a DTAG and (B) = animal was biopsied.

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For the first time during one of the blue whale cruises, killer whales were photographed. Killer whales have been reported to the team as being present in the GoC, and the MERI team collected their first photo-identification images during an encounter with five animals on the 22nd October 2016. The animals appear to be 'Type A' killer whales and the group was comprised of two adult females, one adult male, one sub-adult and one calf (Appendix III). On the 27th February 2017, a group of three killer whales, again appearing to be 'Type A' animals, were observed during the cruise (Fig. 9) (Appendix III). Two adult females and one calf were documented and the animals were seen to make 7-9 minute dives, logging and resting at the surface between dives. This may suggest deep water foraging for fish species, but no clear evidence was collected.

Figure 9. An adult female killer whale observed during the 2017 cruise.

DTAG Study

During the cruise two different adult blue whales (Bm012 and Bm074) were tagged using the DTAG. These deployments resulted in the collection of 3 hours and 14 minutes of tag data (Table 4). The short deployment durations were due, in part, to both tagged individuals sloughing large amounts of skin at the time of tagging (Fig. 11). Although the amount of data collected was considerably less than in previous years, the data are unique, allowing the first comparisons of data collected from the same individual (Bm012) in different years (2015 and 2017).

As in 2016, evidence of shifts in foraging dive depths, indicate a response to the abundance and vertical migration of prey appeared (Fig 10). Importantly, during both the 2017 DTAG deployments, detailed prey mapping was achieved. This will contribute greatly to the dataset collected in 2016, providing further insight into the relationship between whale foraging and the behavior and abundance of prey (Fig. 16, 17 & 18).

Date	Animal ID	Age Class	Deployment ID	Deployment Duration (Hr:min)	Deployment Time (local)	Deployment Location
01-Mar-2017	Bm012	Adult	bm17_060a	0 hr 22 min	15:49	-42.42792 -72.90378
04-Mar-2017	Bm074	Adult	bm17_063a	1 hr 35 min	09:26	-42.34740 -72.83002
04-Mar-2017	Bm074	Adult	bm16_063b	1 hr 17 min	12:28	-42.35681 -72.84677

Table 4. Blue whale DTAG deployment summaries.

DTAG Acoustic Data Analysis

DTAG data continue to be analyzed at WHOI, led by Laela Sayigh. See 'Impact and Future Work' section below.

Genetic Samples

Four genetic samples were collected from blue whales in 2017, two biopsies and two sloughed skin samples collected from tagged animals (Fig. 11) (Table 5). These four samples were collected from three different individuals. Genetic material (DTAG skin sample) was collected from Bm012 on 19 February 2015 and again during this field effort.

Figure 11. Sloughed skin samples in the suction cups of the DTAG (left), were collected and stored in RNAlater

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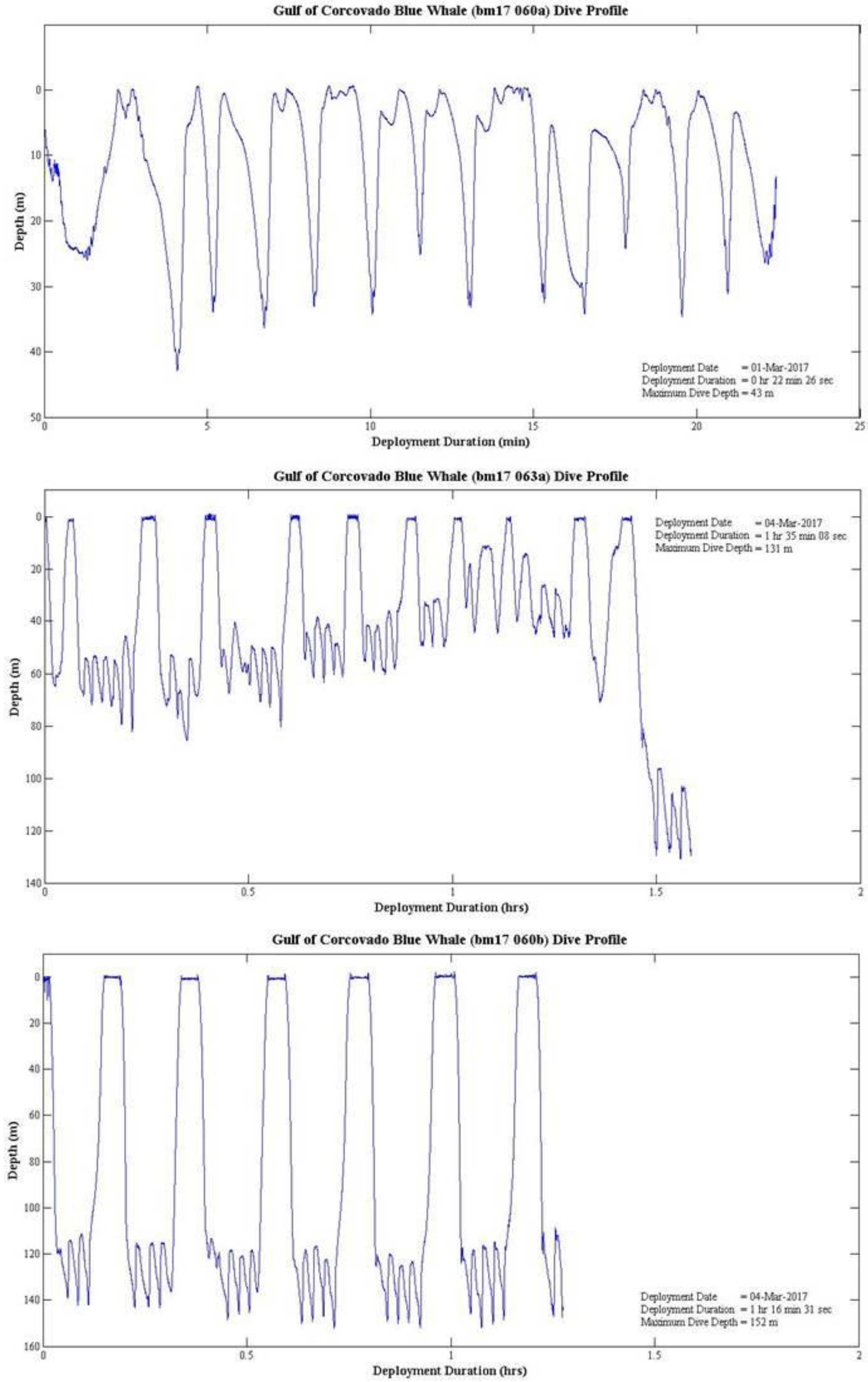

Figure 10. Dive profiles of the two tagged blue whales. Bm074 was tagged twice (bm17_060a/b). Note the difference in diving behavior of the same whale. Deployment duration in hours (x axis) and dive depth in meters (y axis).

Analysis of repeat samples such as these, will allow comparisons to be made about the health of individuals over time. All genetic samples are currently being stored in a -80° freezer at the Andrés Bello National University, Santiago, Chile. Paulina Bahamonde is currently working to establish effective techniques to process the samples as part of a MERI biomagnification and Persistent Organic Pollutants (POPs) investigation. Bahamonde has established an analysis protocol and successfully extracted DNA from the samples. During this process, phenol contamination occurred and 'clean up' protocols are being tested and verified that will allow robust polymerase chain reaction (PCR) DNA amplification to be undertaken.

Twelve genetic samples collected in 2015 were sent to the USA to contribute to a global stock structure assessment. These samples are still in the process of being analyzed in a collaborative partnership between Aimee Lang at the National Oceanographic and Atmospheric Administration (NOAA) and MERI.

Date Collected	Sample Number/ID	Species	Animal ID	Collection Method	Latitude (SOUTH)	Longitude (WEST)
27-Feb-2017	BM20172702_01	*B. musculus*	Bm071	Biopsy	-42.43841	-73.11473
01-Mar-2017	BM20170103_02	*B. musculus*	Bm012	DTAG skin sample	-42.41477	-72.90378
04-Mar-2017	BM20170403_03	*B. musculus*	Bm074	Biopsy	-42.35213	-72.86201
04-Mar-2017	BM20170403_03b	*B. musculus*	Bm074	DTAG skin sample	-42.35147	-72.83577

Table 5. Summary information of the collected genetic samples.

Prey Mapping

The horizontal resolution of the system was dependent on ship speed (typically 5 kts or less) but averaged approximately 2 m between pings. Data were collected on 10 days of the cruise with bad weather preventing data collection on Feb 20, 22, 28, and March 05. A total of 140 km of acoustic survey were conducted. Extended prey mapping was done during focal follows of tagged blue whales, however prey mapping also occurred as often as possible while searching for blue whales during the 2017 field season. Acoustic survey data were collected over a much broader area than in 2016, as well as in regions sampled in 2016 to allow for interannual comparisons (Fig. 12).

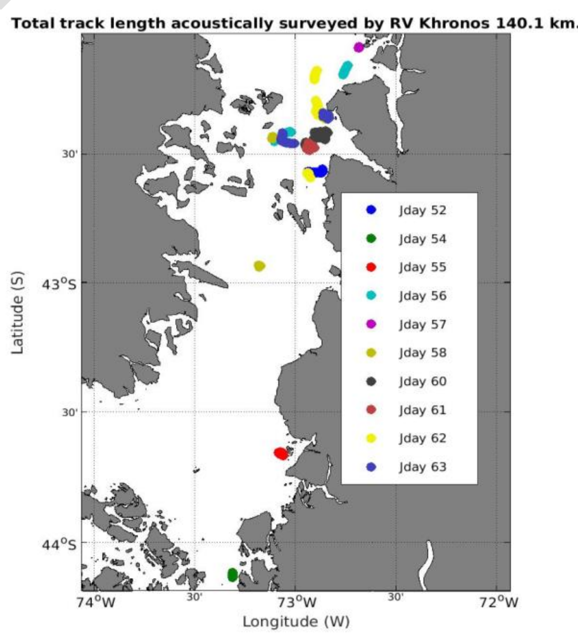

Figure 12. Cruise tracks showing where acoustic prey mapping survey data were collected.

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Fish and zooplankton could be identified by their respective scattering characteristics with fish schools scattering more strongly at 38 kHz, and zooplankton scattering more at 200 kHz.

Fish schools were typically located in dense aggregations very near (within 10 m) of the sea floor or in less dense aggregations in the middle of the water column (Fig. 13a). Zooplankton aggregations were found in the bottom half of the water column (during daytime hours), typically in a thick layer between 40 and 100 m depth (Fig. 13b). There was spatial variability in the thickness and intensity of the zooplankton aggregations.

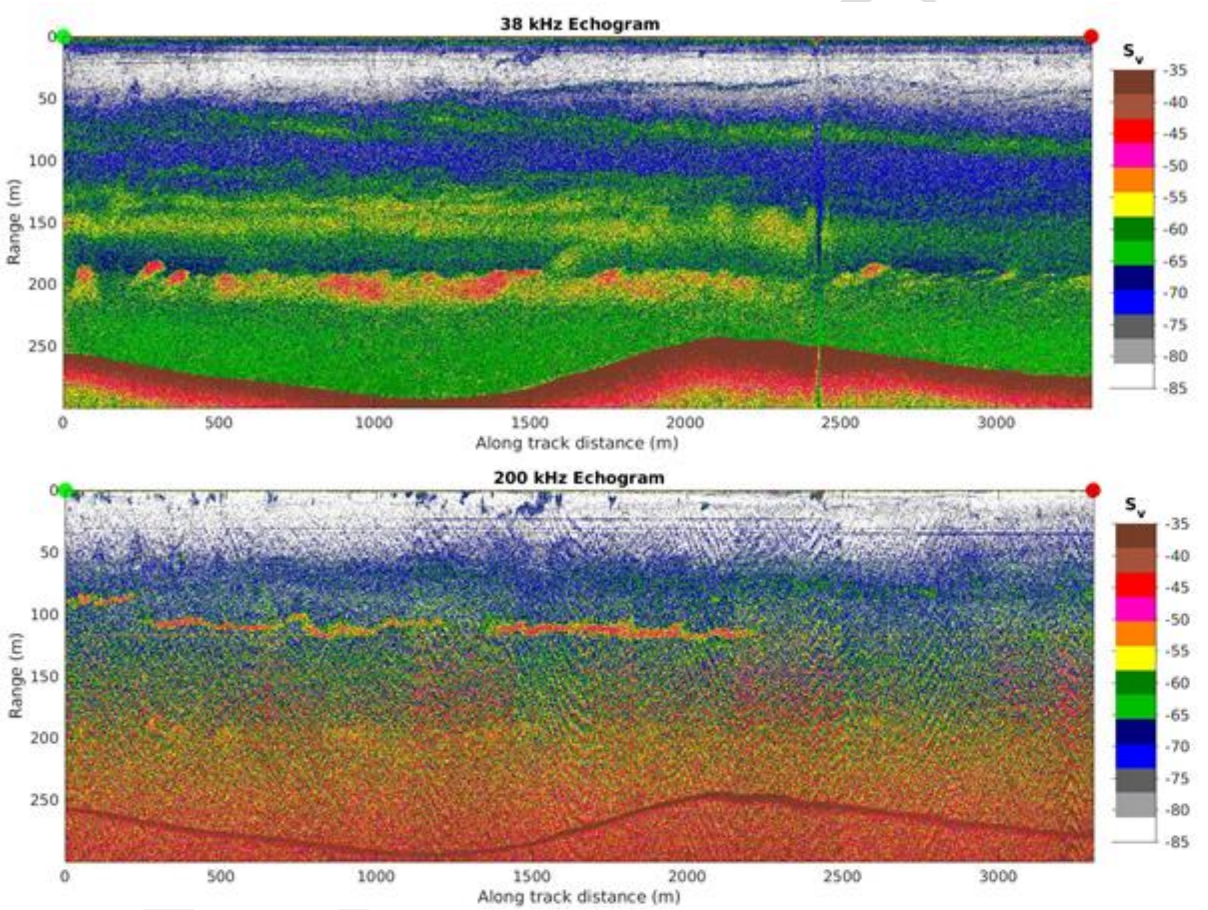

Figure 13. Echograms showing backscatter at 38 (top) and 200 (bottom) kHz. The x and y axes are distance and depth respectively. White and blue colors represent less backscatter with yellows and red colors representing stronger scattering. Krill aggregations are clearly seen in the 200 kHz echogram (bottom) as the thin yellow and red layer near 100 m depth. Fish aggregations can be seen in the 38 kHz echogram (but only faintly in the 200 kHz echogram) as patches or layers at a depth of ~ 200 m. The dark red/brown line at ~ 250 m is the seafloor.

Prey Sampling

Prey sampling trawls were conducted to compliment the prey mapping. Net tows and the CATS tag videos revealed zooplankton were primarily euphausiids (krill), although some amphipods were also caught. Net catch samples were photographed for identification and measurement post-cruise (Fig. 15). Fish species present were noted from records provided by fisherman in the area and included rockfish, cero, and other bottom-associated fish. Krill and other zooplankton samples are being analyzed (Chiang) to determine levels of nitrogen and carbon stable isotopes, mercury and organic pollutants.

Preliminary examination of the data found that although fish and zooplankton aggregations were present in some regions, but aggregations of krill were not as prevalent in the Gulf in 2017 relative to 2016 (analysis is ongoing). One of the few times that krill were abundant in the water column was during the focal follow of the DTAG-ed blue whale on 04 March 2017 (Figure 14). We are currently processing the DTAG data so that further comparisons between whale movement and prey distribution can be made.

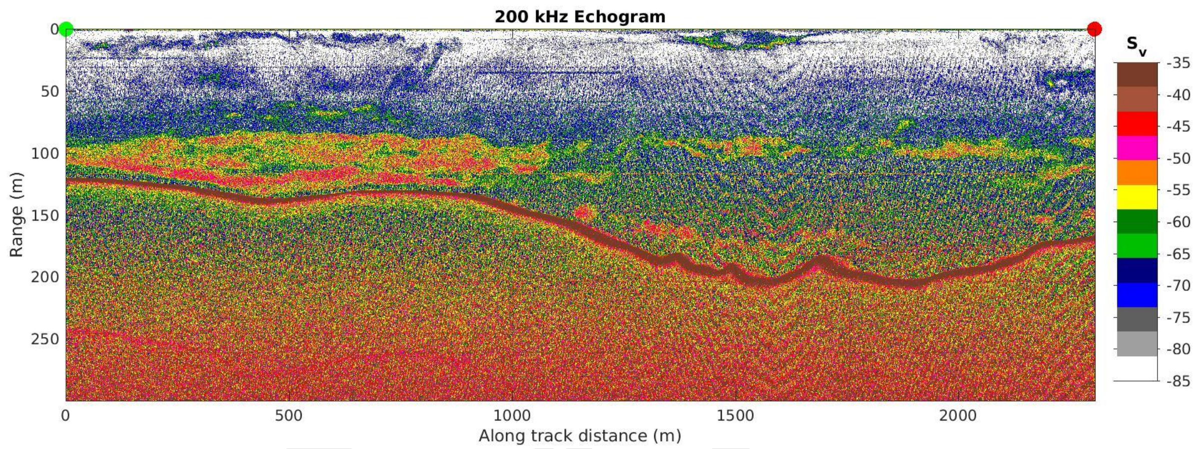

Figure 14. Echogram (200 kHz) showing a large near bottom aggregation of scatterers (depth 80 to 120 m, 0 to 1000 m along track distance) which are likely krill. The blue whale remained in this region for several hours and exhibited behavior indicative of feeding.

Net tows were conducted to identify the acoustic scatterers. The zooplankton were primarily euphausiids (krill), although some amphipods and salps were also caught. Net catch samples were photographed for identification and measurement post-cruise (Figure 15).

Figure 15. Euphausiids (krill) were the dominant zooplankton caught in net tows on March 1st and 4th (left), while a net tow on March 3rd was dominated by salps, a gelatinous zooplankton.

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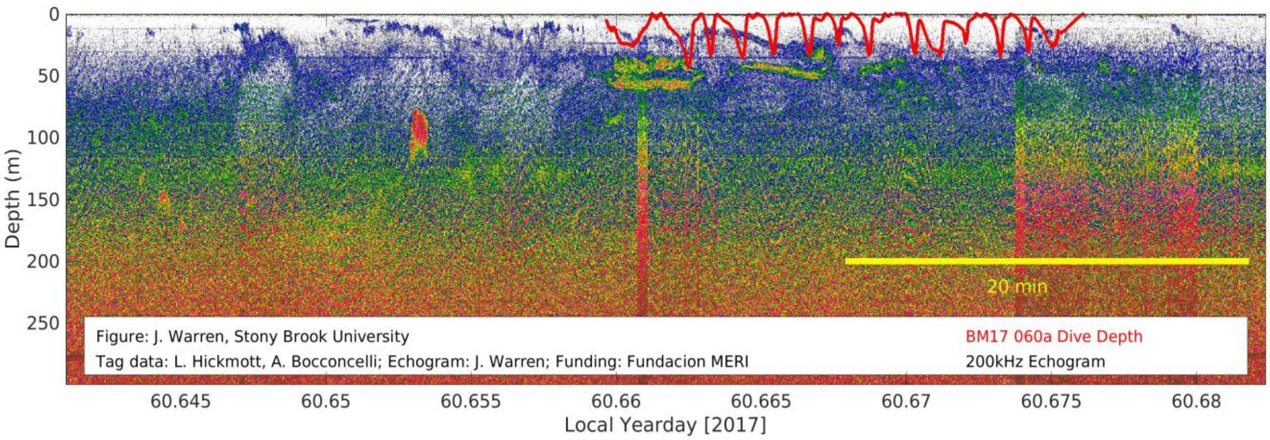

Figure 16. DTAG deployed on 01 March 2017 (BM17 060a) dove shallow (~ 50 m) several times before the tag came off. There was little krill present at this time, but the layers that were present were at a similar depth.

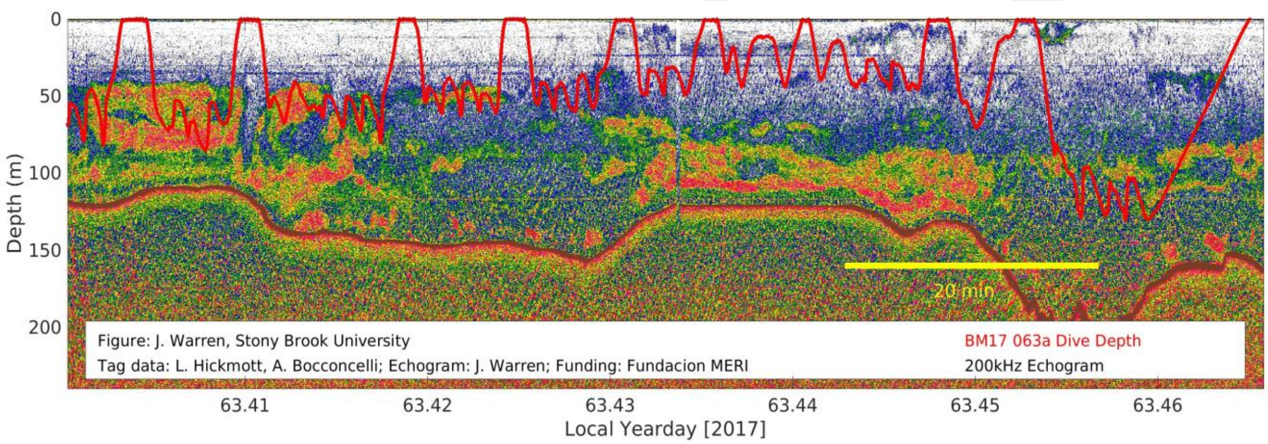

Figure 17. DTAG deployed on 04 March 2017 (BM17 063a) dove shallow (~ 50-100 m) multiple times and then shifted to a deeper dive profile (depths between 100-150m) which continued into the next tag deployment on this whale (Figure 16). Krill distributions varied greatly spatially during these two deployments – the seafloor was shallower during 063a than in 063b, as were the krill aggregations.

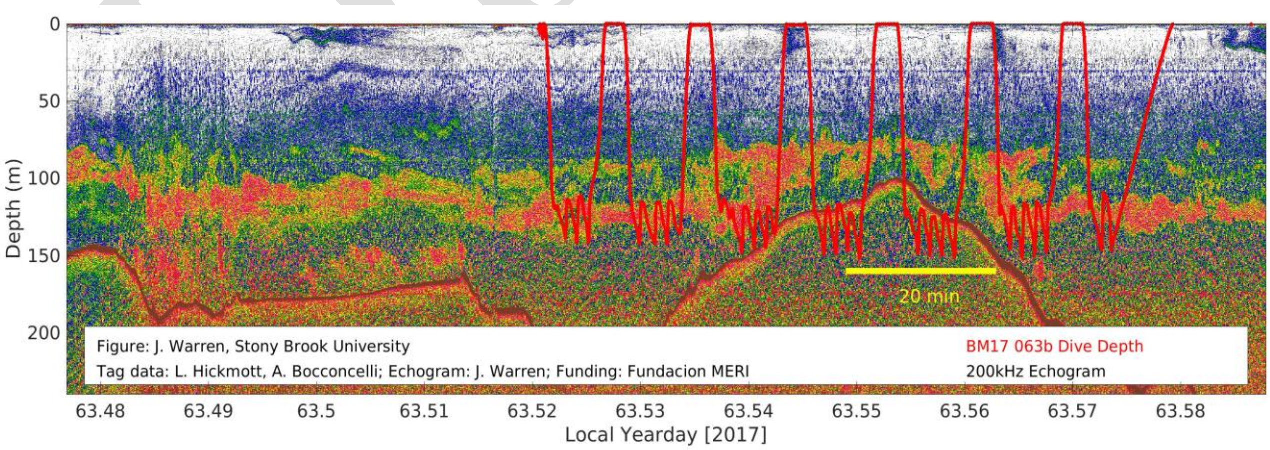

Figure 18. DTAG deployed on 04 March 2017 (BM17 060b) dove much deeper than a few hours earlier (Figure 15). There were large aggregations of krill present at depths greater than 150 m. It should be noted that the prey mapping was not co-located with the whale so the whale did not dive below the seafloor as the red lines suggest in this image.

Integrating Prey & DTAG Data

For the three DTAGs that were deployed, there is good agreement with the depths that the whales dived to and the abundance of krill at those depths as measured by backscatter at 200 kHz. Echograms overlaid with dive profiles are shown for the three tag deployments (Figures 16-18).

CATS Tag & Aerial Photogrammetry

Due to a combination of poor weather (predominately thick fog) and a lack of whales, only one CATS tag deployment was attempted. Unfortunately, the attempt was unsuccessful because the tag was not aligned properly with the whale and the suction cups did not stick. Twelve drone flights were made attempting to take aerial photographs. The cruise provided invaluable field time for Paolo Segre to hone both tagging and drone flight skills. The Stanford University laboratory team is new to quadcopter photogrammetry and therefore, although the photographs collected were ultimately not useful for taking measurements, the flights provided valuable troubleshooting experience.

Passive Acoustic Monitoring

Acoustic Data

Unfortunately, only three of the four SoundTrap's could be retrieved. One mooring could not be found and it is suspected to have been stolen. The three recovered instruments performed without malfunction and recorded data throughout the deployment, collecting a total of 715 hours of passive acoustic data (Table 6). Due to the deployment area near the freshwater sound duct channel, the tide induced currents are strong.

Sound Trap ID	Serial Number	Latitude	Longitude	Water depth (m)	Deployed (UTC)	Recovered (UTC)	Total Data (hrs)	Calibration (db)
7	1543524389	-42.59199	-72.88163	120	20170221 17:31	20170302 16:46	238.5	171.9
8	1543807013	-42.54475	-72.93403	114	20170221 18:42	20170302 12:42	238.5	171.2
9	1543565350	-42.55307	-72.86155	122	20170221 20:18	20170302 15:23	238.5	171.5
M2	1678508058	-42.57388	-72.93625	120	20170221 21:34	Not recovered	-	

Table 6. Passive acoustic array deployment summary.

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As the moorings were designed with surface expression for manual retrieval, tidal currents induce drag and therefore low frequency strumming noise. Time-drift correction is applied using the synchronization pulses that were conducted before deployment and recovery (Figure 19). Nonetheless, a first review of the data revealed numerous SEP and down sweep calls of sufficient quality to be localized using time difference of arrival methods (Fig. 20 and 21).

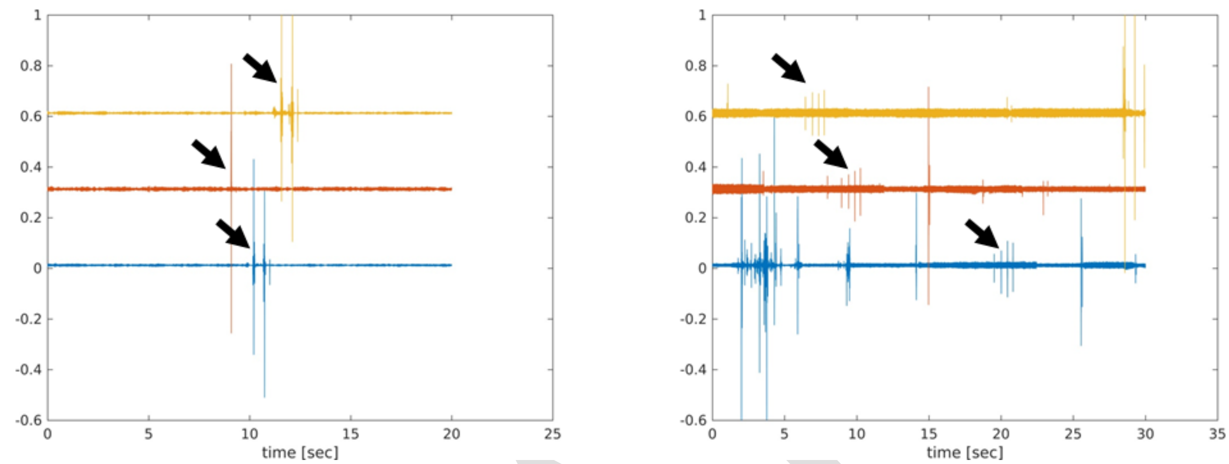

Figure 19. Time synchronization using clapping before (left) and after (right) of deployment. Arrows indicate claps; precise timing will be obtained by signal cross correlation and subsequent sample dropping.

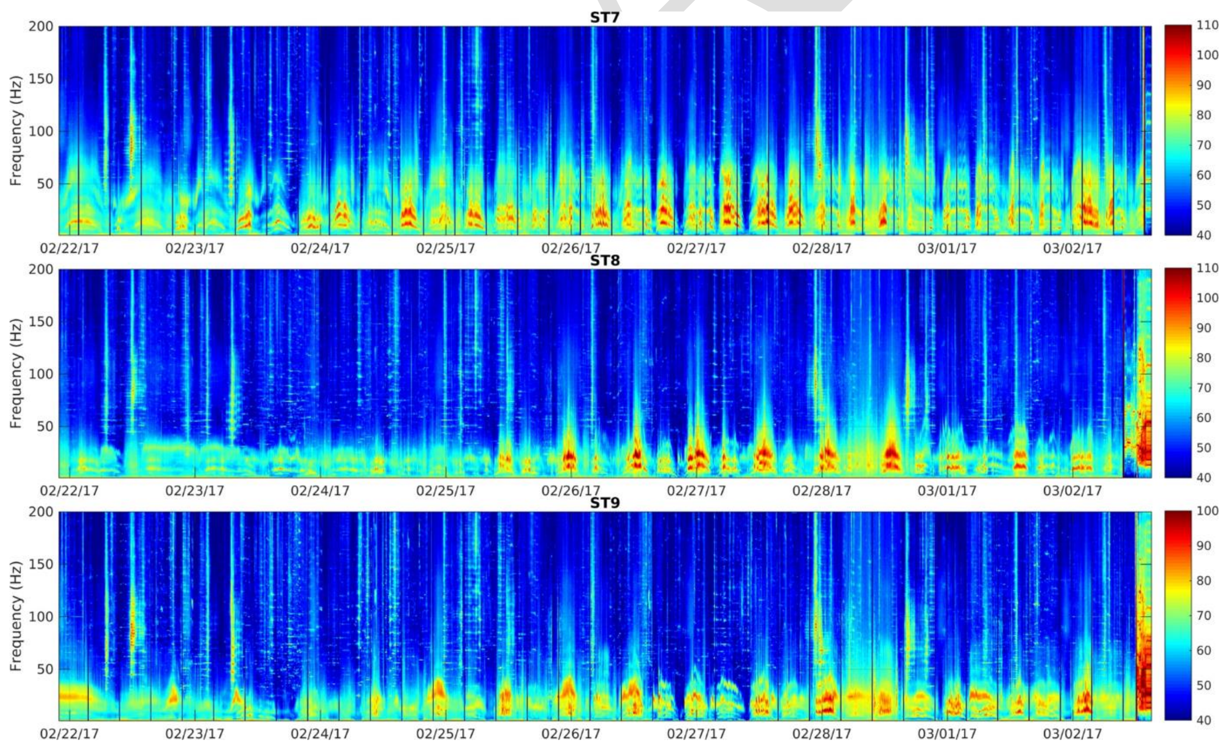

Figure 20. Long-term spectral average shows tidal currents induced low frequency noise.

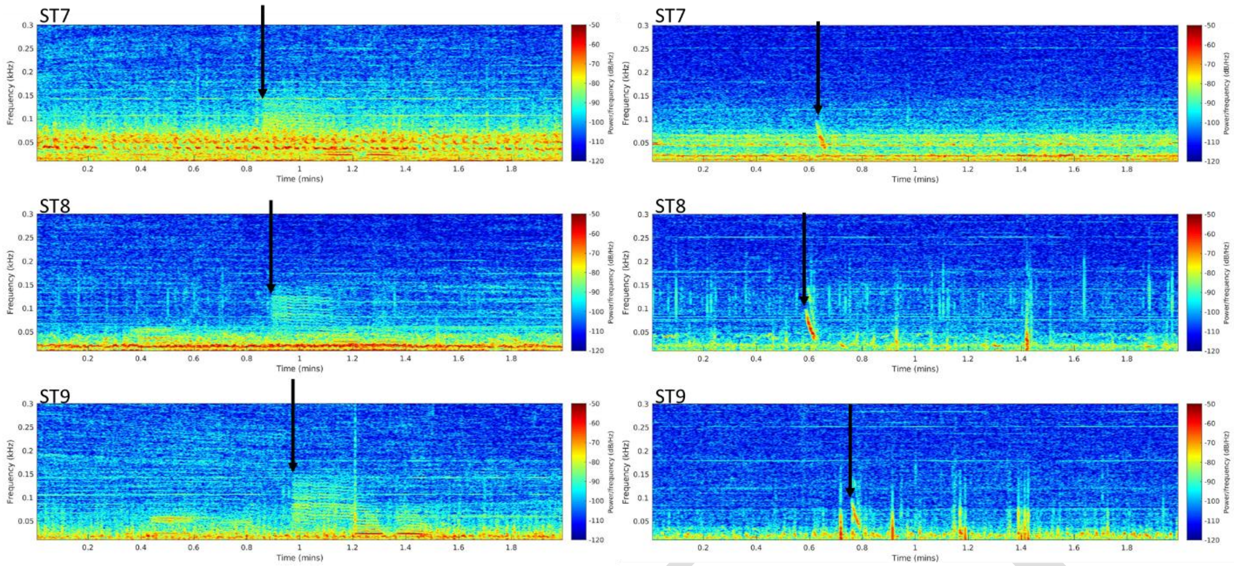

Figure 21. SEP (left) and down sweep (right) calls that were detected on all three hydrophones (top to bottom).

Localization

It was possible to successfully localize whales within the dataset (an example is shown in Fig 22). Within a three hour time period, eight blue whale SEP calls were localized using a time-different of arrival approach. Two tracks of calls in close proximity to one another, indicates that calls within each track come from the same animal. It cannot be distinguished if the two tracks originate from one animal or two. Calls were marked manually and their time-differences obtained by signal cross correlation. Using transmission loss from the calibrated acoustic receivers of the localized calls, it is possible to estimate that with an array deployed in this location, detection of blue whales should be possible at least 40km distance (Fig. 23). This would provide coverage of approximately half of the GoA. High-precision clocks on the acoustic

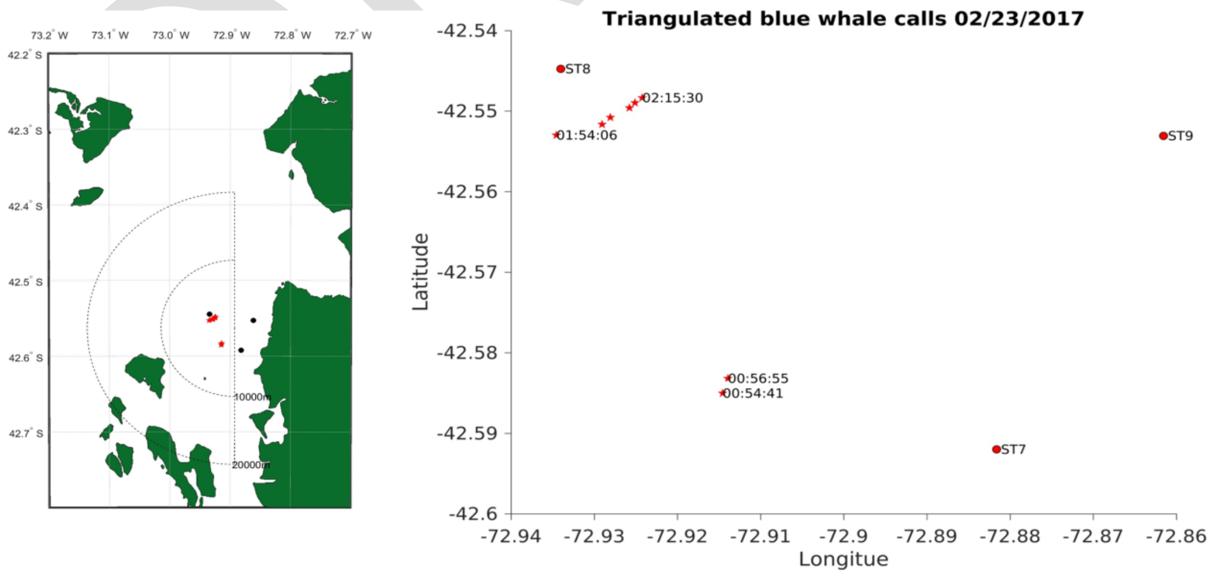

Figure 22. Localized calls in the array context (left). Tracks of two localized whales on February 23rd (right).

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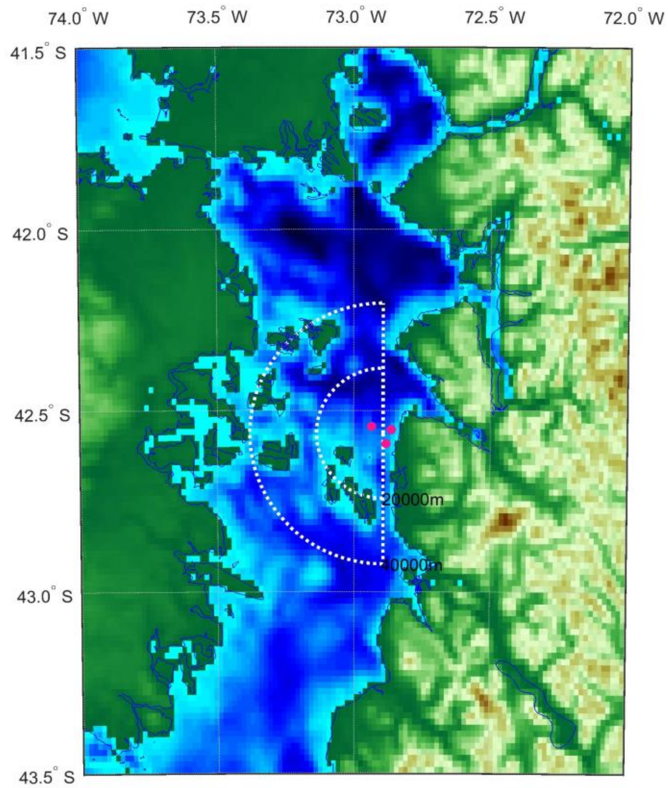

Figure 23. Transmission loss within the passive acoustic array indicated that localization of blue whale SEP calls should be achievable within at least 40km distance.

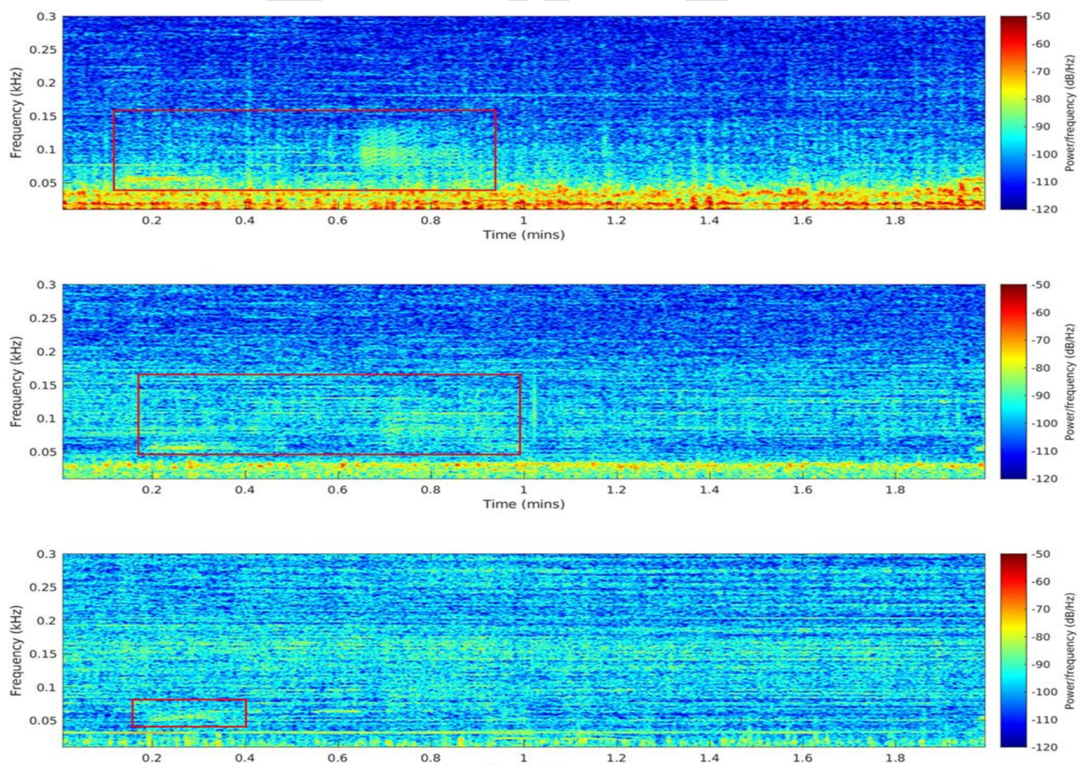

Figure 24. Visual detection of SEP calls to analyze acoustic presence.

recorders, as well as low-noise bottom mounted receivers are necessary to achieve these localization capabilities.

Acoustic Presence

We analyzed the acoustic presence of blue whale SEP calls within the passive acoustic monitoring data. Acoustic data was displayed in 2 min long spectrograms and a human analyst decided whether a SEP call was present or absent (Fig. 24). Blue whale SEP calls were present in 8.8% of the 2 min bins (Fig. 25). Calls were present each day of the field season, in varying occurrence (Fig. 26), clearly showing that whales were in the area, even if they could not be detected visually. An hourly analysis revealed that most calls were detected during the night. This might arise due to higher call density during the night, or due to lower background noise and therefore higher detection probability. A noise analysis will reveal diurnal noise patterns.

Figure 24. SEP calls were present in 8.8% of all 2 min bins.

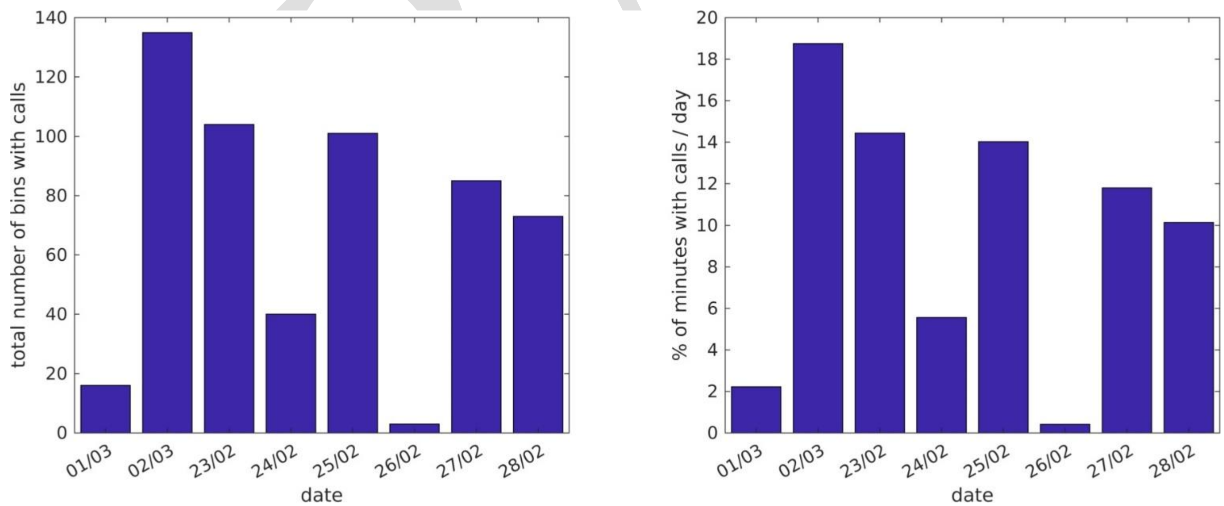

Figure 25. SEP calls were present each day in varying occurrence. Less calls during one day cannot be interpreted as low whale density, because call occurrence has not been corrected for background noise yet.

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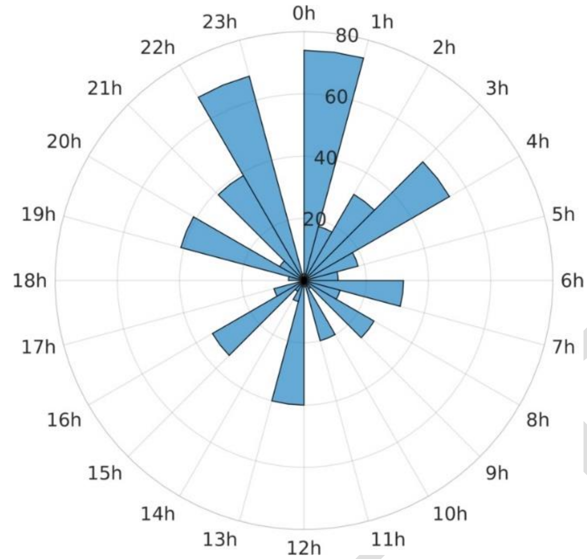

Figure 26. Increased call density during the night-time, might occur due to higher vocal activity or less ambient noise due to less ship traffic.

CTD Casts

Ten CTD casts were made during the cruise between the 19 and 26 February (Fig. 27) (See Appendix IV for location data). CTD casts were made in different areas of the GoC, with a focus on areas where blue whales were found feeding. These data are being analyzed by a team led by Gustavo Chiang to better understand the ecology of the GoC and blue whale prey distribution within it.

Hummingbird Research

The multi-disciplinary team that gathers for the GoC cruises, share a diverse research background and skillset, always alert to research opportunities that may arise during the field effort. During the 2017 cruise, one such research opportunity arose. Paolo Segre's doctoral research focused on kinematics of new world hummingbirds and this background knowledge led to an interesting discovery in 2017. While transiting south through the Gulf of Corcovado repeated sightings of Green-backed Firecrown's (*Sephanoides sephanoides*) approaching the boat were observed: an unusual behavior for hummingbirds. On the northward return trip from Melimoyu sightings of hummingbirds, along with GPS coordinates and direction of travel were recorded (Fig. 28). Over 30 offshore hummingbird sightings ranging

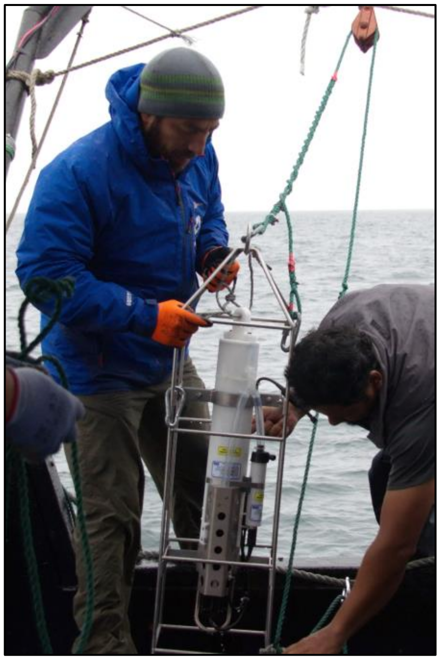

Figure 27. Team members prepare to deploy the CTD.

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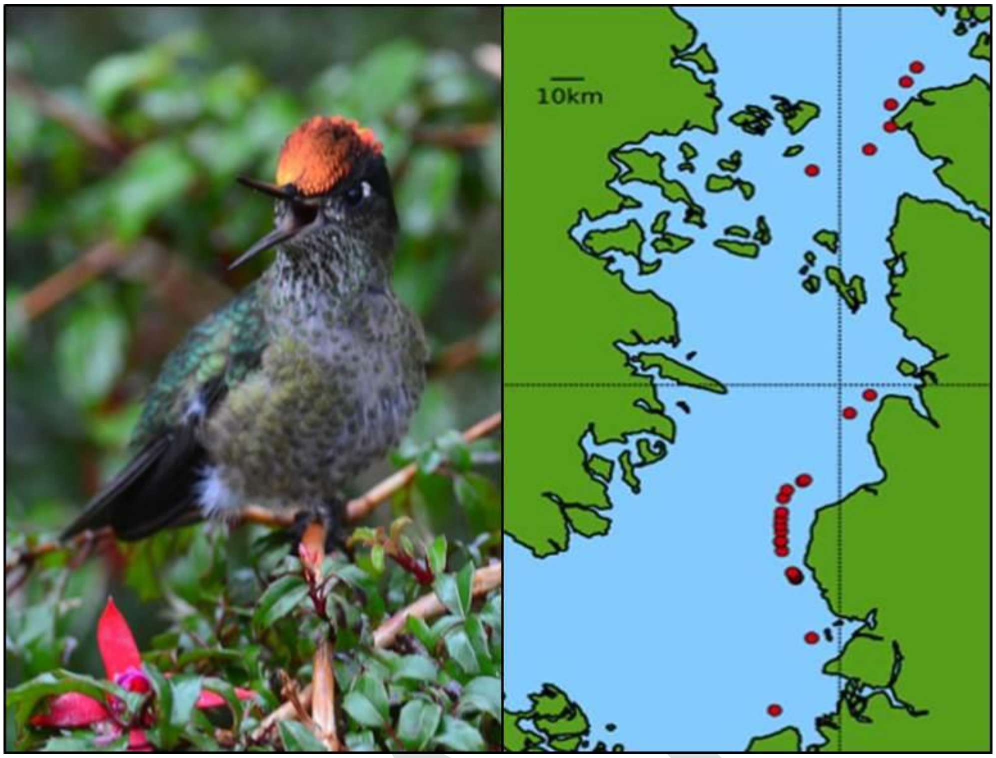

Figure 28. A male Green-backed Firecrown in the Melimoyu Nature Reserve and Green-backed firecrown hummingbird sightings recorded in the Gulf of Corcovado, between February 23 and February 28, 2017. Photo courtesy of Alex Machuca.

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from 1-12 km to the nearest land were documented. Few hummingbird species are known to make extended flights over the ocean and little is known about the dispersal, migration, and connectivity between populations of the Green-backed Firecrown.

The discovery that the Green-backed Firecrown makes long distance flights over open water is of interest to the ornithological community and will be publishable as a naturalist note in an ornithology specific journal.

Impact and Future Work

Despite the poor weather and small number of blue whale encounters, the cruise was a success. Since research efforts began in 2014, the team and their collaborators have generated more than 20 research publications and presentations relating to the blue whales of the GoC. This high level scientific output has brought the science and knowledge gained during the past four years of study in the GoC to a large and diverse audience.

Analysis and publication of data is ongoing, which in turn is leading to new collaborations and plans for further research in the GoC.

Research Output

Published Research Papers - 2017

Mark R. Saddler, Alessandro Bocconcelli, Leigh S. Hickmott, Gustavo Chiang, Rafaela Landea-Briones, Paulina A. Bahamonde, Gloria Howes, Paolo S. Segre, Laela S. Sayigh. Characterizing Chilean blue whale vocalizations with DTAGs: a test of using tag accelerometers for caller identification. Journal of Experimental Biology 2017 : doi: 10.1242/jeb.151498

Published Research Papers - 2016

Bocconcelli, L. Hickmott, G. Chiang, P. Bahamonde, F. Caruso, M. Saddler, and L. Sayigh. 2016. Acoustic behavior of blue whales (*Balaenoptera musculus*) in the Gulf of Corcovado, Chile, recorded on DTAGs. Proceedings of Meetings on Acoustics 27, 040002 (2016); doi: http://dx.doi.org/10.1121/2.0000269.

Cade, D. E., Friedlaender, A. S., Calambokidis, J., & Goldbogen, J. A. (2016). Kinematic diversity in rorqual whale feeding mechanisms. Current Biology, 26(19), 2617-2624.

Colpaert, W., R. Landea-Briones, G. Chiang, and L. Sayigh. 2016. Blue whales of the Chiloe-Corcovado region, Chile: Potential for anthropogenic noise impacts. Proceedings of Meetings on Acoustics 27, 040009 (2016); doi: http://dx.doi.org/10.1121/2.0000304.

Durban, J. W., Moore, M. J., Chiang, G., Hickmott, L. S., Bocconcelli, A., Howes, G., Bahamonde, P. A., Perryman, W. L. and LeRoi, D. J. (2016), Photogrammetry of blue whales with an unmanned hexacopter. Mar Mam Sci, 32: 1510–1515. doi:10.1111/mms.12328

Research Papers in Review or Preparation- 2017

Ellen Jacobs, Maureen Duffy, Jessica Magolan, Barbara Galletti Vernazzani, Elsa Cabrera, Rafaela Landea, Susannah Buchan, Laela Sayigh. First Acoustic Recordings of Critically Endangered Eastern South Pacific Southern Right Whales (Eubalaena australis). In review at Marine Mammal Science.

Maureen Duffy, Megan Wood, Rafaela Landea Briones, Laela Sayigh. A new call type produced by Chilean blue whales in and around the Gulf of Corcovado, Chile. Paper in preparation, to be submitted to Marine Mammal Science in December 2017.

Wouter Colpaert, Walter Zimmer, Rafaela Landea-Briones, and Laela Sayigh. Potential effects of anthropogenic noise on blue whale calling behavior in the Chiloé-Corcovado region, Chile. Paper to be submitted to the Proceedings of the Royal Society B in December 2017

Goldbogen, J.A., Cade, D.E., Boersma A., Calambokidis, J., Kahane-Rapport, S., Segre, P.S., Stimpert. A.S., and A.S. Friedlander. Using digital tags with integrated video and inertial sensors to study moving morphology and associated behavior in large aquatic vertebrates. In review at Anatomical Review.

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Conference Presentations - 2017

Alessandro Bocconcelli, Leigh Hickmott, Gustavo Chiang, Rafaela Landea, Francesco Caruso, Paulina Bahamonde ,Gloria Howes, Paolo Segre, Daniel Zitterbart, Joseph Warren and Laela Sayigh. Blue whales (*Balaenoptera musculus*) behavior in the Chiloense Ecoregion of southern Chile, as recorded on digital acoustic tags. Aural Presentation at IMPAC 4 conference in La Serena, Chile, September 2017.

Alessandro Bocconcelli, Francesco Caruso, Laela Sayigh, Rafaela Landea-Briones, Gustavo Chiang, Paulina Bahamonde, Gloria Howes, Paolo Segre, Joe Warren, and Leigh Hickmott. Day and night diving behavior of blue whales (*Balaenoptera musculus*) in the Chiloense Ecoregion of southern Chile. Poster Presentation at the SMM Biennial Conference in Halifax, Canada, October 2017.

Maureen Duffy, Ellen Jacobs, Jessica Magolan, Rafaela Landea-Briones, Laela Sayigh. Diel patterns of blue whale (Balaenoptera musculus) D calls in the Corcovado Gulf, Chile. Poster presentation at the 22nd Biennial Conference on the Biology of Marine Mammals, Dalhousie, Nova Scotia, Oct 22-28 2017.

Goldbogen, J.A., Cade, D.E., Boersma A., Calambokidis, J., Kahane-Rapport, S., Segre, P.S., Stimpert. A.S., and A.S. Friedlander. Using digital tags with integrated video and inertial sensors to study moving morphology and associated behavior in large aquatic vertebrates. Aural presentation at the Biologging symposium, 22-27 September, Lake Constance, Germany, 2017.

Ellen Jacobs, Maureen Duffy, Jessica Magolan, Rafaela Landea-Briones, Elsa Cabrera, Barbara Galletti, Susannah Buchan, Laela Sayigh. First acoustic recordings of endangered Eastern South Pacific southern right whales (Eubalaena australis). Poster presentation at the 22nd Biennial Conference on the Biology of Marine Mammals, Dalhousie, Nova Scotia, Oct 22-28 2017.

M. Saddler, A. Bocconcelli, L.S. Hickmott, G. Chiang, R. Landea-Briones, P.A. Bahamonde, G. Howes, L.Sayigh. Characterizing Chilean blue whale vocalizations with digital acoustic recording tags: using tag accelerometers for caller identification. Poster presentation at the Acoustical Society of America meeting, 29 June 2017, held in Boston. Won the student award for best poster presentation in Animal Bioacoustics!

Laela Sayigh, Rafaela Landea-Briones, Maureen Duffy, Jessica Magolan, Ellen Jacobs, Megan Wood, Wouter Colpaert, Elsa Cabrera, Barbara Galletti. Passive acoustic monitoring provides insights into baleen whale occurrence and ecology in the Chiloense Ecoregion in southern Chile. Poster presentation at IMPAC4 conference, La Serena, Chile, September 4-8 2017

J. D. Warren and G. Chiang [presenter]. “A cost-effective, non-invasive method for identification of critical habitats of pelagic organisms (foraging “hot spots”) in the Golfo de Corcovado and Golfo de Ancud, Chile using fisheries echosounders.” . Aural presentation, 4th

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International Marine Protected Areas Congress (IMPAC4). La Serena-Coquimbo, Chile. Sep 2017.

J. D. Warren, G. Chiang, P. Segre, L. Hickmott, A. Bocconcelli, G. Howes, P. Bahamonde, and J. Goldbogen. “Blue whale (*Balaenoptera musculus*) foraging movements in the Gulf of Corcovado, Chile are closely related to the distribution and abundance of krill.” . Aural presentation, 22nd Biennial Conference on the Biology of Marine Mammals. Halifax, Canada. Oct 2017.

Conference Presentations - 2016

Bocconcelli, A., L. Hickmott, G. Chiang, P. Bahamonde, F. Caruso, M. Saddler, and L. Sayigh. 2016. Acoustic behavior of blue whales (*Balaenoptera musculus*) in the Gulf of Corcovado, Chile, recorded on DTAGs. Poster presentation at the Effects of Noise on Aquatic Life meeting, Dublin, Ireland, July 2016.

Colpaert, W., R. Landea-Briones, G. Chiang, and L. Sayigh. 2016. Blue whales of the Chiloe-Corcovado region, Chile: Potential for anthropogenic noise impacts. Poster presentation at the Effects of Noise on Aquatic Life meeting, Dublin, Ireland, July 2016.

Colpaert, W., W. Zimmer, R. Landea-Briones, G. Chiang, A. Bocconcelli, and L. Sayigh. 2016. Blue whales increase call rate in the presence of ship noise in the Chiloe-Corcovado region, Chile. Poster presentation at the European Cetacean Society meeting, Madeira, Portugal, March 2016.

Conference Presentations - 2015

Colpaert, W., W. Zimmer, A. Bocconcelli, R. Landea Briones, and L. Sayigh. 2015. Potential effects of anthropogenic noise on blue whale calling behavior in the Chiloé-Corcovado region, Chile. Poster presentation at the 21st Biennial Conference on the Biology of Marine Mammals, San Francisco, CA, 13-18 Dec 2015.

Wood, M. A. Bocconcelli, R. Landea Briones, and L. Sayigh. 2015. Seasonality and distribution of baleen whales in the Chiloe-Corcovado region, Chile, using passive acoustic monitoring. Poster presentation at the 21st Biennial Conference on the Biology of Marine Mammals, San Francisco, CA, 13-18 Dec 2015.

Colpaert, W., R. Landea Briones, and L. Sayigh. 2015. Anthropogenic noise and blue whales in the Chiloé-Corcovado region, Chile. Poster presentation at the Watkins Memorial Marine Mammal Bioacoustics Symposium, 27-29 March 2015.

Wood, M., A. Carroll, R. L. Briones, and L. Sayigh. 2015. Utilizing passive acoustic monitoring to study baleen whale diversity, distribution, and seasonality off the coast of Chile. Poster presentation at the Watkins Memorial Marine Mammal Bioacoustics Symposium, New Bedford, MA, March 2015.

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Public Lectures - 2017

L. Hickmott. Pole to Pole, Insights into Marine Mammal Research. Two presentations for Hampshire schools, November 2017.

L. Sayigh and A. Bocconcelli. Marine Mammals in Patagonia (Chile), at The New Bedford Whaling Museum, October 2017.

L. Sayigh and A. Bocconcelli. Marine Mammals in Patagonia (Chile), at the Martha's Vineyard Public library, October 2017.

L. Sayigh and A. Bocconcelli. Tagging Blue Whales in Patagonia, at the ElderHostel meeting, Falmouth, June 2017.

L. Sayigh and A. Bocconcelli. Blue whales in Patagonia, two presentations to students from Falmouth Public Schools, June 2017.

L. Sayigh and A. Bocconcelli. Marine mammals research in Patagonia, WHOI Museum visitors, Woods Hole, April 2017.

J. D. Warren - Public presentation on "Dining with the Leviathans of the Ocean" as part of the Nature Talks outreach series at Moustache Brewery, Riverhead, NY. 06 Oct 2017.

J. D. Warren - Public presentation on "Whales Around The World: Dining with the Leviathans of the Ocean" as part of the SoMAS Southampton Public Lecture Series. 03 Nov 2017.

Acknowledgments

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Appendix I

Photo-identification images of the 76 blue whales photo-identified between 2014 and 2017.

Chile14_Bm001 (Left Dorsal)

Chile14_Bm001 (Right Dorsal)

Chile14_Bm002 (Left Dorsal)

Chile14_Bm002 (Right Dorsal)

Chile15_Bm002 (Left Dorsal)

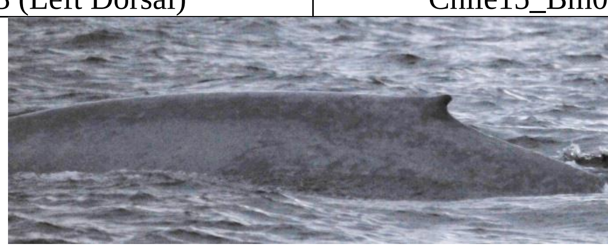
Chile15_Bm002 (Right Dorsal)

Chile14_Bm003 (Left Dorsal)

Chile14_Bm003 (Right Dorsal)

Chile15_Bm003 (Left Dorsal)

Chile15_Bm003 (Right Dorsal)

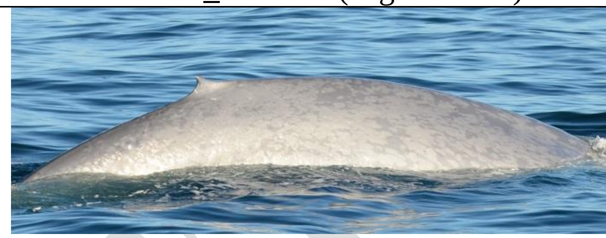


Chile17_Bm003 (Left Dorsal)

 Chile14_Bm004 (Left Dorsal)	 Chile14_Bm004 (Right Dorsal)
 Chile14_Bm005 (Left Dorsal)	 Chile14_Bm005 (Right Dorsal)
 Chile16_Bm005 (Left Dorsal)	 Chile16_Bm005 (Right Dorsal)
 Chile15_Bm006 (Left Dorsal)	 Chile15_Bm006 (Right Dorsal)
 Chile15_Bm007 (Right Dorsal)	
 Chile15_Bm008 (Left Dorsal)	 Chile15_Bm008 (Right Dorsal)

 Chile15_Bm009 (Left Dorsal)	 Chile15_Bm009 (Right Dorsal)
 Chile15_Bm010 (Left Dorsal)	 Chile15_Bm010 (Right Dorsal)
 Chile16_Bm010 (Right Dorsal)	
 Chile15_Bm011 (Left Dorsal)	 Chile15_Bm011 (Right Dorsal)
 Chile15_Bm012 (Left Dorsal)	 Chile15_Bm012 (Right Dorsal)
 Chile17_Bm012 (Left Dorsal)	 Chile17_Bm012 (Right Dorsal)

 Chile15_Bm013 (Left Dorsal)	 Chile15_Bm013 (Right Dorsal)
 Chile15_Bm014 (Left Dorsal)	 Chile15_Bm014 (Right Dorsal)
 Chile15_Bm015 (Left Dorsal)	 Chile15_Bm015 (Right Dorsal)
 Chile15_Bm016 (Left Dorsal)	 Chile15_Bm016 (Right Dorsal)
 Chile15_Bm017 (Left Dorsal)	 Chile15_Bm017 (Right Dorsal)
 Chile15_Bm018 (Left Dorsal)	 Chile15_Bm018 (Right Dorsal)

 Chile15_Bm019 (Left Dorsal)	 Chile15_Bm0019 (Right Dorsal)
 Chile16_Bm019 (Left Dorsal)	 Chile16_Bm0019 (Right Dorsal)
 Chile15_Bm020 (Left Dorsal)	 Chile15_Bm020 (Right Dorsal)
 Chile15_Bm021 (Left Dorsal)	 Chile15_Bm021 (Right Dorsal)
 Chile15_Bm022 (Left Dorsal)	 Chile15_Bm022 (Right Dorsal)
 Chile15_Bm023 (Left Dorsal)	 Chile15_Bm023 (Right Dorsal)


Chile15_Bm024 (Left Dorsal)


Chile15_Bm024 (Right Dorsal)


Chile15_Bm025 (Left Thorax)

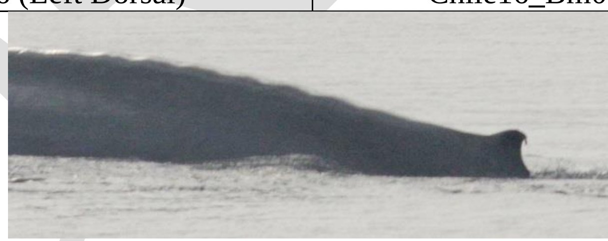

Chile15_Bm025 (Right Thorax)


Chile15_Bm026 (Left Dorsal)


Chile15_Bm026 (Right Dorsal)


Chile16_Bm026 (Left Dorsal)


Chile16_Bm026 (Right Dorsal)


Chile15_Bm027 (Left Dorsal)

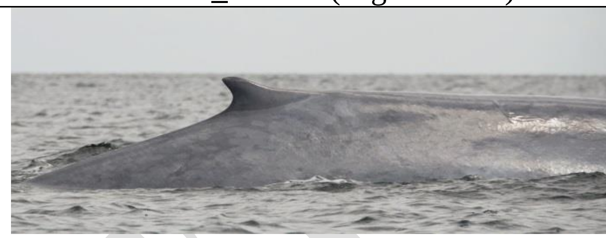

Chile15_Bm028 (Left Dorsal)


Chile15_Bm028 (Right Dorsal)


Chile15_Bm029 (Left Dorsal)


Chile15_Bm029 (Right Dorsal)


Chile16_Bm029 (Left Dorsal)


Chile16_Bm029 (Right Dorsal)

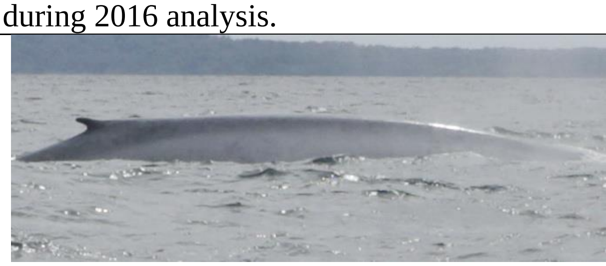

Chile15_Bm030 (Left Dorsal)


Chile15_Bm030 (Right Dorsal)


Chile15_Bm031 (Left Dorsal)


Chile15_Bm056 (Right Dorsal) misidentified as Bm021 during 2015 analysis. Assigned new number during 2016 analysis.


Chile16_Bm032 (Left Dorsal)


Chile16_Bm032 (Right Dorsal)


Chile16_Bm033 (Left Dorsal)


Chile16_Bm034 (Left Dorsal)


Chile16_Bm034 (Right Dorsal)


Chile16_Bm035 (Right Dorsal)


Chile16_Bm036 (Left Dorsal)


Chile16_Bm036 (Right Dorsal)


Chile16_Bm037 (Left Dorsal)


Chile16_Bm038 (Left Dorsal)

Chile16_Bm039 (Left Dorsal)

Chile16_Bm039 (Right Dorsal)

Chile16_Bm040 (Left Dorsal)

Chile16_Bm041 (Left Dorsal)

Chile16_Bm041 (Right Dorsal)

Chile16_Bm042 (Left Dorsal)

Chile16_Bm042 (Right Dorsal)

Chile16_Bm043 (Left Dorsal)

Chile16_Bm044 (Right Dorsal)

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Chile16_Bm045 (Left Dorsal)


Chile16_Bm045 (Right Dorsal)


Chile16_Bm046 (Left Dorsal)


Chile16_Bm046 (Right Dorsal)

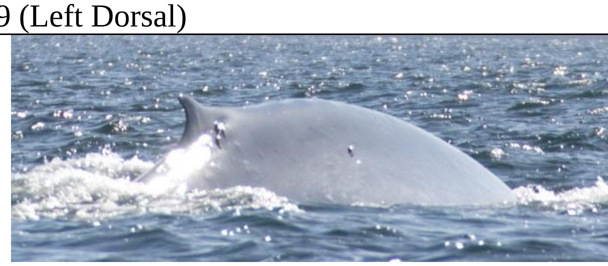

Chile16_Bm047 (Left Dorsal)


Chile16_Bm048 (Left Dorsal)


Chile16_Bm048 (Right Dorsal)


Chile16_Bm049 (Left Dorsal)


Chile16_Bm050 (Left Dorsal)


Chile16_Bm050 (Right Dorsal)

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Chile16_Bm051 (Left Dorsal)


Chile16_Bm052 (Left Dorsal)


Chile16_Bm052 (Right Dorsal)

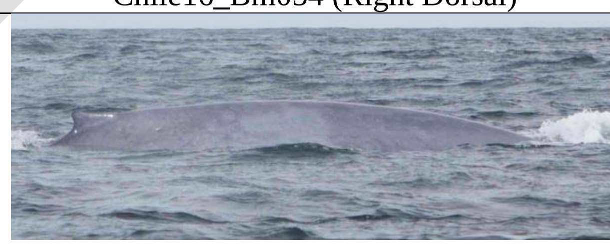

Chile16_Bm053 (Left Dorsal)


Chile16_Bm053 (Right Dorsal)


Chile16_Bm054 (Left Dorsal)


Chile16_Bm054 (Right Dorsal)


Chile16_Bm055 (Left Dorsal)


Chile16_Bm055 (Right Dorsal)


Chile16_Bm057 (Right Dorsal)

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Chile16_Bm058 (Left Dorsal)


Chile16_Bm058 (Right Dorsal)


Chile16_Bm059 (Left Dorsal)


Chile16_Bm059 (Right Dorsal)


Chile16_Bm060 (Left Dorsal)


Chile16_Bm060 (Right Dorsal)


Chile16_Bm061 (Left Dorsal)


Chile16_Bm062 (Left Dorsal)


Chile16_Bm063 (Right Dorsal)

Chile16_Bm064 (Right Dorsal)

Chile16_Bm065 (Left Dorsal)

Chile16_Bm065 (Right Dorsal)

Chile16_Bm066 (Left Dorsal)

Chile16_Bm067 (Right Dorsal)

Chile16_Bm068 (Right Dorsal)

Chile16_Bm069 (Left Dorsal)

Chile16_Bm069 (Right Dorsal)

DRAFT


Chile16_Bm070 (Left Dorsal)


Chile17_Bm071 (Left Dorsal)


Chile17_Bm071 (Right Dorsal)


Chile17_Bm072 (Left Dorsal)

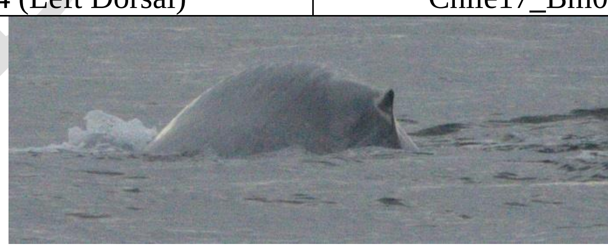

Chile17_Bm072 (Right Dorsal)


Chile17_Bm073 (Left Dorsal)


Chile17_Bm073 (Right Dorsal)


Chile17_Bm074 (Left Dorsal)

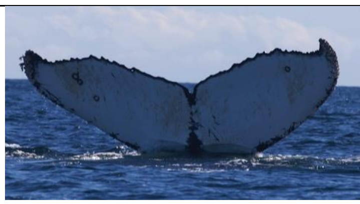
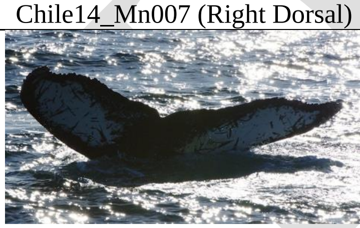

Chile17_Bm074 (Right Dorsal)


Chile17_Bm075 (Left Dorsal)

 Chile17_Bm076 (Left Dorsal)	 Chile17_Bm076 (Right Dorsal)

Appendix II

Photo-identification images of the 14 humpback whales photo-identified between 2014 and 2017.

 Chile14_Mn001	 Chile14_Mn002	 Chile14_Mn003
 Chile14_Mn004	 Chile14_Mn005	 Chile14_Mn006 (Right Dorsal)
 Chile14_Mn007 (Right Dorsal)	 Chile14_Mn008	 Chile14_Mn009
 Chile14_Mn010	 Chile14_Mn011 (Left Dorsal)	 Chile14_Mn011 (Right Dorsal)
 Chile15_Mn012	 Chile17_Mn013	 Chile17_Mn014

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Appendix III

Photo-identification images of the eight killer whales photo-identified between 2016 and 2017.

 Chile16_Oo001 (Left Dorsal)	 Chile16_Oo001 (Right Dorsal)
 Chile16_Oo002 (Left Dorsal)	 Chile16_Oo002 (Right Dorsal)
 Chile16_Oo003 (Left Dorsal)	 Chile16_Oo003 (Right Dorsal)
 Chile16_Oo004 (Left Dorsal)	 Chile16_Oo004 (Right Dorsal)

 Chile16_Oo005 (Left Dorsal)	 Chile16_Oo005 (Right Dorsal)
 Chile17_Oo006 (Left Dorsal)	 Chile17_Oo006 (Right Dorsal)
 Chile17_Oo007 (Left Dorsal)	 Chile17_Oo007 (Right Dorsal)
 Chile17_Oo008 (Left Dorsal)	 Chile17_Oo008 (Right Dorsal)

Appendix IV

CTD Cast Data

16 de febrero de 2017 - Ensamblaje de CTD

19 de febrero de 2017 - Inicio protocolos de uso y mantención de CTD

Cast 1 y 2: Lance de prueba a 4.5m de profundidad. Localidad: Caleta Buil.

Inicio: 16:34

Fin: 17:00

20 de febrero de 2017 - Inicio de utilización regular de CTD

Cast 3: 20-02-2017

Coordenadas: 42° 7084´ S : 72° 8940´ W

Inicio: 10:30

Fin: 11:10

Cast 4: 20-02-2017

Coordenadas: 42° 5851´ S : 72° 5236´ W

Inicio: 12:50

Fin: 13:35

Cast 5: 20-02-2017

Coordenadas: 43° 03´ 27´´ S : 73° 06´27´´ W

Inicio: 15:34

Fin: 16:15

Cast 6: 21-02-2017

Coordenadas: 42° 35´04´´ S : 72° 58´ 50´´ W

Inicio: 13:50

Fin: 14:40

Cast 7: 21-02-2017

Coordenadas: 42° 34´57´´ S : 72° 56´13´´ W

Inicio: 17:05

Fin: 17:45

Cast 8: 21-02-2017

Coordenadas: 42° 32´78´´ S : 72° 56´03´´ W

Inicio: 18:41

Fin: 19: 20

Cast 9: 23-02-2017

Coordenadas: 44° 07´74´´ S : 73° 18´56´´ W

Inicio: 12:40

Fin: 13:15

Cast 10: 26-02-2017

Coordenadas: 42° 05´03´´ S : 72° 41´02´´ W

Inicio: 7:33

Fin: 8:00

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