Investigating the ecology and behavior of blue whales (*Balaenoptera musculus*) in the Gulf of Corcovado, Chile
Technical Report 2018

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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 ahead of the Khronos in the Gulf of Corcovado. Photograph taken Paulina Bahamonde under Chilean research permit: Ministerio de Economia, Fomento y Turismo, Subsecreteria de Pesca y Acuicultura, MERI 488-FEB-2018 Ballena Azul, Golfo Corcovado.

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.

Since the onset of this study in 2014, it has become apparent that the eastern side of the Gulf of Ancud (GoA) is a preferred foraging habitat for blue whales visiting the region. The GoA has subsequently become a key research area for this study.

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), Dr. Paolo Segre (Stanford University) and Daniel Zitterbart (WHOI) were sought to investigate habitat use, prey availability and the energetics of blue whale foraging in the GoC/GoA.

As this study has evolved, new questions and concerns relating to the GoC/GoA 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.

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 and GoA, Chile, which began in 2014 with the support of the Melimoyu Ecosystem Research Institute (MERI).

OBJECTIVES

This investigation had four principle objectives, (1) to obtain data on the diving, foraging and vocal rates of individual blue whales in the GoC and GoA (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 and (4) to assess oceanographic variables to characterize the forging areas. Secondary objectives included collecting water samples for a whale health microbiome study led by Amy Apprill (WHOI), and deploying a hydrophone mooring for an acoustic monitoring project led by Sonia Español-Jiménez (MERI).

DTAG Study

This investigation aimed to acquire data on the ecology, foraging and acoustic behavior of individual blue whales in the GoC and GoA, 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.

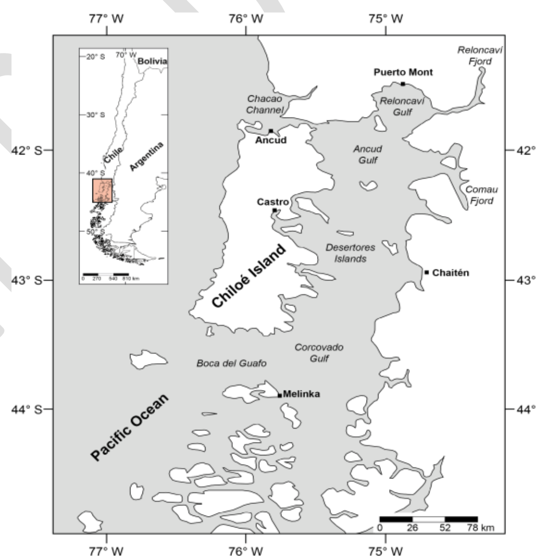

Figure 1. Maps indicating the location of the study region on the coast of Chile (inset) and the principle study areas, the Gulf of Corcovado and Gulf of Ancud.

Biopsy Sampling

To further our knowledge of the genetic stock from which the blue whales of the GoC/GoA 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, any collected samples will contribute 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/GoA being led by Gustavo Chiang and Paulina Bahamonde.

Prey Mapping and Plankton-Oceanographic Sampling

To further investigate foraging and habitat use, prey mapping surveys and qualitative zooplankton samples were taken at the locations of feeding whales. An oceanographic grid was set to deploy CTD and assess water column characteristics. 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, contaminant biomagnification and oceanographic investigations being undertaken by Fundación MERI in the region.

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.

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, Paulina Bahamonde (MERI) the 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. Sonia Español-Jiménez (MERI) was responsible for the deployment of the acoustic mooring and along with Paulina Bahamonde, also collected photo-identification images and assisted with field logistics. Carlos Cantergiani Suazo was responsible for CTD casts and the subsequent data analysis. Daniel Casado was employed as a video chronicler and helped with all aspects of cruise logistics when required. Laela Sayigh (WHOI) acted as the whale vocalization lead analyst.

Figure 3. The RV *Khronos*.

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

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 (MERI staff) and tagger (Hickmott) to deliver the DTAG 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.

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

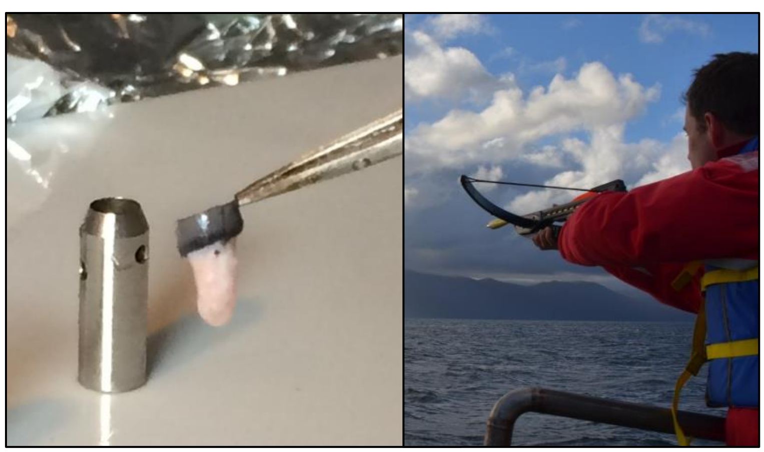

Figure 4. Stainless steel biopsy tips were used to collect skin and blubber samples. Biopsy bolts were deployed using a crossbow.

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.

Genetic Samples

Biopsy Sampling - To collect skin and blubber samples from free ranging blue whales, a 150lb draw weight 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 liquid nitrogen, in preparation for laboratory analysis.

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

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'.

CTD Casts

To better understand the physical oceanography and habitats within the GoC/GoA, 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.

Water Sampling

Water samples were collect in order to determinate microbial community along the GoC/GoA. Seawater at 10 and 100 mt. depth was sampled using a previously disinfected Niskin bottle at sites where CTD was set up. Water sampling were collected in 2L sampling bottle and a large volume (1.5 – 2L) was filtered through 0.2 μm polycarbonate filters using a peristaltic pump. Collected filters were stored liquid nitrogen, in preparation for laboratory analysis.

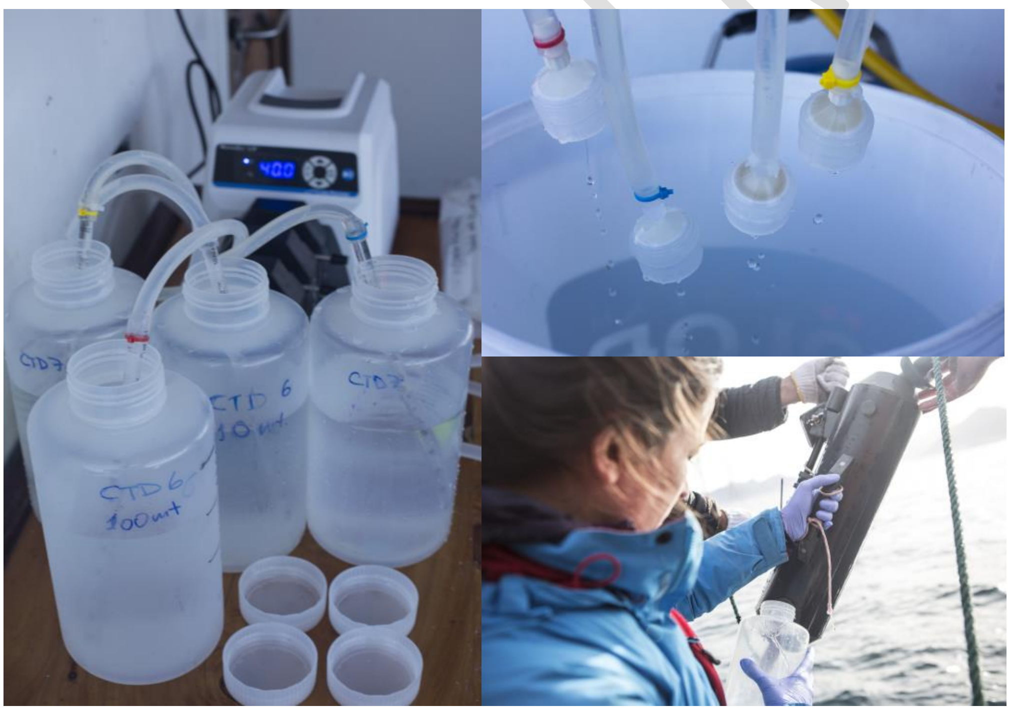

Figure 6. The sampling of water was by a Nikkin bottle at 10 m and 100 m. Water was collected in 2 lt. bottle to be pumped by a peristaltic pump through 0.2 μm polycarbonate filters.

Sample name	Date	Time	Location	Latitude	Longitude	Sample type	seawater depth (m)	Volume
chile2018_83	19.02.18	16:37	CTD1	43º 01' 55.7"	73º 11' 55.8"	seawater	10	2000 ml
chile2018_84	19.02.18	16:53	CTD1	43º 01' 55.7"	73º 11' 55.8"	seawater	100	2000 ml
chile2018_85	20.02.18	10:20	CTD2	43º 36' 0.2"	73º 42' 82.8"	seawater	10	1200 ml
chile2018_86	20.02.18	10:30	CTD2	43º 36' 0.2"	73º 42' 82.8"	seawater	100	2000 ml
chile2018_87	22.02.18	09:24	CTD3	43º 36' 26.1"	73º 07' 07.4"	seawater	10	1000 ml
chile2018_88	22.02.18	09:24	CTD3	43º 36' 26.1"	73º 07' 07.4"	seawater	10	1000 ml
chile2018_89	22.02.18	10:00	CTD3	43º 36' 26.1"	73º 07' 07.4"	seawater	100	2000 ml
chile2018_90	22.02.18	15:50	CTD4	43º 02' 82.2"	73º 03' 02.8"	seawater	10	2000 ml
chile2018_91	22.02.18	15:39	CTD4	43º 02' 82.2"	73º 03' 02.8"	seawater	100	2000 ml
chile2018_92	25.02.18	14:08	CTD5	42º 30.153	72º 52.064	Seawater	10	400 ml
chile2018_93	25.02.18	14:08	CTD5	42º 30.153	72º 52.064	Seawater	10	650 ml
chile2018_94	25.02.18	13:54	CTD5	42º 30.153	72º 52.064	Seawater	100	2000 ml
chile2018_95	26.02.18	09:34	CTD6	42º 30' 18.7"	72º 13' 22.5	seawater	10	1900 ml
chile2018_96	26.02.18	09:21	CTD6	42º 30' 18.7"	72º 13' 22.5	seawater	100	2000 ml
chile2018_97	26.02.18	12:25	CTD7	42º 27' 52.8"	72º 00' 44.4	seawater	10	700 ml
chile2018_98	26.02.18	12:25	CTD7	42º 27' 52.8"	72º 00' 44.4	seawater	10	950 ml
chile2018_99	26.02.18	12:13	CTD7	42º 27' 52.8"	72º 00' 44.4	seawater	100	2000 ml
chile2018_100	28.02.18	12:05	CTD8	42º 42' 12.1"	72º 53' 26.0"	seawater	10	2000 ml
chile2018_101	28.02.18	11:50	CTD8	42º 42' 12.1"	72º 53' 26.0"	seawater	100	1800 ml
chile2018_102	03.03.18	11:05	CTD9	42º 19' 02.5"	72º 01' 50.8"	seawater	10	1300 ml
chile2018_103	03.03.18	11:05	CTD9	42º 19' 02.5"	72º 01' 50.8"	seawater	100	2000 ml
chile2018_104	03.03.18	15:12	CTD10	42º 16' 35.1"	72º 52' 48.5"	seawater	10	600 ml
chile2018_105	03.03.18	15:12	CTD10	42º 16' 35.1"	72º 52' 48.5"	seawater	10	900 ml
chile2018_106	03.03.18	15:02	CTD10	42º 16' 35.1"	72º 52' 48.5"	seawater	100	2000 ml
chile2018_107	03.03.18	18:23	CTD11	42º 06' 21.8"	72º 41' 24.3"	seawater	10	2000 ml
chile2018_108	03.03.18	18:16	CTD11	42º 06' 21.8"	72º 41' 24.3"	seawater	100	1300 ml

Table 1: Date, time and location of the water samples collection at 10 and 100 m. depth.

RESULTS
Field Effort

A 16 day cruise was completed (19th February to 6th March 2018), departing from the port of Dalcahue, Chiloé Island, Chile. Based on survey results from previous cruises, search effort aimed to focus within the north eastern region of the GoC (Chaitén, Islote Nihuel and Chumilden) and eastern side of the GoA. Historic blue whale habitat use areas (Melinka, Melimoyu and Tic Toc), would be surveyed if whales were absent in the northern areas. Over the 16 survey days the vessel travelled 999 nm, during 194 hours of 'on effort' surveying (Fig. 7).

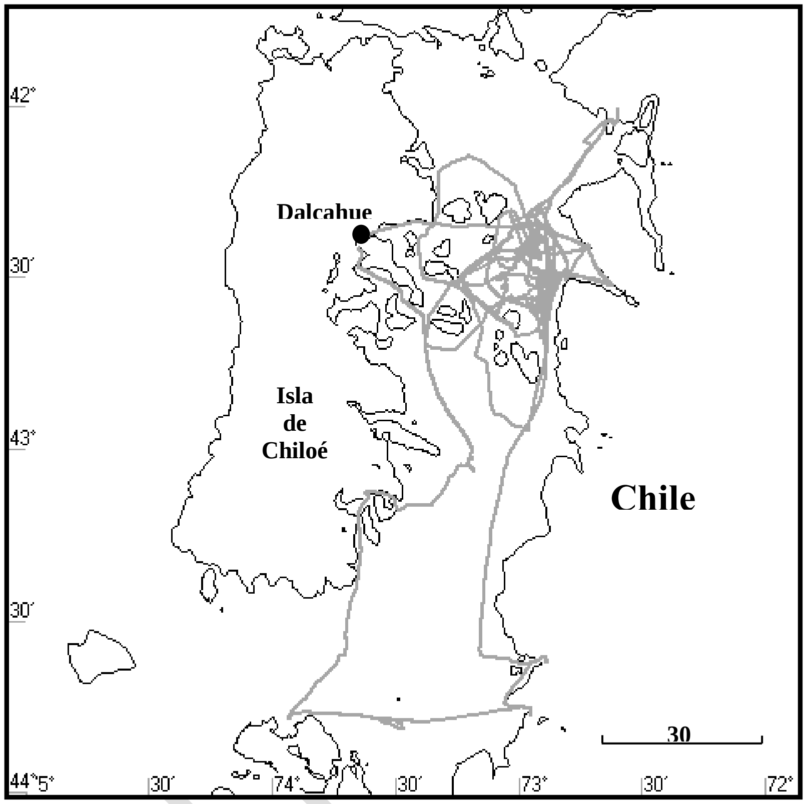

Figure 7. The study area and grey vessel track of the RV Khronos, indicating where the research effort was conducted.

Efforts were made to co-ordinate with other vessels and operators using the GoC/GoA to find blue whales during the cruise.

The survey effort resulted in 249 sightings of eight mammal species, with sightings being made on each of the 16 survey days (Table 1). 80 % (n = 200) of all sighting were of two otariid species, the South American fur seal (*Arctocephalus australis*) and the South American sea lion (*Otaria flavescens*) (Table 2).

Five different cetacean species were recorded, with blue whales comprising 67% of the 48 cetacean sightings (Table 2).

Scientific Name	Common Name (Spanish)	Common Name (English)	Number of Sightings	Mean Group Size, SD (Range)
Arctocephalus australis	Lobo fino	South American fur seal	103	1.9, 3.9 (1 – 40)
Balaenoptera musculus	Ballena azul	Blue whale	32	1.1, 0.2 (1 – 2)
Cephalorhynchus eutropia	Delfín chileno	Chilean dolphin	2	3.5, 0.7 (3 – 4)
Lagenorhynchus australis	Delfín austral	Peale´s dolphin	5	4.2, 2.8 (2 – 9)
Lontra felina	Chungungo	South American marine otter	1	1 (1)
Otaria flavescens	Lobo marino	South American sea lion	97	3.4, 20.2 (1 – 200)
Orcinus orca	Orca	Killer whale	1	3 (3)
Phocoena spinipinnis	Marsopa espinosa	Burmeister's porpoise	8	1.4, 0.5 (1 – 2)

Table 2. Table of mammal species recorded, with the number of sightings per species, mean group size, standard deviation and ranges.

Photo-identification

9,856 photo-identification images were taken of two cetacean species during 20 encounters (Table 3). 18 blue whale groups containing 1 to 3 individuals were photo documented between the 19th February and 06th March (Tables 2 and 3) (Appendix I). Eight individual blue whales were photo-identified, five of which were resights of whales encountered in previous years and three were new animals (Table 3). With the addition of the three new whales, the MERI blue whale photo-identification catalogue now contains 79 individuals (Appendix I).

Scientific Name	Common Name	Number of Photo-ID Encounters
Balaenoptera musculus	Blue whale	18
Lagenorhynchus australis	Peale´s dolphin	2

Table 3. Cetacean species documented using photo-identification, with the number of encounters per species.

Of the five whales seen in previous survey years, one animal Bm011 was first seen and biopsied in 2015. At that time, Bm011 was a calf, accompanying its mother Bm010 (see genetics data for issues surrounding this individual). Bm011 is now at least three years old and independent.

Bm024 was first observed in 2015 and appeared emaciated. It is encouraging to observe that some animals in poor body condition are able to recover, as when seen in 2018 Bm024 appeared to be a healthy robust individual. The three remaining resighted individuals, Bm052, Bm053 and Bm070, were first seen in 2016 and not again until 2018.

The photo-identification results, indicate site fidelity (for the period of the cruise), with seven of the whales resighted on multiple days, with Bm011 and Bm070 both recorded being present in the area for twelve days (Table 4).

Date	**EncSeq**	**Latitude**	**Longitude**	**Time (UTC)**	**Group Size**	**ID's**	**Age Class**
19-Feb-18	2	-43.04750	-73.21388	21:21	2	Bm077(N) Bm078(T)(N)	Sub-Adult Sub-Adult
23-Feb-18	1	-42.56969	-72.88390	10:38	2	Bm011(T)(B) Bm053	Juvenile Adult
23-Feb-18	2	-42.52806	-72.87417	18:23	1	Bm052	Adult
23-Feb-18	3	-42.50250	-72.86667	18:41	1	Bm070	Adult
23-Feb-18	4	-42.34611	-72.99472	20:38	1	Bm024	Adult
24-Feb-18	1	-42.54694	-72.95833	14:31	2	Bm052 Bm079	Adult Adult
24-Feb-18	2	-42.49300	-72.91536	17:10	1	Bm011(T)	Juvenile
24-Feb-18	3	-42.51861	-72.92000	23:41	1	Bm070	Adult
25-Feb-18	1	-42.49184	-73.03234	18:53	1	Bm070	Adult
25-Feb-18	2	-42.52244	-73.05253	21:53	1	Bm053(T)	Adult
27-Feb-18	1	-42.56065	-72.88621	12:56	1	Bm052(T)	Adult
01-Mar-18	1	-42.44976	-73.04795	12:39	3	Bm024 Bm053 Bm079(N)	Adult Adult Adult
02-Mar-18	1	-42.43958	-73.01187	12:29	3	Bm052 Bm070 Bm079	Adult Adult Adult
02-Mar-18	2	-42.40567	-72.95759	18:48	2	Bm024(T) Bm070	Adult Adult
03-Mar-18	1	-42.42521	-72.94685	11:19	1	Bm024	Adult
03-Mar-18	2	-42.29622	-72.91545	15:39	1	Bm053	Adult
06-Mar-18	1	-42.59972	-72.90389	12:19	1	Bm011	Juvenile
06-Mar-18	2	-42.52917	-72.92417	14:38	1	Bm070	Adult

Table 4. Blue whale encounter and photo-identification summaries. (T) = tagged with a DTAG, (B) = animal was biopsied and (N) = new animal.

DTAG Study

Five different blue whales were tagged using the DTAG (Table 5) and their diving and foraging behavior was consistent with previous years (Fig. 8a & 8b). These deployments resulted in the collection of 45 hours and 27 minutes of tag data (Table 5). Two long deployments (>12 hrs) were recorded and one individual (Bm011) was tagged twice within a two-day period, resulting in the collection of 24 hours and 37 minutes of DTAG data within a 35 hour period (Fig. 8a & 9). It is clear in the data that a diurnal shift happens, from deep daytime foraging to a shallow pattern of diving during the night (Fig. 9). One animal (Bm052) tagged during this cruise, was previously tagged in 2016. These are the first comparable data for one individual collected over multiple years. Comparative data were collected from an individual (Bm012) in 2015 and 2017, however the 2017 deployment was only 22 minutes in duration, limiting what could be done with the two datasets.

Date	Animal ID	Age Class	Deployment ID	Deployment Duration (Hr:min)	Deployment Time (UTC)	Deployment Location
19-Feb-2018	Bm078	Sub-Adult	bm18_050a	18 sec	23:33:33	-43.16003 -73.35140
23-Feb-2018	Bm011	Juvenile	bm18_054a	19 hr 53 min	13:46:36	-42.56969 -72.88390
24-Feb-2018	Bm011	Juvenile	bm18_055a	5 hr 45 min	18:36:04	-42.49300 -72.91536
25-Feb-2018	Bm053	Adult	bm18_056a	1 hr 30 min	22:20:38	-42.52244 -73.05253
27-Feb-2018	Bm052	Adult	bm18_058a	5 hr 40 min	13:07:26	-42.56065 -72.88621
02-Mar-2018	Bm024	Adult	bm18_061a	12 hr 39 min	21:18:47	-42.43394 -72.96053

Table 5. Blue whale DTAG deployment summaries.

The two datasets collected for Bm052 (2016 = >9 hrs, 2018 = >5 hrs) will allow more rigorous analysis. A comparison of the number of dives made per hour, revealed a striking consistency for this individual (Table 6, Fig. 10). Four hours of data (highlighted in grey in Figure 10) were compared between the two years, with the first hour of the tag deployments being omitted to account for possible effects of tagging on baseline behavior. Within the four-hour analysis period for both years Bm052 consistently performed six dives per hour (Table 6).

	2016	2018
Total No. of Dives	24	22
Mean No. Dives Per Hr	6	5.5
S.D.	0	0.58

Table 6. A comparison of the number of dives made by Bm052 during a four-hour period in 2016 and 2018.

DTAG Acoustic Data Analysis

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

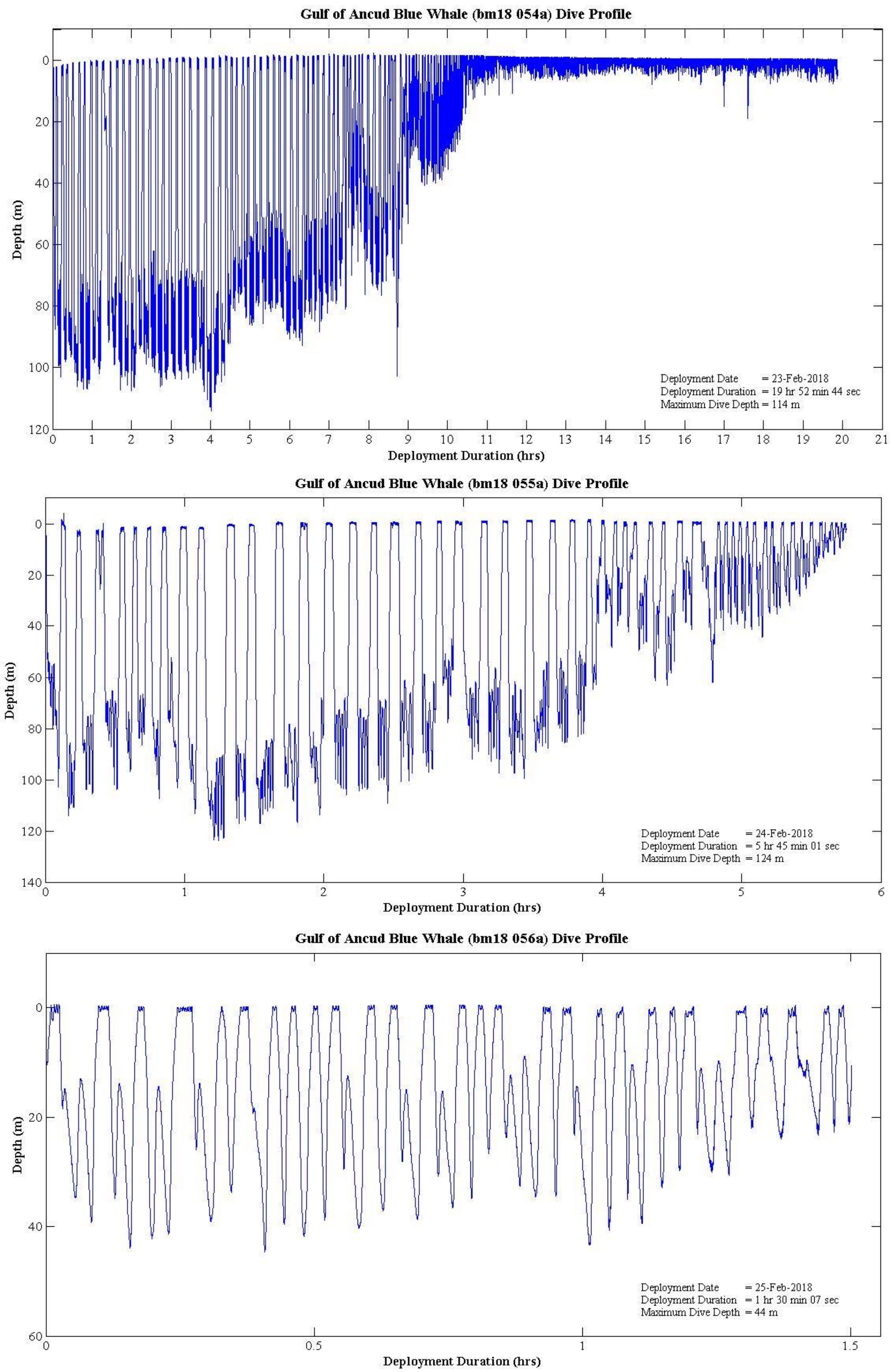

Figure 8a.The two dive profiles from Bm011; note the difference in diving behavior of the same whale. The final is that of Bm053. Deployment duration in hours (x axis) and dive depth in meters (y axis).

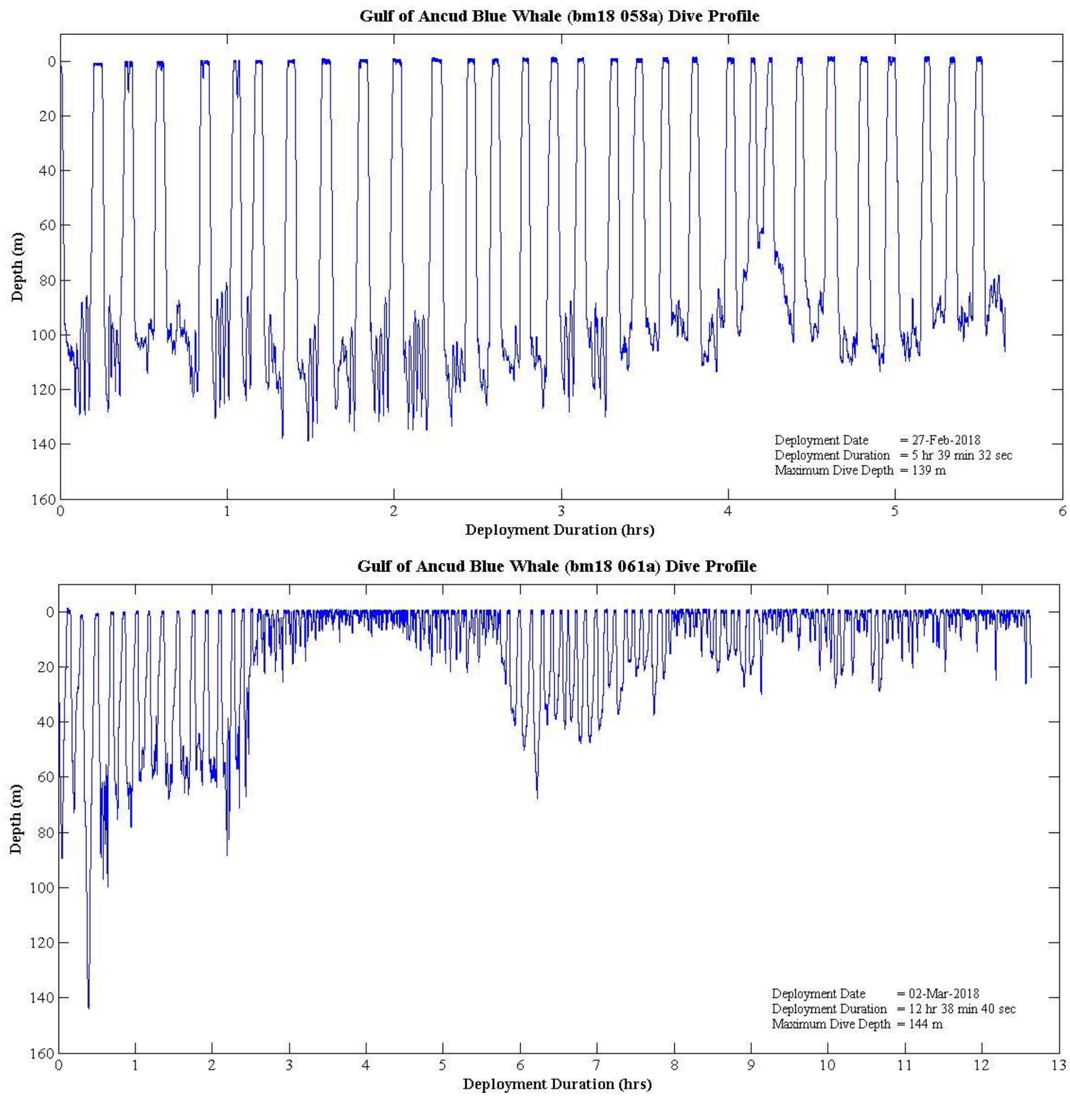

Figure 8b. Dive profiles of Bm052 and Bm024. Deployment duration in hours (x axis) and dive depth in meters (y axis).

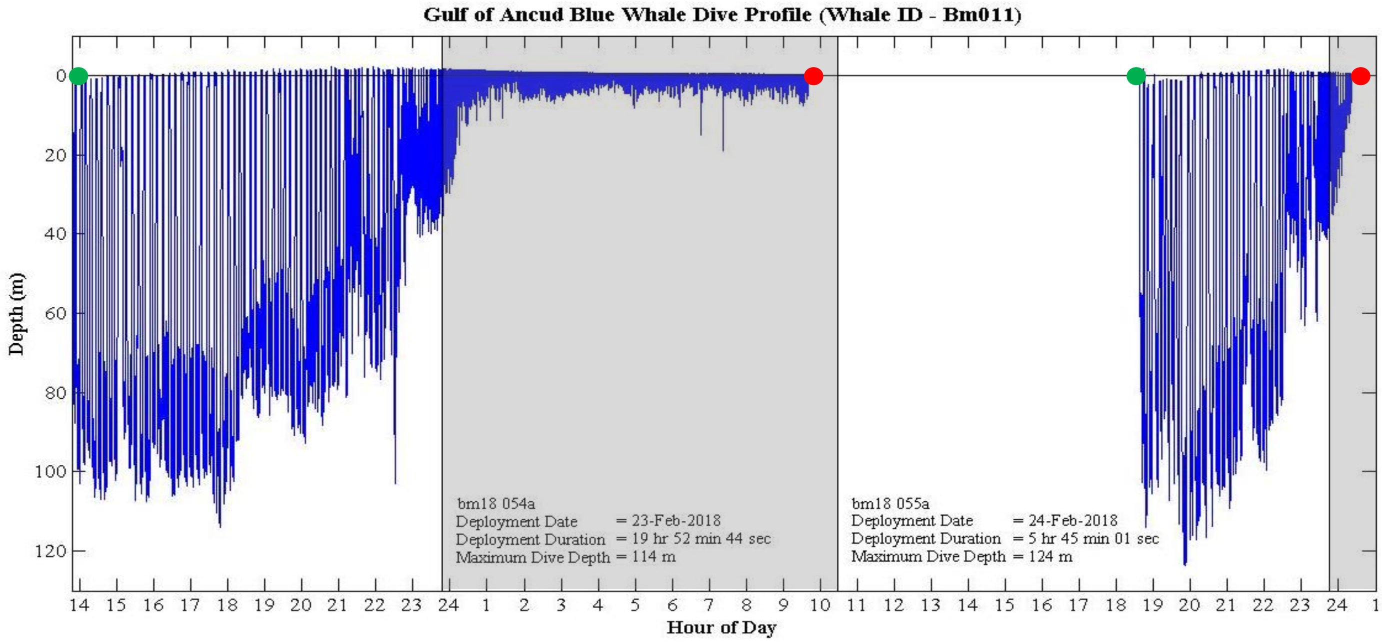

Figure 9. The two dive profiles collected from Bm011 during a 35-hour period. Bm074 was tagged twice (bm17_060a/b). Note the difference in diving behavior of the same whale. Grey blocks indicate nighttime hours. Green and red dots indicate the start and stop of each of the tag deployments. Time of day (UTC) (x axis) and dive depth in meters (y axis).

Genetic Samples

Six genetic samples were collected from blue whales in 2018, one biopsy and five sloughed skin samples collected from tagged animals (Fig. 10) (Table 6). These samples were collected from four different individuals. Genetic material (biopsy and DTAG skin sample) were collected from Bm011 and will be compared to the biopsy sample collected from this animal in 2015.

Blue Whale Sex Determination

Total genomic DNA was extracted using the standard phenol-chloroform method (Sambrook et al., 2001 and Aljanay & Martinez, 1997), with some modifications. Later, the extract was cleaned using Wizard® DNA Clean-Up System from Promega, following protocols determined by the manufacturer.

Date Collected	Sample Number/ID	Species	Animal ID	Collection Method	Latitude (SOUTH)	Longitude (WEST)
23-Feb-2018	BM20182302_01	*B. musculus*	Bm011	Biopsy	-42.56768	-72.87864
24-Feb-2018	BM20182402_01	*B. musculus*	Bm011	DTAG skin sample	-42.58081	-72.88518
25-Feb-2018	BM20182502_01	*B. musculus*	Bm011	DTAG skin sample	-42.51867	-72.92248
26-Feb-2018	BM20182602_01	*B. musculus*	Bm053	DTAG skin sample	-42.53045	-73.04361
27-Feb-2018	BM20182702_01	*B. musculus*	Bm052	DTAG skin sample	-42.57541	-72.91226
02-Mar-2018	BM20180203_01	*B. musculus*	Bm024	DTAG skin sample	-42.42882	-72.95676

Table 7. Summary information of the collected genetic samples.

The amplifications were performed with DreamTaq Green PCR Master Mix (2X) from ThermoFisher was used to determine sex of blue whales genetically from skin using the set of primers described by Jayasankar et al, 2008:

SRY F (CCC ATG AAC GCA TTC ATT GTG TGG)
SRY R (ATT TTA GCC TTC CGA CGA GGT CGA TA)

ZFX/ZFY F (ATA ATC ACA TGG AGA GCC ACA AGC T)
ZFX/ZFY R (GCA CTT CTT TGG TAT CTG AGA AAG T)

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

A total of 30 samples were analyzed. 13 male blue whales, 10 female blue whales and 7 non-determinates are shown in Tables 8a and 8b. This is preliminary data and the sex needs to be confirmed by further analysis.

Two anomalous results have been recorded that require further investigation. Firstly, a sample collected on 15-Feb-2015 has been genetically identified as a male, whilst during field observations this animal was accompanied by a calf and was recorded as a female. Secondly, one animal (Bm012) that has been sampled twice, once in 2015 and again in 2017, has been genetically identified firstly as a female in 2015 and as a male in 2017. Due to these anomalies, all genetic data will be reassessed to determine the cause of the anomalous results.

Specie	ID	Date	Sample	Observations	Sex & ID No.
B. musculus	160215_Chile_BM01	16-02-15	Biopsy		**Male** – Bm008
B. musculus	170215_Chile_BM02	17-02-15	Biopsy	Recorded as calf of Bm010 during field observations	**Male** – Bm011
B. musculus	170215_Chile_BM03	17-02-15	Skin from DTAG	Recorded as mother of Bm011 during field observations	**Male** – Bm010
B. musculus	190215_Chile_BM04	19-02-15	Skin from DTAG		**Female** – Bm012
B. musculus	220215_Chile_BM05	22-02-15	Biopsy	Same whale BM15_053a	ND – Bm002
B. musculus	220215_Chile_BM06	22-02-15	Skin from DTAG	Same whale BM15_053a	ND – Bm002
B. musculus	230215_Chile_BM07	23-02-15	Biopsy	Only microsample BM15_054a	**Female** (field observation) – Bm013
B. musculus	230215_Chile_BM08	23-02-15	Biopsy	Calf of BM15_054a (skin only)	**Female** – Bm014
B. musculus	230215_Chile_BM09	23-02-15	Skin from DTAG	BM15_054a (skin only)	**Female** (field observation) – Bm013
B. musculus	260215_Chile_BM10	26-02-15	Biopsy	BM15_057a	**Female** – Bm016
B. musculus	260215_Chile_BM11	26-02-15	Skin from DTAG	BM15_057a (from rear upper suction cup)	ND – Bm016
B. musculus	030315_Chile_BM12	03-03-15		Blow sample	ND – Bm017
B. musculus	030315_Chile_BM13	03-03-15	Biopsy	calf of blow sample mother (BM17)	**Male** – Bm018
B. musculus	040315_Chile_BM14	04-03-15	Biopsy	xenobalanus fin photogram pair (ring sample, only skin no blubber)	**Female** – Bm020
B. musculus	040315_Chile_BM15	04-03-15	Biopsy	Small fin (two spots on right side photogram pair)	**Male** – Bm019

Table 8a. PCR analysis results from samples collected from blue whales in the GoC and GoA during 2015, 2016 and 2017 campaigns. Anomalous results are highlighted in red.

Specie	ID	Date	Sample	Observations	Sex & ID No.
B. musculus	060315_Chile_BM16	06-03-16	Skin from DTAG	skin sample from tag, whale BM15_064a	ND – Bm025
B. musculus	BM201602_01	18-02-16	Biopsy		**Female** – Bm036
B. musculus	BM201602_49A	19-02-16	Skin from DTAG		**Female** – Bm036
B. musculus	BM201602_02	21-02-16	Biopsy	Very poor sample, almost none	ND – Bm041
B. musculus	BM201602_03	22-02-16	Biopsy		**Male** – Bm041
B. musculus	BM201602_054A	23-02-16	Skin from CAT-TAG	It should be _53A	**Male** – Bm045
B. musculus	BM201602_054B	25-02-16	Skin from CAT-TAG	Very poor sample, in a cotton - It should be _55A	ND – Bm050
B. musculus	BM201602_057a	26-02-16	Skin from DTAG		**Female** – Bm054
B. musculus	BM201602_132	28-02-16	Skin from DTAG		**Male** – Bm060
B. musculus	BM201602_62b	02-03-16	Skin from DTAG	Sample in a cotton	**Female** – Bm069
B. musculus	BM201603_04	03-03-16	Biopsy	Same whale of BM201602_62b	ND – Bm069
B. musculus	BM201603_05	03-03-16	Biopsy		**Female** – Bm065
B. musculus	BM20172702_01	27-02-17	Biopsy		**Male** - Bm071
B. musculus	BM20170103_02	01-03-17	Skin from DTAG	Sample from same whale collected in 2015 returned a **FEMALE** result	**Male** - Bm012
B. musculus	BM20170403_03c	04-03-17	Biopsy		**Male** - Bm074
B. musculus	BM20170403_03b	04-03-17	Skin from DTAG		**Male** - Bm074

Table 8b. PCR analysis results from samples collected from blue whales in the GoC and GoA during 2015, 2016 and 2017 campaigns. Anomalous results are highlighted in red.

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 Blue Whale study in February and March 2017 in the Gulf of Corcovado. The system was mounted on the port side of the RV Khronos at a depth of 1m (Figure 12) and collected data from ~ 2m depth to the bottom of the water column with a vertical resolution of approximately 10 cm.

Figure 12. 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 which allowed for the echosounder to provide depth and information on water column scatterers in real time.

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 all days of the cruise with the exception of Feb 21 when the boat did not leave the anchorage due to bad weather. A total of 278 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 2018 field season. Acoustic survey data in 2018 were collected over wide geographic range and had several surveys with substantial areal coverage around some tagged animals. There is good overlap in spatial coverage between the 2018 data and that for previous years (Figures 13,14).

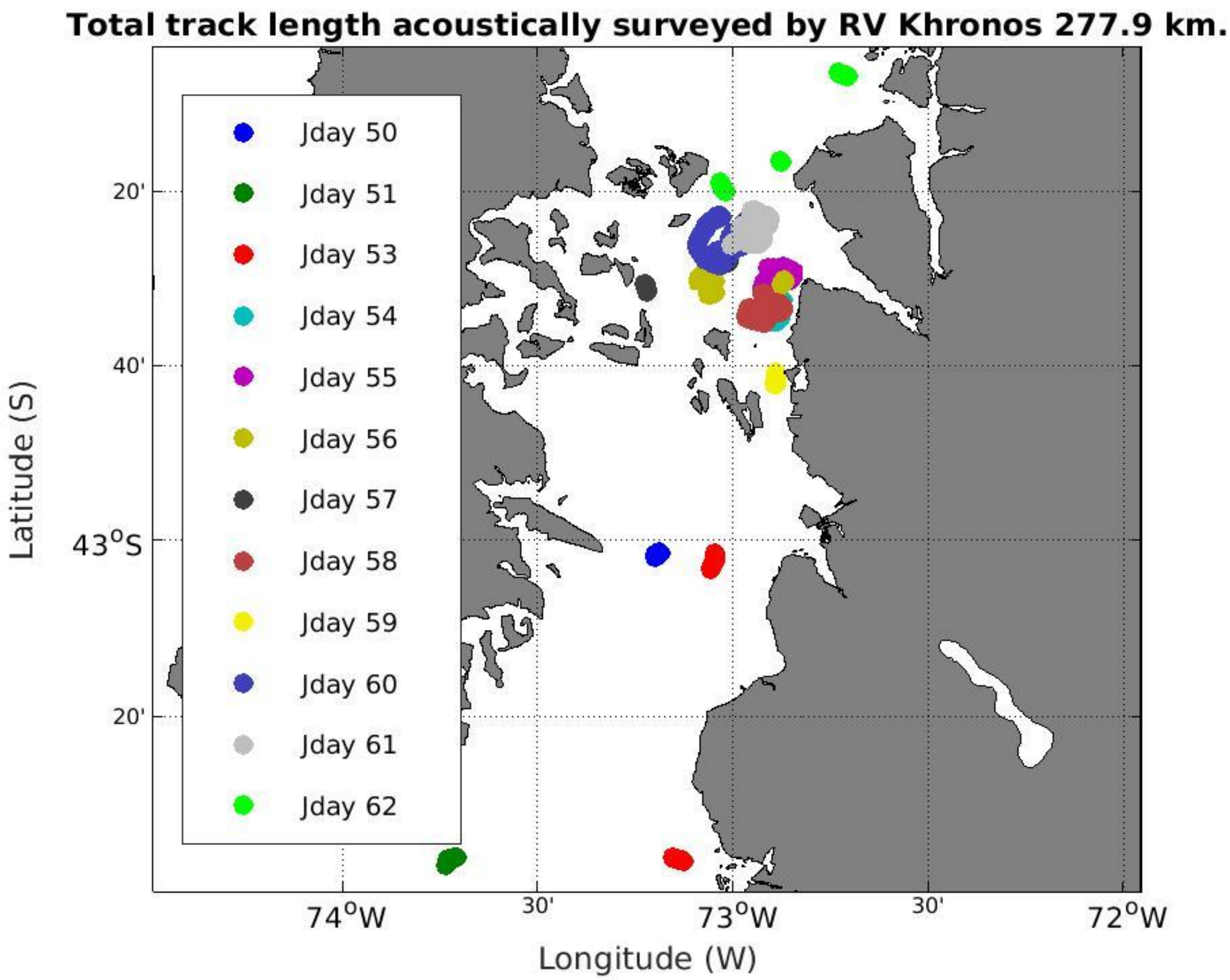

Figure 13. Cruisetracks showing where acoustic survey data were collected.

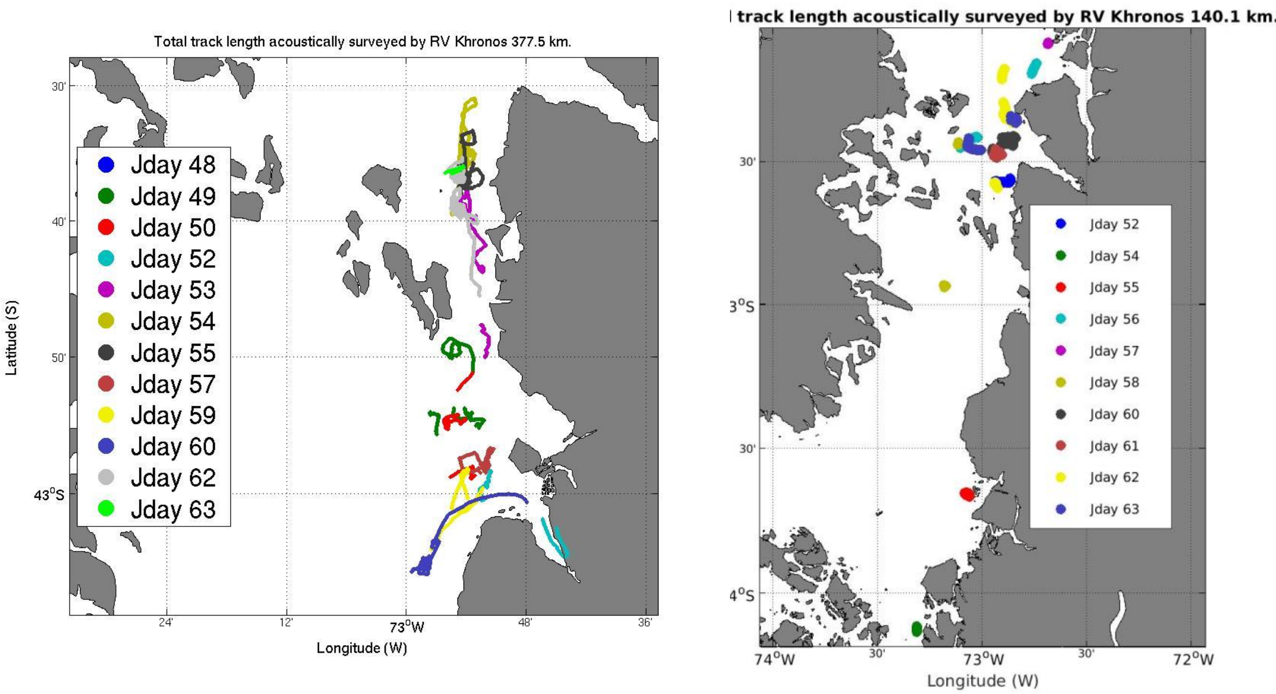

Figure 14. Cruisetracks of acoustic data collection from 2016 (left) and 2017 (right).

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 (Figure 15a). Zooplankton aggregations were found in the middle of the water column (during daytime hours), typically in a layer between 40 and 100 m depth (Figure 15b). There was spatial variability in the thickness and intensity of the zooplankton aggregations.

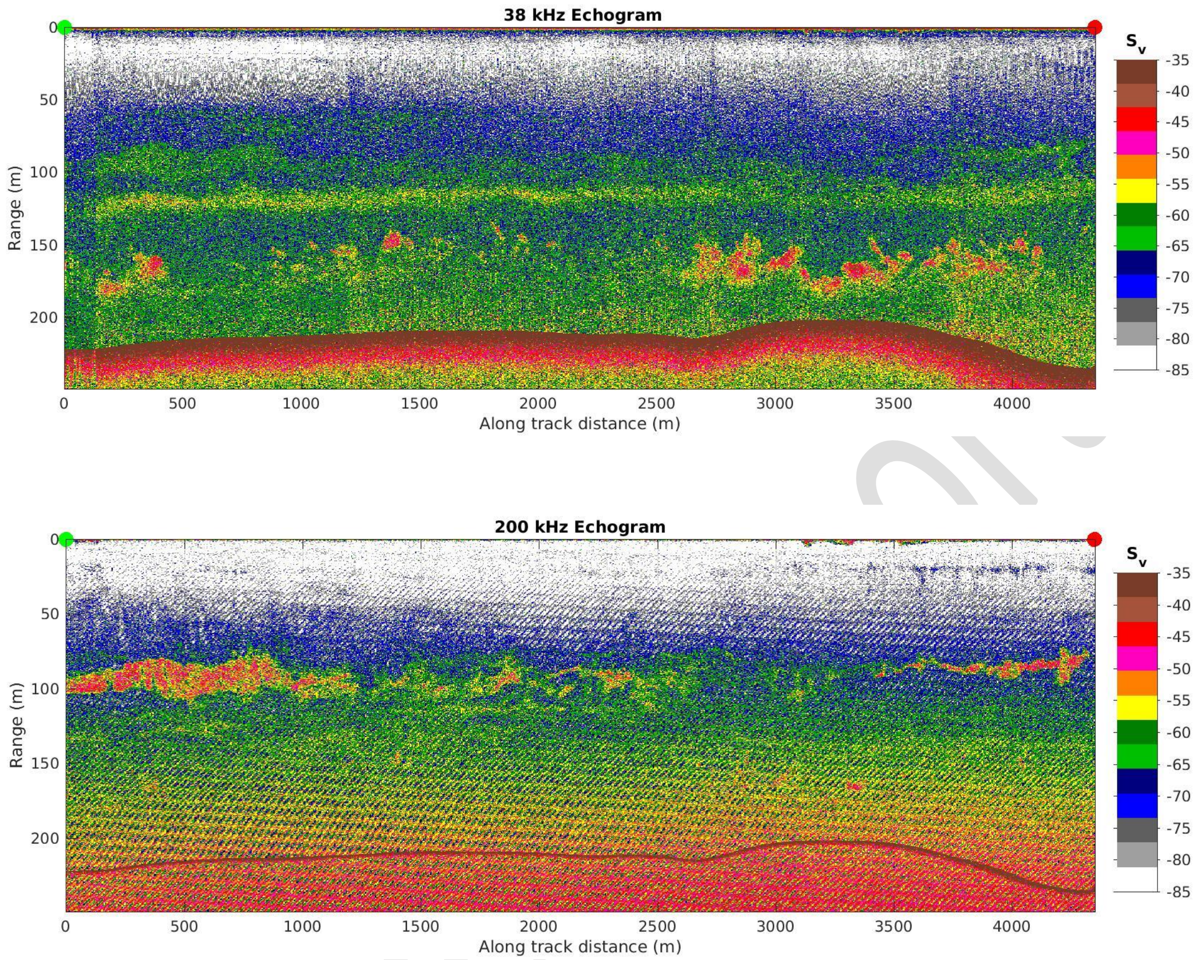

Figure 14. Echograms showing backscatter at 38 (top) and 200 (bottom) kHz. The x and y axes are distance and depth respectively. White and blue colors represent less backscatter with yellows and red colors representing stronger scattering. Krill aggregations are clearly seen in the 200 kHz echogram (bottom) 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 ~ 150-200 m and near the seafloor. The dark red/brown line at ~ 220 m is the seafloor

As seen in previous years, some aggregations of krill were quite dense and large (Figure 16).

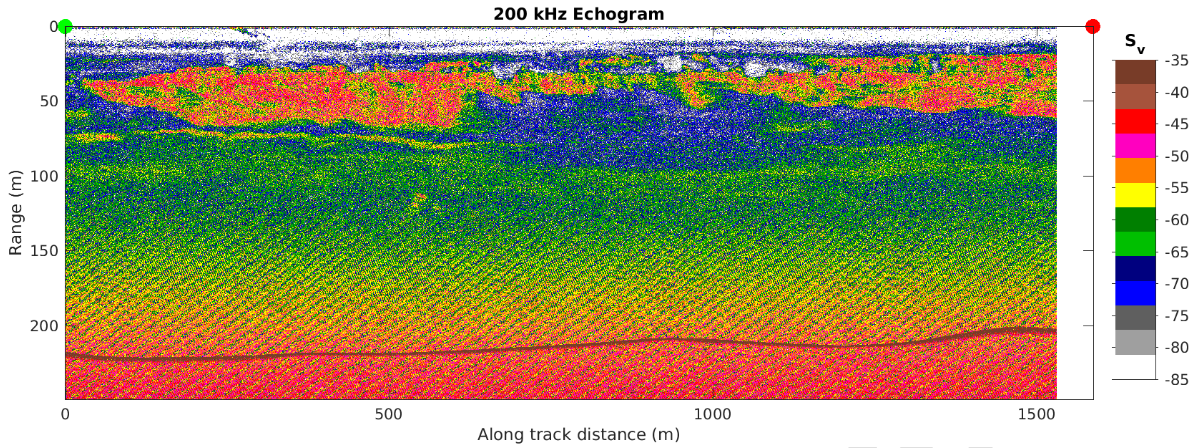

Figure 16. Echogram (200 kHz) showing a large near surface aggregation of scatterers (depth 40 to 70 m, 0 to 1500 m alongtrack distance) which are likely krill.

Net Tow Sampling

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 (Figures 17-18).


Figure 17. Euphausiids (krill) were the dominant zooplankton caught in most net tows (left), with two species caught (middle), as well as larval or juvenile euphausiids (right). Species identifications are pending.

Figure 18. Several other types of zooplankton and nekton were caught in net tows during 2018 including (from left to right): salps, copepods, amphipods (Themisto sp. Likely), and even one juvenile octopus.

During the cruise, zooplankton samples were collected using a bongo net in 11 oceanographic stations, following prey mapping and/or tagged whale. Mainly we found euphasiids (in number and biomass), but there was significative presence of amphipods, pteropods and copepods. We separated samples by functional group and/or morpho for stable isotopes and contaminants analysis. All samples were frozen at -20°C until analysis. See details in table 9.

Plankton trawls station	Location	Date (Hour)	Sample	Observation
ST1		19.02.2018 (15:30) 10´ trawls at ≈60m depth.	190218_01 Red amphipod 190218_02 Amphipod 190218_03 Pteropods 190218_04 Clione sp. 190218_05 Krill 190218_06 Copepods 190218_07 Tomopteridae	>75% of biomass was Pteropods
ST2		20.02.2018 (11:10) 10´trawl at ≈60m depth.	200218_08 200218_09	>90% of biomass was amphipods
ST3		22.02.2018(10:05) 12´ at ≈60m depth.	220218_10 Krill 220218_11 black amphipods 220218_12 red amphipods 220218_13 Pterapods	>80% of biomass was krill

			220218_14 Clione sp.	
ST4		22.0.2018 (16:15) 10´trawl at ≈60m depth.	220218_15 Krill 220218_16 black amphipod	>80% of biomass was krill
ST5		24.02.2018 (21:30) 10´trawl at ≈60m depth	240218_17A Krill 240218_17B Krill	100% krill Trawl while following tagged whale (Bm18_55a)
ST6		25.02.2018 (14:45) 10´trawl at ≈60m depth	250218_18 Krill	Very few biomass, only krill
ST7		26.02.2018 (09:30) 10´trawl at ≈60m depth	260218_19 Krill 260218_20 fish larvae 260218_21 black amphipods	>80% of biomass was krill
ST8		28.02.2018 (12:30) 10´trawl at ≈60m depth	280218_22 salps 280218_23 amphipods 280218_24 pteropods 280218_25 krill	
ST9		03.03.2018 (12:44) 10´trawl at ≈60m depth	030318_26 amphipod 030318_27 krill 030318_28 krill	>90% of biomass was krill
ST10		03.03.2018 (16:00) 10´trawl at ≈60m depth	030318_29 krill 030318_30 amphipods	
ST11		03.03.2018 (18:25) 10´trawl at ≈60m depth	030318_31 krill 030318_32 jellyfish	

Integrating Prey & DTAG Data

As we expect (based on previous field seasons), the maximum dive depth of the blue whale recorded by the DTAG corresponds with the depth where krill (their prey) reside (as measured by backscatter at 200 kHz) and are most abundant. Echograms overlaid with dive profiles provide insight into blue whale foraging behavior (Figure 19).

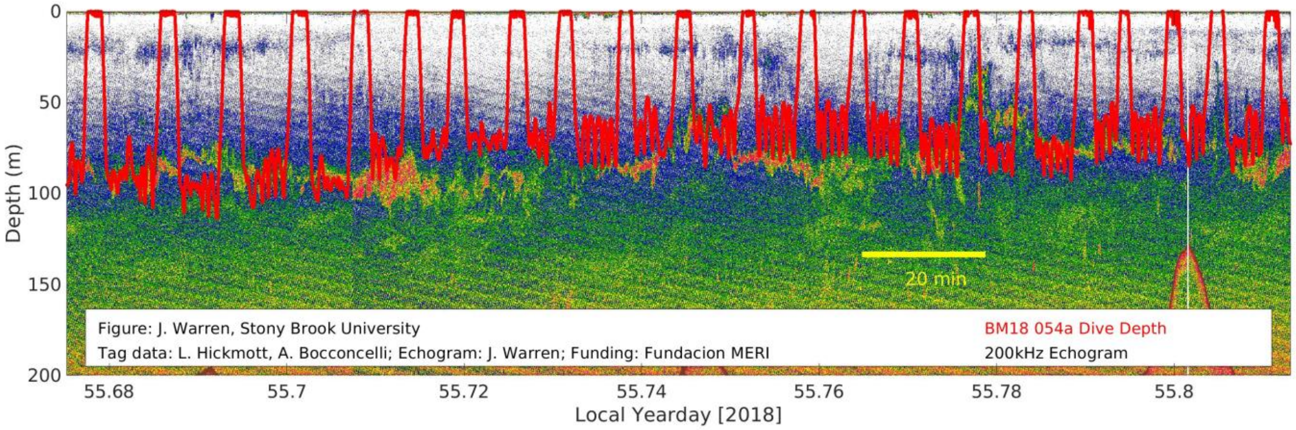

Figure 19. DTAG deployed on 24 February 2018 (BM18 054a) dove repeatedly to a depth of ~ 100 m over a 3-hour period while the ship was surveying around the tagged whale. At the bottom of each dive, the whale did a series of 5-6 smaller up/down movements that often (based on previous years) correspond to lunge feeding events. We are currently in the process of processing the tag data for lunge detections. For this 3-hour period, there were small layers or aggregations of krill present, but the layer depth (and whale dive depths) were fairly constant.

Passive Acoustic Monitoring

SoundTrap was deployed to obtain long temporal acoustic data. The effort for obtain recordings was focus at humpback whales to continue with the study of why humpbacks are singing in a feeding area when it is supposed to be with reproductive goals.

Based on previous studies, it was determined that the SoundTrap would be placed in the Guafo North area because it is where more songs of humpback whales have been detected.

On February 20 at 18.05 a SoundTrap was placed at 51.7 meters. It was installed by means of an anchorage line with an anchor and two surface buoys. It was anchored near Melinka, at coordinates -43.78075 S -73.93102 W.

The device, ST300 HF with external battery pack, was programmed to record 15 minutes every 30 minutes at 24000 Hz sampling rate, thus having a recording capacity of 119 days.

In August, Sonia Español-Jiménez will return to the area to recovery the equipment and subsequent data analysis.

CTD Casts

In a total of 11 stations, the CTD was deployed to measure conductivity, density, salinity and temperature in the water column in GoA and GoC (Fig. 20).

In general, the CTD was deployed to a maximum depth of ≥180 m and a minimum of ≥102 m, with 5 stations in GoC and 6 in GoA (Fig. 21).

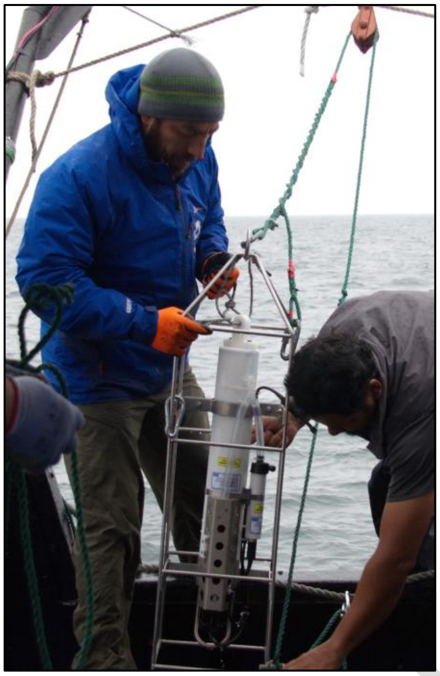

Figure 20. Team members prepare to deploy the CTD.

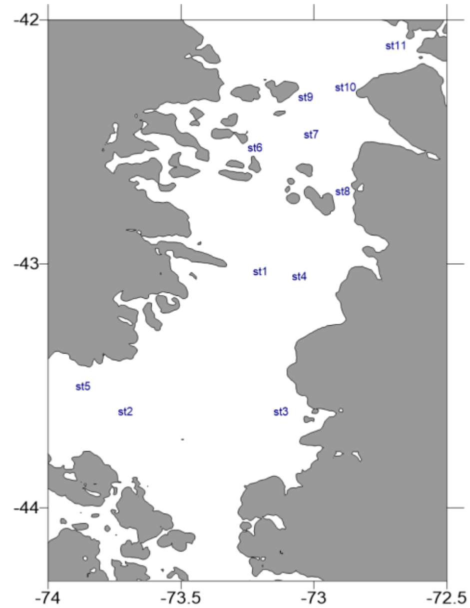

Figure 21.- CTD sampling stations in GoA and GoC. Some stations were repeated from 2017´s expedition and we expanded the sampling grid to GoC

In 9 out 11 stations, we observed the influence of freshwater input to GoA and GoC (Fig. 22). Surface waters showed salinity below characteristic ocean levels. Stations 1 and 4 showed water column characteristics typical from sea, with salinity, conductivity, density and temperature values that were homogenous from surface to deeper waters. The rest of the stations showed a very stratified water column with freshwater influence (lower salinity) especially in stations 5, 7, 9, 10 and 11. In this preliminary analysis, we observed that most of the sightings have been around those areas, and freshwater inputs could be playing a significant part in whale foraging habitat.

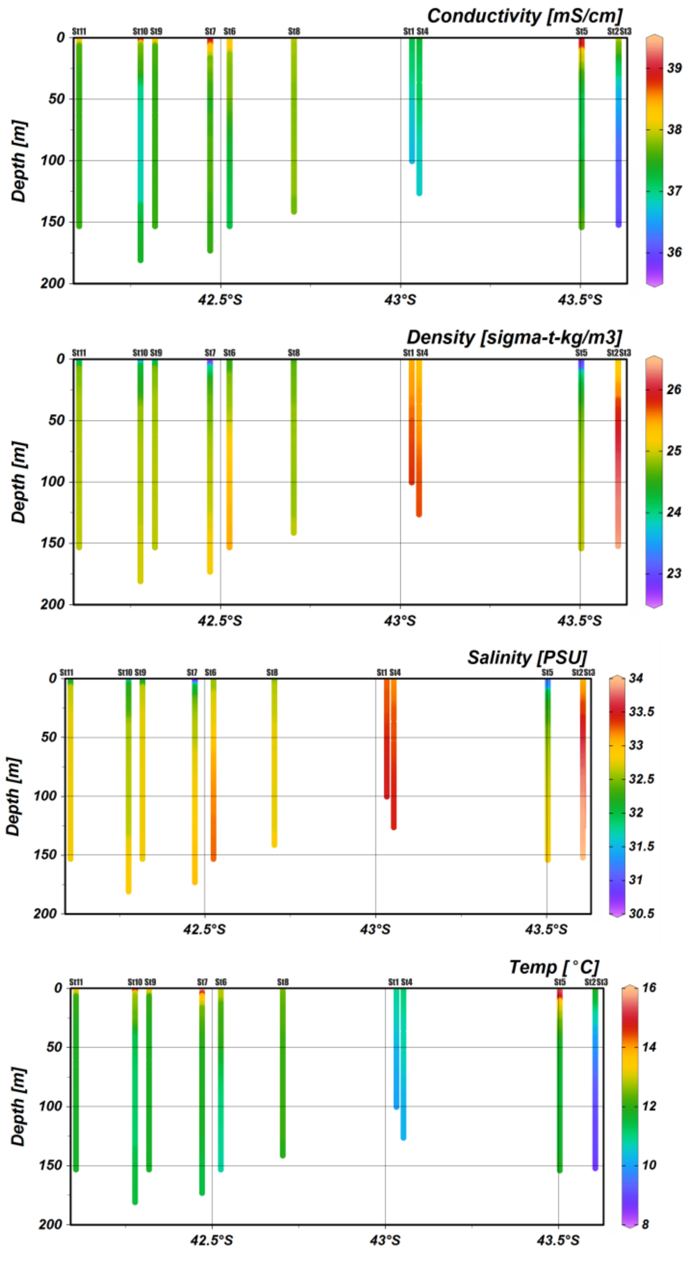

Figure 22. CTD data (Conductivity, Density, Salinity and Temperature) in water column for the 11 stations in GoA and GoC.

Impact and Future Work

It was evident during the study that there were few whales in the area, as the same individuals were repeatedly resighted. Despite this, a large amount of DTAG and prey mapping data were successfully collected. During the field effort more CTD casts and net tows were performed than in previous years, generating a more detailed dataset to contribute to Chiang's large scale study of the GoC environment.

Outreach

On Saturday, February 17, from 5 pm to 7:30pm, at the Public Library "Martina Barrientos Barbero" the community of Castro and surrounding area was invited to celebrate the fifth year of the Blue Whale Expedition. Both together, The MERI Foundation and the Municipality of Castro, Chiloé, held the first "Community and Science" meeting. The event's goal was to share the major findings obtained during the five expeditions at the Ancud Gulf and Corcovado Gulf area. The activity invited at audiences of all ages, as a family activity. We talked topics such as the characteristics of the great blue whale, their behavior in the area and the facing threats, among others through didactic videos and participative exhibitions.

"Whales travel the seas year after year to feed and reproduce, being a faithful indicator of the health of marine ecosystem. That is, if the whales change their behavior (communication, movement, reproduction and feeding), it might indicate that the ocean is sick. The Corcovado Gulf is a privileged place to receive the whales in their feeding and socialization phase", highlights the Foundation's scientific director, Gustavo Chiang. In this context, attendees are invited to actively collaborate in marine conservation based on cetacean registration, environmental responsibility on land and when sailing, and the dissemination of what has been learned.

To finalize the event, the documentary "Patagonia Azul, the interconnection of life" was showed as a co-production between MERI Foundation and DC Photo.

In addition, local people helped to the expedition with sightings before and during the expedition.

Specie	Number	Date	Latitude	Longitude	Comments
B. musculus	2	23-02-18	43 22.037	73 30.468	From Francisca
B. musculus	2	19-02-18	43 46.812	73 37.528	From Naviera Austral (Queulat Ferry) to Gloria
Whale	1	05-03-18	43 45 28,5	73 41 32,7	Whale heading north 8nm at North of Melinka. Message to Francisca
Whale	1	06-03-18			Whale 5nm at WSW from Ayacara, heading South. Message to Francisca
Whale	1	21-02-18			From Naviera Austral (Queulat Ferry) to Catalina. Closed to San Pedro Island
Whale	1	24-02-18	43°49,6	073° 27,7	Message to Catalina

Table 9. Sighting of local people in collaboration with the Blue Whale Expedition.

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

Research Output

Published Research Papers – 2018

Español-Jiménez, S. and van der Schaar, M. 2018. First record of humpback whale songs in Southern Chile: Analysis of seasonal and diel variation. Marine Mammal Science. doi:10.1111/mms.1247

Research Papers in Review or Preparation- 2018

Español-Jiménez S., Bahamonde B., Chiang G., Häussermann V. (enviada). Discovering sounds in Patagonia, characterizing sei whale (*Balaenoptera borealis*) downsweeps in south-eastern Pacific Ocean. Ocean Science.

Conference Presentations – 2018

Alejandro Cuevas, Alejandro Veragua, Sonia Español-Jiménez, Gustavo Chiang & Felipe Tobar. An automatic method for a detection of blue whale calls. 8th International Workshop on Detection, Classification, Localization, and Density Estimation of marine mammals using passive acoustics, Paris. 2018

Carlos Cantegiani, Gustavo Chiang. Aproximación a un modelo predictivo de uso de hábitat por ballenas azules (*Balaenoptera musculus*) basado en mediciones oceanográficas satelitales, entre la ecoregión chiloense y el golfo de corcovado (42°-45°S). XXXVIII Congreso de Ciencias del Mar, Valdivia, Chile. 14-18 de mayo.

Sonia Español-Jiménez, Paulina Bahamonde, Gustavo Chiang & Vreni Häussermann. Vocalizaciones de la ballena sei en el golfo de Penas, Chile. XXXVIII Congreso de Ciencias del Mar, Valdivia, Chile. 14-18 de mayo.

Sonia Español-Jiménez, Neus Pérez-Gimeno & Álvaro Paredes. Estimación del ruido de las embarcaciones de un área de gran relevancia para diferentes especies de cetáceos, el Golfo del Corcovado, Chile. XXXVIII Congreso de Ciencias del Mar, Valdivia, Chile. 14-18 de mayo.

Public Lectures – 2018

L. Hickmott. Blue Whales – Consummate Consumers. Three presentations for the National Geographic Society, covering blue whales in Antarctica and our Chilean blue whale research supported by MERI, November 2017.

Published Research Papers – 2017

A. Cuevas, A. Veragua, S. Español-Jiménez, G. Chiang and F. Tobar. 2017. Unsupervised blue whale call detection using multiple time-frequency features. Conference on Electrical, Electronics

Engineering, Information and Communication Technologies. Chile, 2017, pp. 1-6. doi: 10.1109/CHILECON.2017.8229663.

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. The Anatomical Record, 300:1935-1941 (2017). doi.10.1002/ar.23650

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

Conference Presentations – 2017

Sonia Español-Jiménez, Neus Pérez-Gimeno, Álvaro Paredes, Leigh Hickmott, Alessandro Bocconcelli, Gloria Howes, Paulina Bahamonde, Gustavo Chiang. Tráfico marítimo y ballenas en el Golfo del Corcovado. Segundo Simposio de Investigación de Mamíferos Marinos en Chile. La Serena 1-2 Diciembre.

Alejandro Cuevas, Alejandro Veragua, Sonia Español-Jiménez, Gustavo Chiang, Felipe Tobar. Sistema para procesar grandes volúmenes de datos en bioacústica: Aplicación a ballena azul. Segundo Simposio de Investigación de Mamíferos Marinos en Chile. La Serena 1-2 Diciembre.

Carlos Cantergiani & Gustavo Chiang. Approach to a predictive model of habitat selection by blue whales (*Balaenoptera musculus*) based on satellite oceanographic measurements, between Chiloense ecoregion and Corcovado gulf (42° - 45°S). International Marine Protected Areas Congress - IMPAC4, La Serena, Segundo Simposio de Investigación de Mamíferos Marinos en Chile. La Serena 1-2 Diciembre.

Alejandro Cuevas, Alejandro Veragua, Sonia Español, Gustavo Chiang y Felipe Tobar. "Framework for Processing Large Datasets in Bioacustic: The Blue-Whale Case Study", IEEE EVIC 2017. [best poster award, not peer reviewed, not indexed]

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.

Carlos Cantergiani, Gustavo Chiang. Approach to a predictive model of habitat selection by blue whales (*Balaenoptera musculus*) based on satellite oceanographic measurements, between Chiloense ecoregion and Corcovado gulf (42° - 45°S). International Marine Protected Areas Congress - IMPAC4, La Serena, 4-8 September. E-poster.

Sonia Español-Jiménez, Neus Pérez-Gimeno, Álvaro Paredes, Leigh Hickmott, Alessandro Bocconcelli, Gloria Howes, Paulina Bahamonde, Gustavo Chiang. Maritime traffic and whales in the Corcovado Gulf, Chile. International Marine Protected Areas Congress - IMPAC4, La Serena, 4-8 September. E-poster.

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 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

Alejandro Veragua, Alejandro Cuevas, Gloria Howes, Paulina Bahamonde, Gustavo Chiang and Felipe Tobar. "Blue whale's call detection using unsupervised learning with temporal and spectral features." IEEE EVIC 2016 [best poster award (3rd place), not peer reviewed, not indexed]

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.

Durban J., Moore M., Chiang G., Hickmott L., Bocconcelli A., Bahamonde P., Howes G., Perryman W. & LeRoy D. Fotogrametria de ballenas azules con un hexacoptero no tripulado. XXXVI Congreso de Ciencias del Mar. May 23rd-27th, Concepcion, Chile.

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.

Moore M., Durban J., Fearnbach H., Leroi D., Miller C, Kerr C., Caruso F., Perryman W., Chiang G., Hickmott L. & A. Bocconcelli. Large Whale Photogrammetry and Blow Collection using Unmanned Multi-copters. 21st Biennial Conference on the Biology of Marine Mammals: Bridging the Past Toward the Future. December 13th-18th, San Francisco CA. USA.

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.

Public Lectures – 2018

G. Chiang, S. Español-Jiménez, A. Bocconcelli, P. Bahamonde. "Community and Science" lecture. Public Library "Martina Barrientos Barbero", Castro, Chile.

Bahamonde P. ¿Qué nos dice el comportamiento cetáceo de la salud del mar? “IV Temporales de Ciencia de Chiloé” Public Library "Martina Barrientos Barbero", Castro, Chile.

Español-Jiménez S. Estudiando a las ballenas a través de sus sonidos. “Ciclo de charlas mes del mar” Universidad Andrés Bello, Santiago, Chile.

Public Lectures – 2017

P. Bahamonde and D. Casado. Patagonia Azul, la interconexión de la Vida. Interview for PlanetaC E-Magazine. Santiago. August 2017.

MERI. Participation in Ciencia al Parque. organized by Par Explora Santiago-Norte, Santiago, November 2017.

MERI. Participation in Festival ConCausa. Santiago, November 2017.

G. Chiang. Bailahuen la voz de las ballenas del sur. One presentation during Festival Puerto de Ideas, Valparaiso, November 2017.

G. Chiang. Interview by Nadia Politis for TV Show Ciencia en primera Persona (CNN-Chile). August 2017.

G. Howes. Cetáceos de Patagonia. Workshop in Puerto Gaviota to strengthen a responsible whale watching tourism. Organized by CIEP. Puerto Gaviota, August 2017.

G. Chiang. Colaboración para la conservación de Patagonia. During the seminar Biodiversidad y conservación marina, organized by Par Explora Aysen, Coyhaique. May 2017.

G. Chiang. Bailahuén la voz de las ballenas del sur. Four presentations during Festival Puerto de Ideas, Antofagasta, April 2017.

MERI. #Somosmar en Lollapaloozza, April 2017

MERI. Environmental Educational Program. 15 workshops for schools in Northern Patagonia, Valdivia and Santiago.

Español-Jiménez S. Hablando con científicos, organized by Par Explora Los Ríos, Valdivia. 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)

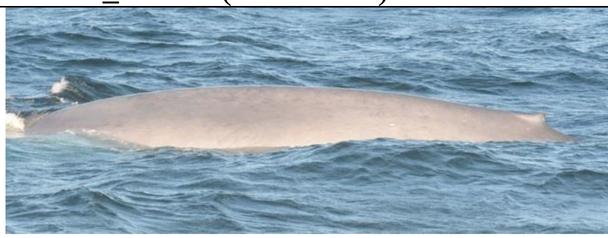

Chile15_Bm006 (Left Dorsal)


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)

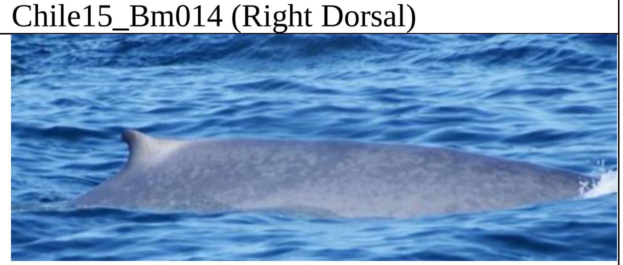
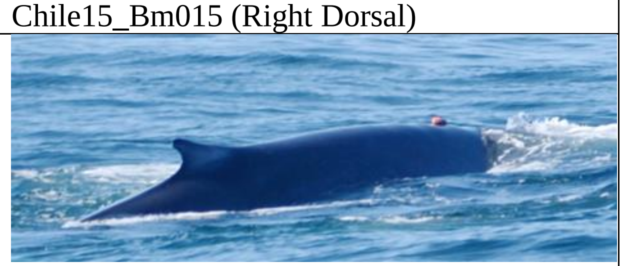

Chile16_Bm010 (Right Dorsal)


Chile15_Bm011 (Left Dorsal)


Chile15_Bm011 (Right Dorsal)


Chile18_Bm011 (Left Dorsal)

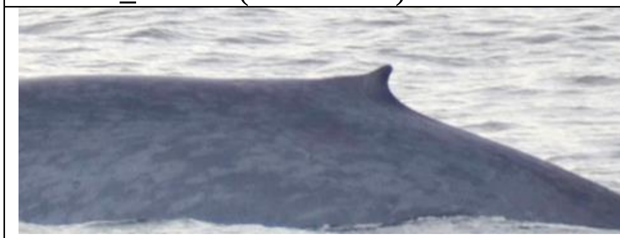

Chile18_Bm011 (Right Dorsal)

 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)

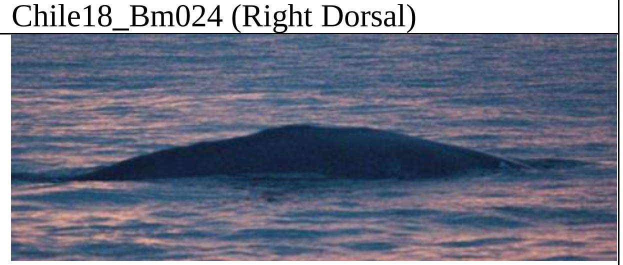

Chile15_Bm024 (Left Dorsal)


Chile15_Bm024 (Right Dorsal)


Chile18_Bm024 (Left Dorsal)


Chile18_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)


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)
 Chile16_Bm051 (Left Dorsal)	
 Chile16_Bm052 (Left Dorsal)	 Chile16_Bm052 (Right Dorsal)
 Chile18_Bm052 (Left Dorsal)	 Chile18_Bm052 (Right Dorsal)


Chile16_Bm053 (Left Dorsal)


Chile16_Bm053 (Right Dorsal)


Chile18_Bm053 (Left Dorsal)


Chile18_Bm053 (Right Dorsal)


Chile16_Bm054 (Left Dorsal)


Chile16_Bm054 (Right Dorsal)


Chile16_Bm055 (Left Dorsal)


Chile16_Bm055 (Right Dorsal)


Chile16_Bm057 (Right Dorsal)


Chile16_Bm058 (Left Dorsal)


Chile16_Bm058 (Right Dorsal)

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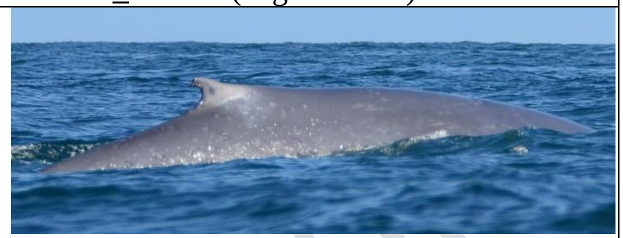
 Chile16_Bm060 (Left Dorsal)	 Chile16_Bm060 (Right Dorsal)
 Chile16_Bm061 (Left Dorsal)	
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 Chile16_Bm063 (Right Dorsal)	
 Chile16_Bm064 (Right Dorsal)	


Chile16_Bm065 (Left Dorsal)


Chile16_Bm065 (Right Dorsal)


Chile16_Bm066 (Left Dorsal)

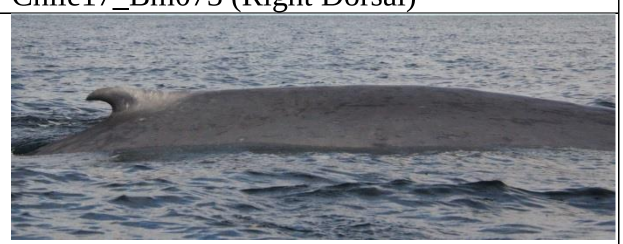

Chile16_Bm067 (Right Dorsal)

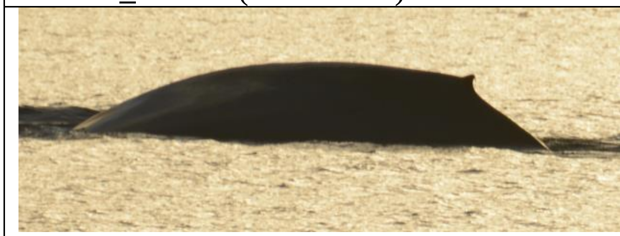
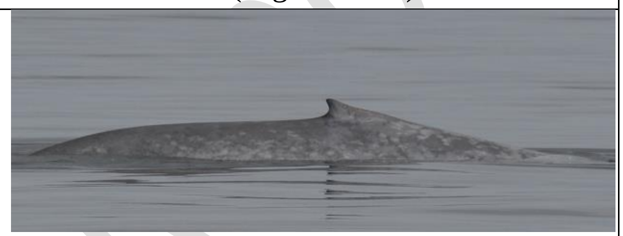

Chile16_Bm068 (Right Dorsal)


Chile16_Bm069 (Left Dorsal)


Chile16_Bm069 (Right Dorsal)


Chile16_Bm070 (Left Dorsal)

 Chile18_Bm070 (Left Dorsal)	 Chile18_Bm070 (Right 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)
 Chile18_Bm077 (Left Dorsal)	 Chile18_Bm077 (Right Dorsal)
 Chile18_Bm078 (Left Dorsal)	 Chile18_Bm078 (Right Dorsal)
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