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Comparisons within Southern Hemisphere Blue Whale Catalogue in the Southeast Pacific and Eastern Tropical Pacific region reveals strong site fidelity to feeding areas and connectivity between southern Chile and Eastern Tropical Pacific¹

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Comparisons within Southern Hemisphere Blue Whale Catalogue in the Southeast Pacific and Eastern Tropical Pacific region reveals strong site fidelity to feeding areas and connectivity between southern Chile and Eastern Tropical Pacific¹

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Abstract

Blue whales occur in the Southeast Pacific and Eastern Tropical Pacific (ETP) but little is known about their long-term movements. The Southern Hemisphere Blue Whale Catalogue is a platform to share individual photo-identification catalogues among blue whale research groups. Comparisons of 838 photo-identified blue whales from five different research groups working in southern and northern Chile and the ETP, as well as opportunistic sightings, provided 25 re-sightings. One match revealed information on the connectivity and migration of blue whales from southern Chile to the ETP. Other matches were found within southern Chile and within northern Chile, providing further evidence for strong site fidelity to feeding areas. The longest re-sighting occurred over 18 years and one animal was seen 11 times on six different years. This is the first regional assessment of blue whale photo-identification and habitat use along the Southeast Pacific and the ETP. Our results highlight the importance of collaborative work to understand blue whale movements and migration, and show that some groups of whales use discrete feeding areas.

Introduction

In the Southern Hemisphere, the pygmy blue whale (*Balaenoptera musculus breviceauda*) in the Indian Ocean and western Pacific Ocean and the Antarctic blue whale (*B. m. intermedia*) in the Southern Ocean are currently recognized as two subspecies by the Taxonomy Committee of the Society for Marine Mammalogy². In addition, the yet unnamed subspecies or Chilean blue whale has been proposed as a separate subspecies (*B.m. spp.*) because it is morphologically (Branch *et al.* 2007; Pastene *et al.* 2020), genetically (LeDuc *et al.* 2007; LeDuc *et al.* 2017), and acoustically (McDonald *et al.* 2006) distinct. More recently, Leslie *et al.* (2020) used drone photographs to show that these Chilean blue whales are morphologically intermediate in size (both total length and relative tail length) between pygmy and Antarctic blue whales and further supports the uniqueness of these whales.

Chilean blue whales are known to feed during the austral summer and autumn (late December to early May) in southern Chile off Isla Grande de Chiloe and in the Corcovado Gulf (Cummings and Thompson 1971a, b; Gilmore 1971; Findlay *et al.* 1998; Hucke-Gaete *et al.* 2004; Cabrera *et al.* 2005; Abramson and Gibbons, 2010; Försterra and Häussermann 2012; Galletti Vernazzani *et al.* 2012a). An additional feeding aggregation of blue whales off Isla Chanaral in northern Chile was first reported in 2012 but this area is not used annually by blue whales. (Galletti Vernazzani *et al.* 2012b).

Photo-identification data from long-term studies and a coordinated, multi-site effort is required to accurately assess population abundance, population trend and connectivity of blue whales (IWC 2017). Since 2008, the International Whaling Commission (IWC) Scientific Committee has supported the collaborative Southern Hemisphere Blue Whale Catalogue (SHBWC) to facilitate this work (IWC 2009). To date, the SHBWC represents the most important collection of blue whale catalogues in the Southern Hemisphere. Blue whales off Chile and Australia have become assessment priorities for the sub-committee on Other Southern Hemisphere Whale Stock population assessments (IWC 2017).

Previous photo-identification comparisons from SHBWC catalogues from areas off the Southeast Pacific, the Eastern Tropical Pacific (ETP), the Southern Ocean (Galletti Vernazzani and Cabrera 2011; Galletti

¹ This paper is respectfully and fondly dedicated to the memory of Dr. Carole Carlson who greatly contributed to the research and studies of the Chilean blue whale population.

² <https://www.marinemammalscience.org/species-information/list-marine-mammal-species-subspecies/>

Vernazzani and Olson 2012; Olson *et al.* 2020) and waters off Australia, New Zealand and Sri Lanka (Galletti Vernazzani *et al.* 2019) have been reported.

The first matching process for different areas off Chile and ETP was conducted with about 300 individuals uploaded to the SHBWC through 2009. Only one match between different catalogues was found over a ten-year period; both sighting locations were in southern Chile (Galletti and Cabrera 2011). Following the first matching process, the SHBWC has received important new contributions for the Southeast Pacific region (Galletti Vernazzani *et al.* 2021) and the matching process for identification photos from this region has been completed. This paper presents results of comparisons between catalogues of blue whales off Chile, Peru and the ETP received at the SHBWC through March 2020.

Methods

The SHBWC now contains photo-IDs of more than 2,189 individual blue whales. These whales have been geographically separated into four major regions from waters off: 1) Antarctica, 2) Australia/New Zealand/Indonesia, 3) Southern Africa/Madagascar, and 4) Gulf of California/Eastern Tropical Pacific/South America (Galletti Vernazzani *et al.* 2021). Blue whales are individually identifiable from the unique pattern of mottling on both sides of the body near the dorsal fin (Sears *et al.* 1990), and from the highly variable dorsal fin shape (Gendron and Ugalde de la Cruz 2012). Separate photographic collections for left sides, right sides and flukes are maintained under the SHBWC. Left and right side photographs of individual blue whales were compared between each group to determine the number of individuals re-sighted in different study sites.

By March 2020, the Gulf of California/Eastern Tropical Pacific/South America sub-catalogue of the SHBWC included photographs of 838 individuals comprising 619 left side IDs, 625 right side IDs, and 11 photo-IDs from flukes (Table 1). Records in the regional catalogue from the Gulf of California/Eastern Tropical Pacific/South America area were contributed by: 1) the 1997/98 IWC/SOWER survey off Chile, 2) Centro de Conservacion Cetacea off southern and northern Chile between 2004 and 2015, 3) the MERI Foundation off southern Chile between 2014 and 2017, 4) Panthalassa off northern Chile between 2010 and 2019, 5) SWFSC/NOAA during various years between 1992 to 2009 off the Galápagos Islands, Peruvian waters and the Costa Rica Dome, and 6) opportunistic sightings off Peru, northern Chile and southern Chile from 2010-2018. Details on opportunistic sightings are given in Table 2.

Whale photographs received by March 2020 from South America and ETP were compared for this report (n=838 IDs). Matching histories of each whale within the catalogues of each research group are not included. Details, when available, are given for each match found between records contributed by different research groups.

Results

Comparisons of left and right photo-IDs were completed and 25 matches were found. Most of the matches were within southern Chile (n=22) but they covered a wide area in the north from 40° to 47° in the south. There were two matches within northern Chile (29°) despite a relatively small sample size (n=67). No matches were found between northern and southern waters of Chile.

One match provided important evidence about migration movements and connectivity of blue whales between southern Chile and Eastern Tropical Pacific. The individual involved (Figure 1 - ID#25, Table 3) was first seen by SWFSC/NOAA on 21 October 2003 about 500 miles south of Galapagos Islands and 700 miles west of Peru (9,06°S-89,02°W). It was later seen by the CCC three times on 22 February 2006 (41,89°S-74,12°W) and again on 21 and 22 February 2008 (41,99°S-74,17°W and 42,00°S-74,09°W) off northwestern Isla de Chiloe. There are approximately 2,450 miles between the ETP location and the southern Chile location.

The longest time between recaptures was 18 years. This match was previously reported between a sighting made on 5 January 1998 from IWC SOWER Cruise 1997/98 and a sighting made by CCC on 13 March

2008, approximately 220 km apart in southern Chile (Galletti Vernazzani and Cabrera, 2011). The whale was later seen again by CCC off northwestern Isla de Chiloe on 21 February 2015 (ID#22, Table 3).

Two whales have been seen over a period of 12 field seasons/years, also in the CCC Catalogue. These whales were previously named by CCC as *Moro* (ID#19, Table 3) and *Shimi* (ID#17, Table 3).

Moro was last seen on 23 November 2018 in the Gulf of Penas by Isabella Clegg and the crew of the research group Patagonia Projects, who contributed their opportunistic photographs to the SHBWC. The whale had been seen previously by CCC off northwestern Isla de Chiloe during 2007, 2008 and 2014.

Shimi was seen four times in 2006, 2010 and 2017 off northwestern Isla de Chiloé. In 2006, this whale exhibited a severe skin condition along the entire body that was classified as blister-like lesions (Brownell *et al.* 2008). The last opportunistic photographs from 2017 were contributed by Sheila Wright. Preliminary photo-ID comparisons showed that these lesions persisted over a 11-year period (Figure 2). However, the appearance of the lesions remained virtually unchanged over this period – perhaps indicating, at least in this animal, that they were not a progressive, or even life-threatening, disease.

Six whales have been seen over 11 years in southern Chile. One of them, named *Valentina* (ID#2, Table 3), has been sighted 11 times and recorded on six different years. This is the whale that have been found more times over the studied period.

Another whale (ID#15 and 16) was first seen by CCC at northwestern Isla de Chiloe in 2009, resighted in 2010 by the Huinay Scientific Field Station (Försterra and Häussermann, 2012) and again by the MERI foundation in 2016, both in the east inlets. This corresponds to one of the previously two (ID#20) reported matches between CCC and Huinay Scientific Field Station (Försterra and Häussermann, 2012).

A smaller database was available in northern Chile with contributions from CCC (2012-2013, n=30) and from Phantalassa (n= 37). Two matches were found (ID# 23 and 24) off Isla de Chañaral; both whales were first seen by CCC in 2013 and both whales were resighted by Phantalassa in 2017, all sightings occurred on different days.

Discussion and conclusions

Our results found 22 matches between blue whales off southern Chile. This is consistent with the high overall annual return rate previously reported for Isla de Chiloe (Galletti Vernazzani *et al.* 2012, 2017).

Using photo-ID data from 2004 to 2012, the number of blue whales feeding in the waters off Isla de Chiloe was estimated as ~570-760 whales, with periodic fluctuations in abundance suggesting that use of this survey area varies between years (Galletti Vernazzani *et al.* 2017). Försterra and Häussermann (2012) already reported that two out of five whales opportunistically photographed in the east inlets waters of the Chiloe region were previously sighted off northwestern Isla de Chiloe. The matches found in this study between the west coast of Isla de Chiloe and the east inlets of Chiloe region provide further evidence that whales travel between these two areas.

A sighting of a known individual from the Chilean blue whale population in the Gulf of Penas extends the range of the subspecies and raises further questions about its habitat use. Furthermore, it may represent an expansion of the southern Chile feeding area or another feeding site (Clegg *et al.* In Prep.).

The photo-id collection of the SHBWC also provides the opportunity to assess other important aspects such as health status. The images of the match of the individual with skin lesions over 11-year period are a clear illustration of this, and also indicate the value that such data can have for conducting other studies such as the prevalence of scars.

Galletti Vernazzani *et al.* (2017) reported that blue whales seen in Chiloe were not seen in Isla de Chañaral (northern Chile) because of the lack matches between these areas. We found two matches within northern

Chile (n=67), and none within southern Chile (n=771). These data provide further evidence of strong site fidelity.

Only one match between northern and southern Chile has been reported (Galletti Vernazzani *et al.* 2012a) to date. In this regard, it has been suggested that Chilean blue whales regularly visit multiple feeding sites along the Chilean coast during the summer season, explaining both the regional site fidelity and the lack of population structuring between feeding sites (Galletti Vernazzani *et al.* 2017).

Our match between ETP and southern Chile provides further evidence on the migration of blue whales and the connectivity between these regions. Based on year-round sightings of unidentified blue whales, the Eastern Tropical Pacific (ETP - Costa Rica Dome, Galapagos waters) has been proposed as a possible winter destination of this population (Reilly and Thayer 1990; Palacios 1997). Genetic, acoustic, satellite tag and photo-identification data have also found connections between the whales found off southern Chile and the ETP (Buchan *et al.* 2014, 2015; Torrez-Flores *et al.* 2015, Hucke-Gaete *et al.* 2018). These observations strongly suggest that at least some Chilean blue whales from southern Chile feeding ground migrate to west of the Galapagos Islands and into the Eastern Tropical Pacific (ETP) for breeding and calving.

Chilean blue whales are not the only Southern Hemisphere baleen whale to use the southern ETP during winter. Southern Hemisphere humpback whales also winter in Central American waters (Rasmussen *et al.* 2007). Therefore, this unique spatial overlap occurs in populations of both species from the Southern Hemisphere and Northern Hemisphere. In both cases, the warmer ETP waters may be important for rapid calf development and growth (Rasmussen *et al.* 2007).

Our study is the first regional assessment of blue whale photo-identification and habitat use along the Southeast Pacific and the ETP. Our results highlight the importance of collaborative work to better understand blue whale movements that provided insights into blue whale migration and showed the discrete use of feeding areas for certain groups of whales. Continued international collaboration will contribute to a better understanding of blue whales in this region and help identify critical areas that need further management and their health status.

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Figure 1 – Individual blue whale (ID#25, table 3) sighted off a) ETP on 2003 and b) southern Chile on 2006

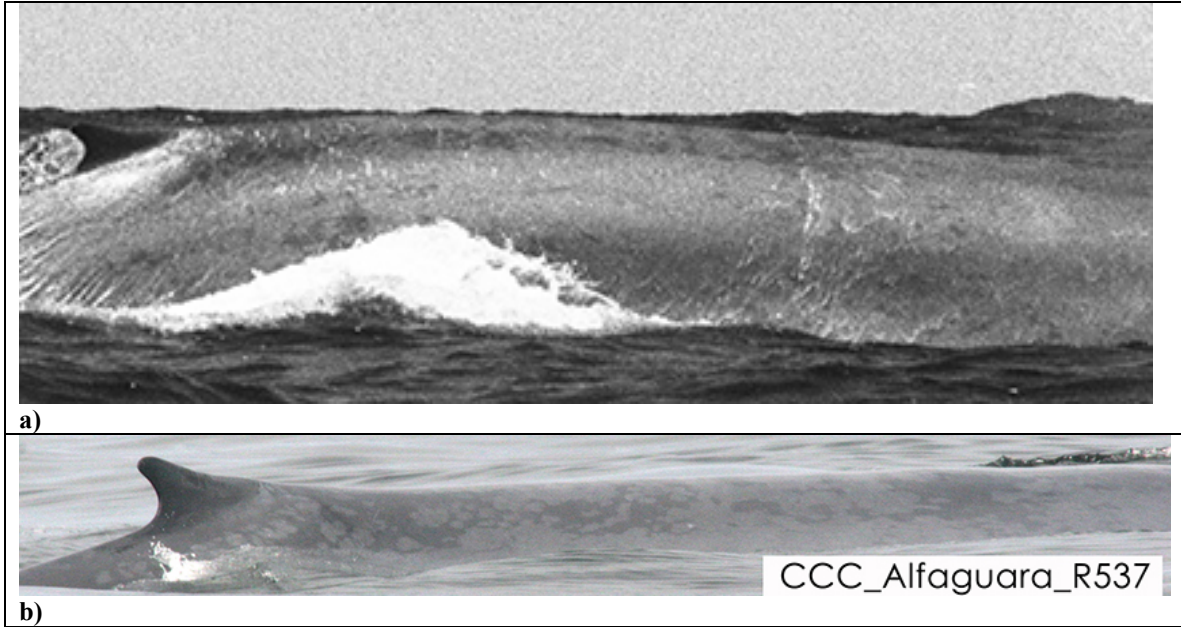


Figure 2 - Individual blue whale (ID#17, table 3) with blister-like lesions sighted off northwestern Isla de Chiloe on a) 2006 and b) 2017

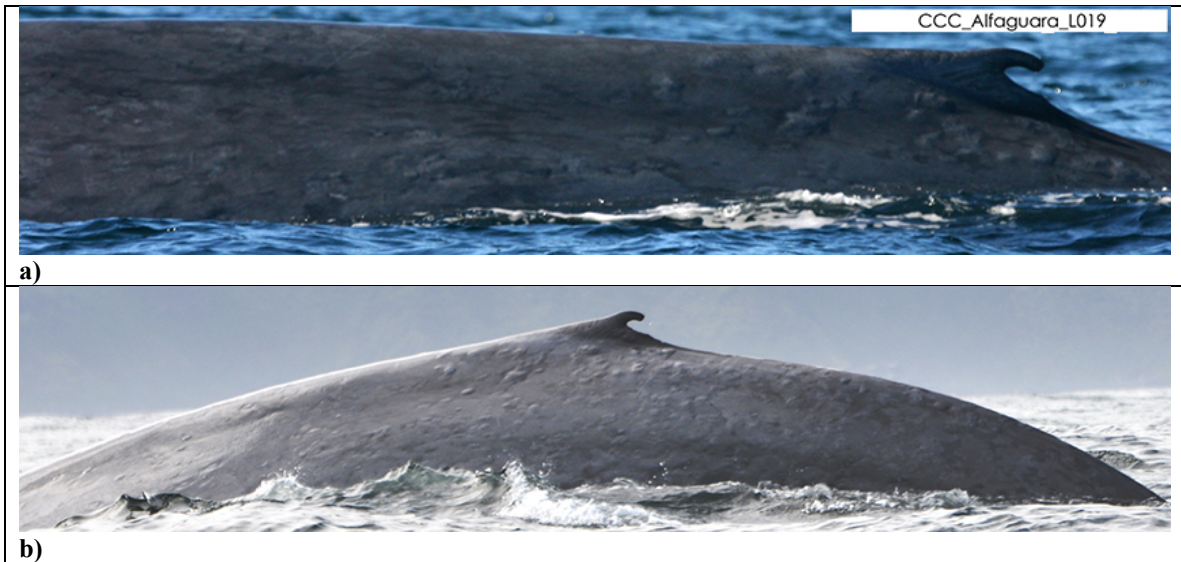


Table 1 – Summary of photographic collection of blue whale photo-identifications under the Gulf of California/ETP/South America sub-catalogue of the SHBWC as of March 2020

Group	Years	Whales IDs	Fluke	Left	Right	Area
SWFSC	1992-2009	83	0	60	53	Peru, Ecuador, ETP
CCC	2004-2015	621	0	469	484	Northern and southern Chile
IWC Chile	1997-1998	21	0	14	9	Chile
MERI	2014-2017	60	9	48	45	Southern Chile
Phantalassa	2010-2019	37	2	16	28	Northern Chile
Opportunistic Southeast Pacific	2010-2018	16	0	12	6	All
Sub-total		838	11	619	625	

Table 2 – Summary of opportunistic blue whale photo-identifications off Southeast Pacific as of March 2020

WhaleID	Contributor	Date of sighting	Location	Lat	Long
Huinay10 001	Vreni Haussermann – Huinay Foundation	24-04-2010	Fiordo Comau, southern Chile	-42,314012	-72,485994
Huinay10 002	Vreni Haussermann – Huinay Foundation	24-04-2010	Fiordo Comau, southern Chile	-42,314012	-72,485994
Huinay10 003	Vreni Haussermann – Huinay Foundation	26-05-2010	Fiordo Comau, southern Chile	-42,314012	-72,485994
Huinay10 004	Vreni Haussermann – Huinay Foundation	26-05-2010	Fiordo Comau, southern Chile	-42,314012	-72,485994
Huinay10 005	Vreni Haussermann – Huinay Foundation	26-05-2010	Fiordo Comau, southern Chile	-42,314012	-72,485994
Chiloe11	Fabian Ritter	02-03-2011	Cruce Corcovado-Moraleda, southern Chile	-43,534640	-73,347384
Chiloe13	Juan Pablo Castro	01-02-2013	Isla Lilihuapi, southern Chile	-42,1444	-72,585000
Peru15	Aldo Pacheco / Fiorella Sanchez-Salazar	28-08-2015	Los Organos, northern Peru	-4,129233333	-81,1685
Peru15b	Aldo pacheco / Fiorella Sanchez-Salazar	28-08-2015	Los Organos, northern Peru	-4,129233333	-81,1685
Peru15c	Aldo pacheco / Fiorella Sanchez-Salazar	28-08-2015	Los Organos, northern Peru	-4,129233333	-81,1685
Corcovado16	Marcelo Flores	31-03-2016	Golfo Corcovado, southern Chile	-43.878	-73.23
Mejillones16	Ana Maria Garcia Cegarra	20-11-2016	Peninsula de Mejillones, northern Chile	-23,20861111	-70,6072222
Chiloe17	Sheila Wright	08-02-2017	Puñihuil, southern Chile	-41,92472222	-74,0391666
Chiloe17b	Sheila Wright	08-02-2017	Puñihuil, southern Chile	-41,92472222	-74,0391666
Peru18	Aldo Pacheco	12-08-2018	Los Organos, northern Peru	-4,09368	-81,0996
GolfoPenas18	Isabella Clegg	23-11-2018	Golfo Penas, southern Chile	-46,724682	-75,510022

Table 3 - Results from comparisons among SHBWC groups from South America and ETP as of March 2021

ID	Groups	Whales IDs	Date and Location 1	Date and Location 2	Date and Location 3	Date and Location 4	Date and Location 5	Date and Location 6	Date and Location 7	Date and Location 8	Date and Location 9	Date and Location 10	Date and Location 11	#Years Seen	Time spanning (seasons)
Southern Chile															
1	CCC & MERI	CCC_037 and Bm 054	16-02-06 -41,91111 -74,10222	20-02-08 -41,84253 -74,21783	26-02-16 -42,99051 -72,87564									3	11
2	CCC & MERI	CCC_043* and Bm019	17-02-2006 -41,92806 -74,09917	20-04-2007 -41,75911 -74,17815	21-04-2007 -41,897 -74,139	20-01-2008 -41,965 -74,090	02-03-2008 -42,00776 -74,28084	13-03-2008 -41,95693 -74,25914	20-02-2010 -41,85797 -74,12638	24-03-2010 -41,90308 -74,20868	25-04-10 -41,88951 -74,25352	04-03-2015 -43,0407 -72,9172	22-02-2016 -42,88766 -72,8817	6	11
3	CCC & MERI	CCC_057 and Bm041	22-02-2006 -41,88722 -74,12917	12-02-2010 -41,77006 -74,10218	21-02-2016 -42,93982 -72,86562									3	11
4	CCC & MERI	CCC_071 and Bm032	24-02-2006 -41,98417 -74,14361	02-02-2008 -41,9089 -74,1810	10-02-2008 -41,96335 -74,17275	02-03-2008 -42,02002 -74,16606	18-02-2016 -42,8832 -73,12686							3	11
5	CCC & MERI	CCC_074 and Bm023	01-03-2006 -41,82972 -74,10944	22-02-2007 -41,96077 -74,21408	05-03-2015 -42,4311 -72,9661									3	10
6	CCC & MERI	CCC_096 and Bm067	21-03-06 -41,91667 -74,14639	11-03-15 -41,62010 -74,15500	02-03-16 -42,60742 -72,92172									3	11
7	CCC & MERI	CCC_203 and Bm017	26-04-07 -41,88413 -74,20288	03-03-14 -43,35120 -73,15970										2	8
8	CCC & MERI	L337 and Bm043	06-04-2010 -41,96007 -74,11016	22-02-2016 -42,94008 -72,85789										2	7
9	CCC & MERI	L349 R859 and Bm008	24-04-10 -41,95338 -74,33427	25-04-10 41,91777 74,28621	04-03-15 -42,86730 -72,99990									2	6
10	CCC & MERI	L358 and Bm076	25-04-2010 -41,84252 -74,31728	03-03-2017 -42,40131 -72,82657										2	8
11	CCC & MERI	L458 and Bm037	15-03-2013 -42,22581 -74,45403	01-04-2013 -41,96771 -74,18470	23-02-2015 -41,93553 -74,32824	19-02-2016 -42,95552 -72,88731								3	4
12	CCC & MERI	L458, R954 / R983 and Bm064	15-03-13 -42,22581 -74,45403	01-04-13 -41,96771 -74,18470	23-02-15 -41,93553 -74,32824	01-03-16 -42,65032 -72,93481								3	4
13	CCC & MERI	R957 and Bm 057	01-04-13 -41,98293 -74,20119	28-02-16 -43,06036 -72,95380										2	4
14	CCC & MERI	L487 and Bm072	04-03-2015 -41,97252 -74,20985	25-02-2017 -42,45093 -73,1014										2	3
15 & 16	CCC & MERI & Opportunistic	CCC_387 - Bm065 and Huinay 003	19-04-2009 -42,05151 -74,41516	26-05-2010 -42,31401 -72,48599	02-03-2016 -42,58027 -72,9023									3	8

17	CCC & Opportunistic	CCC_027* * and Chiloe 17b	16-02-06 -41,91806 -74,25278	25-02-06 -42,04000 -74,18528	30-01-10 -41,95821 -74,18208	08-02-17 -41,92472 -74,03917									3	12
18	CCC & Opportunistic	CCC_159 and Chiloe 17	08-03-07 -41,96474 -74,24531	08-02-17 -41,92472 -74,03917											2	11
19	CCC & Opportunistic	CCC_200* ** and Golfo Penas 18	26-04-07 -41,90218 -74,18292	27-04-07 -41,848140 -74,266720	17-03-08 -41,12283 -74,04732	27-01-14 -42,07393 -74,22601	28-01-14 -42,06798 -74,21519	23-11-18 -46,72468 -75,51002							4	12
20	CCC & Opportunistic	CCC_216 and Huinay 002	27-04-07 -41,84687 -74,23619	24-04-10 -42,314012 -72,485994											2	4
21	CCC & Opportunistic	CCC_276 and Chiloe 13	20-02-08 -41,98965 -74,18537	21-02-08 -41,95978 -74,15201	28-02-13 -42,14440 -72,58500										2	6
22	IWC SOWER & CCC	Ch009 - CCC 315	05-01-98 -39,96000 -74,15000	13-03-08 -41,94 -74,29	21-02-15 -41,84575 -74,26669										3	18
Northern Chile																
23	CCC & Phantalassa	L432/ R935 - PTHS011	16-02-13 -28,98290 -71,56507	18-01-17 -29,0507 -71,549811	15-01-17 -28,981189 -71,540836										2	5
24	CCC & Phantalassa	L429 - PTHS025 -	15-02-13 -29,06649 -71,57204	17-02-13 -29,00095 -71,58929	15-02-17 -29,010709 -71,560619	11-02-17 -29,041697 -71,561681	14-02-17 -29,02614 -71,53584								2	5
ETP and southern Chile																
25	SWFSC/NOA & CCC	E0318 - CCC 058	21-10-2003 -9,06 -89,02	22-02-2006 -41,88722 -74,12916	21-02-2008 -41,98616 -74,16531	22-02-2008 -42,0006 -74,09354									3	6

* Whale named *Valentina*

** Whale named *Shimi*

*** Whale named *Moro*