Chilean blue whales off Isla Grande de Chiloe, 2004-2010: distribution, photo-identification and behavior

Bárbara Galletti Vernazzani[1], Carole A. Carlson[2], Elsa Cabrera[1] and Robert L. Brownell Jr.[3]

1 Centro de Conservación Cetacea (CCC) - Casilla 19178 Correo 19, Santiago, Chile – barbara@ccc-chile.org
2 Provincetown Center for Coastal Studies, 5 Holway Avenue, Provincetown, MA 02657, USA
3 Southwest Fisheries Center, NOAA, 1352 Lighthouse Ave, Pacific Grove, California, 93950, USA

ABSTRACT

A collaborative research program (the Alfaguara Project) has collected information related to the conservation status of Chilean blue whales (*Balaenoptera musculus)* off Isla Grande de Chiloe, off southern Chile, through eight aerial and 85 marine surveys. A total of 365 individual blue whales was photo-identified from 2004 to 2010. Approximately 20% of all catalogued individuals were resighted within the same season and 31% were resighted between years. Recaptures of photo-identified individuals from other areas to the north and south of our main study area support the hypothesis that the feeding ground off southern Chile is extensive and dynamic. The high overall annual return and sighting rates highlight the waters off northwestern Isla de Chiloe and northern Los Lagos as the most important aggregation areas known for this species in Chile and the Southern Hemisphere. Observations on feeding and social behavior also were recorded. To monitor the conservation status of these whales, it is essential that long-term photographic identification research and line-transect surveys to monitor health conditions and population trends be continued off northwestern Isla de Chiloe. The high frequency of large vessels in the mouth of the Chacao Channel (along the north side of Chiloe) and the high number of blue whales in the area raises the possibility of vessel collisions. Therefore, it is necessary to develop and implement a conservation plan for these whales to address this and other potential threats.

KEYWORDS
Distribution, site fidelity, feeding, photo-ID, Chilean blue whale, eastern South Pacific Ocean, Chile

INTRODUCTION

During the 20th century, blue whales (*Balaenoptera musculus*) became a principal target of the whaling industry worldwide (Clapham *et al.*, 1999). Off Chile, the first commercial catches occurred in 1908 from a land station in San Carlos, Corral (Pastene and Quiroz 2010). Between 1926 and 1971, catches of approximately 3,000 blue whales were reported with 670 taken in the 1960's (Aguayo *et al.*, 1998).

Until recently, only two subspecies of blue whale have been recognized in the Southern Hemisphere: the pygmy blue whale (*Balaenoptera musculus brevicauda)* in the Subantarctic zone and the Antarctic or true blue whale (*B. m. intermedia*) that summers in the Antarctic Zone (Rice, 1998). Blue whales in Chilean waters have been classified as either Antarctic blue whales or pygmy blue whales (Aguayo L., 1974). Branch *et al.* (2007a) reported that adult female blue whales taken off Chile are intermediate in length between the total lengths of the two subspecies recognized in the Southern Hemisphere and may represent a unique population or a different subspecies. In addition, LeDuc *et al*. (2007) analyzed genetic samples from off southwestern Australia, the southeastern Pacific (Chile), and the Antarctic and found that the genetic differentiation between Antarctic blue whales and pygmy blue whales was not markedly greater than between Australian and Chilean blue whales. Although more data are needed to resolve this question, the IWC (2006) agreed that the blue whales off Isla Grande de Chiloe (= Isla de Chiloe) differ from Antarctic blue whales and therefore need to be managed as a separate population.

Outside of Antarctic waters, aggregation areas used by blue whales are poorly known (Branch *et al*., 2007b) and specific feeding areas are almost unknown (Gill 2002, Hucke-Gaete *et al*., 2004). Recently, blue whales have been reported in the waters of the northern Los Lagos region (Galletti Vernazzani *et al*., 2005, 2006, 2008), off the west coast of Isla de Chiloe (Cabrera *et al*., 2005), extending south to the Corcovado Gulf, and the Chonos Archipelago (Hucke-Gaete *et al*. 2004). Additionally, only two sightings have been reported during winter in the inlet waters east of Chiloe near the mainland (Abramson and Gibbons, 2010). Our systematic research highlighted the northwestern coast of Isla de Chiloe as an important feeding area in the austral summer and early fall (Cabrera *et al.*, 2006; Galletti Vernazzani *et al*, 2005, 2006, 2007a, 2008). These studies also indicated that the sighting rate of blue whales off northwestern Isla de Chiloe is among the highest in the Southern Hemisphere (Branch *et al.*, 2007b).

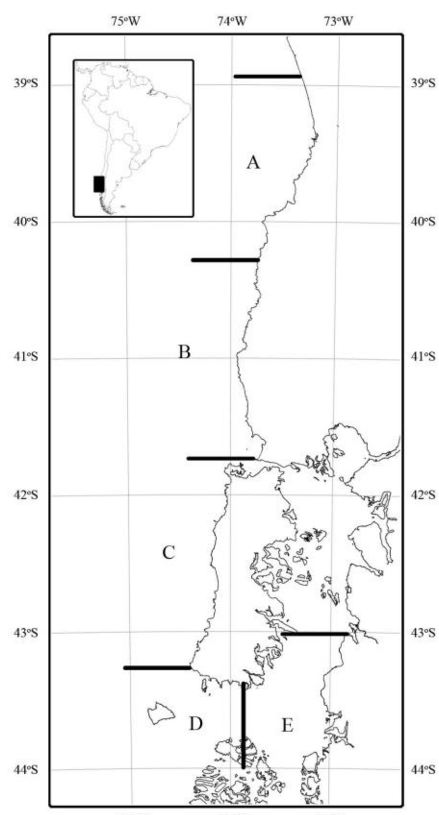
Here we present summary results of the Alfaguara (Chilean blue whale) Project conducted by the Centro de Conservacion Cetacea (CCC) from 2004 to 2010. Information on group size, behavior, distribution, relative abundance, photo-identification, and site fidelity is analyzed. Potential threats and conservation implications for the Chilean blue whale population are discussed.

METHODS

Study area

The study covers an area of approximately 33,259km^2, from 39^{o}S to 44^{o}S within 20nm from the coastline (Figure 1). In 2005 and 2006, the area of coverage was from 40^{o}S to 43^{o}S and it was extended from 36^{o}S to 44^{o}S in 2007 and 2008. Dedicated marine surveys for photo-identification and other research activities were conducted primarily off northwestern Isla de Chiloe, between 41º45'S and 42º12'S within 12 nm from the coastline, on board the 7m *Alfaguara* research vessel. One marine survey was conducted off northern Los Lagos in 2008 and one around the Corcovado Gulf in 2004 on board a 30m Chilean Navy surveillance vessel.

Figure 1 – Study area with five sub-areas: A= south Araucania and Los Rios; B=northern Los Lagos; C=west Isla de Chiloe; D=west Corcovado Gulf; E=east Corcovado Gulf



Aerial surveys and spatial analyses

In December 2003, we conducted an aerial survey off Isla de Chiloe with no sightings of baleen whales. From 2004 to 2010, we conducted one aerial survey each year between February and April. These nine aerial surveys were conducted to monitor blue whale distribution and relative abundance in southern Chile (39^o-44^oS) thanks to the support of the Chilean Navy (DIRECTEMAR). Three of these aerial surveys were conducted using standard line transect methods to estimate abundance (Buckland et *al.*, 1993) and will be reported on in future publications. In 2004, visibility was too poor to allow completion of the aerial survey so only data from 2005 to 2010 are used in our spatial analyses.

All aerial surveys were conducted with Beaufort Sea State less than 4 and covered an area from shore up to a maximum of 20nm. Most surveys were conducted on board a four-seat, twin engine Cessna Skymaster aircraft with flat windows flown at an altitude of 900 feet and an average airspeed of 120 knots. Helicopters were used only in February 2005 and March 2008. Two dedicated observers, one seated on each side of the aircraft, recorded sighting data and weather conditions. The pilot and co-pilot from the Chilean Navy also contributed to the sighting effort. The transect lines and locations of whales were recorded using a Global Positioning System (GPS). Weather and sea conditions were recorded at the start of each transect or whenever weather conditions changed.

When a group of whales was sighted, species, location, time, group size, behavior and other species present were recorded by each observer. While conducting aerial line-transect surveys to estimate abundance, the downward angle to the group perpendicular to the aircraft's track (at 90^o) was also measured using a hand-held clinometer (Suunto PM5/360PC). Since blue whales are highly visible from the air, surveys were conducted in 'passing mode' (i.e. the aircraft did not leave the trackline to investigate a sighting) (Buckland *et al*., 1993), except when species identification or group size was uncertain and close to the trackline. In these cases, survey effort was broken off to circle the animals and then the trackline was resumed at the break point.

Based on data collected from aerial surveys, blue whale distribution in southern Chile was assessed and relative abundance, using sighting per unit effort (SPUE in groups of blue whales per km) and density kernel estimates, was calculated. Density kernels have been used to graphically represent blue whale density distribution in southern Australia (Gill, 2011). Comparisons of SPUE were performed within five sub-areas, varying from 6.407km^2 to 6.877km^2 each (Figure 1) and at a smaller scale using a 10km^2 grid. Sighting data were weighted by survey effort (km) to correct biases.

Marine surveys

Boat-based photo-identification surveys were conducted during Beaufort Sea State 3 or less. Sound recordings, fecal, and plankton samples also were collected with associated data on group composition, location and behavior of whales as well as weather, sea conditions, sea surface temperature and association with other marine fauna such as birds or marine mammals.

Photo-identification analyses

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 in some cases permanent scars can be used to identify or confirm individuals. We maintain separate photographic catalogues for the left and right sides of the head region, dorsal fin, flank and caudal peduncles, but here we only used the left-side flank with dorsal fin catalogue. The overall consistency in research design, data collection techniques and data analysis allowed between-year comparisons to be made (Cabrera *et al*., 2006).

Clear, well-focused photographs of individual blue whales were compared within season to determine the number of individuals sighted, resighting matches and residency time (number of days between first and last sightings within the same season). All individual whales were then compared to the master CCC catalogue to determine if they were new or unknown. The overall annual return rate was calculated as the proportion of individuals resighted in later years. Photographs of low quality or whales only partially photographed were not included in the catalogue.

Group size and behavioral analyses

Group size was calculated using all data obtained during marine and aerial surveys. Behavioral analyses were performed using data from marine surveys conducted from 2006 to 2008 to ensure overall consistency in research design and data collection.

The following behavioral patterns were established following terms used previously (Gill, 2002; Sears *et al*., 1999) and personal observations made by us in southern Chile: (1) "side-fluking" - the whale rolled on one side and exposed one tip of the fluke, sometimes exposing the distended throat pleats; (2) "fluking-up" - the fluke is raised out of the water; (3) "circling movements" - the whale made continual changes in swim direction over a radius of 1km; (4) "social behavior" - chasing, partial breaches, high-speed swimming and forceful blows are observed while two or more whales are interacting; (5) "head out of the water" - the whale lift its head out of the water; (6) "fast swimming" - swimming at more than 12 knots; (7) "prolonged dive times" - dives are longer than 10 minutes; (8) "sub-surface travel" whales swim just below the surface; (8) and "stationary" - whales do not move at the surface. The presence of light reddish-brown feces was also recorded. Contingency tables were used to investigate if there was an association between any behavior and observations of feces.

RESULTS

Distribution and relative abundance

Eight aerial surveys were conducted between February and April 2005 to 2010, with a total on-effort distance of 4,352 km. We recorded 203 blue whales in 138 groups. The northernmost blue whale sighting was at 40.39^{o}S and 73.80^{o}W and the southernmost sighting was at 43.80^{o}S and 73.38^{o}S (Figure 2). No mother-calf pairs were observed.

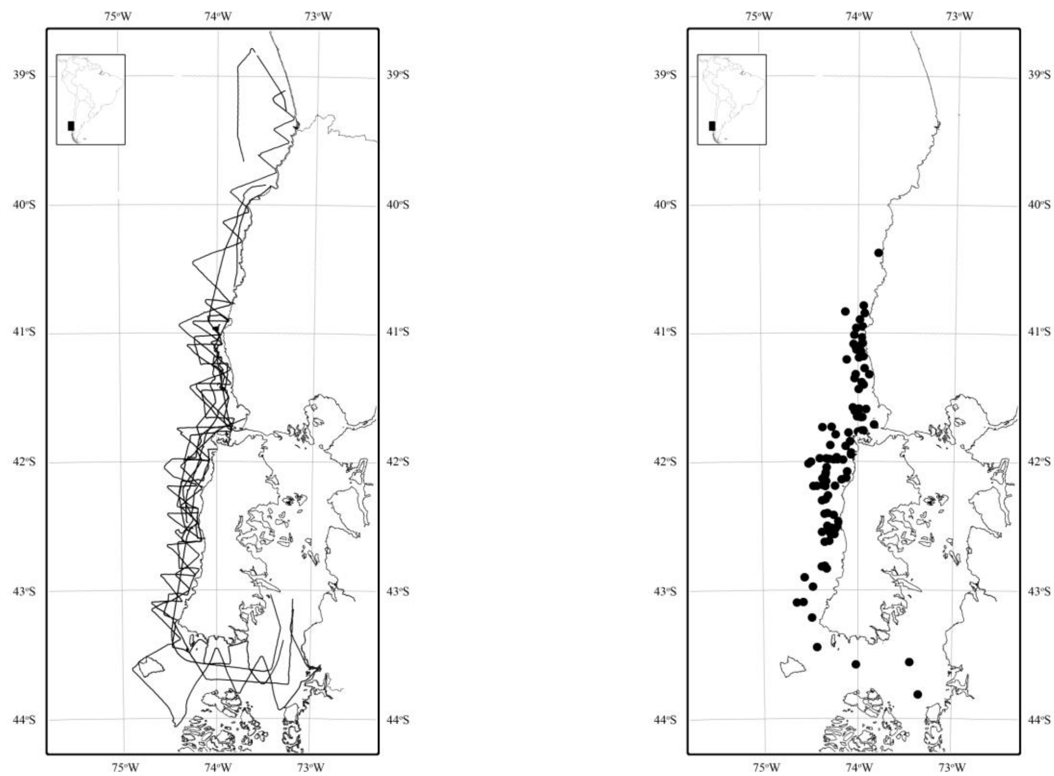
Relative abundance is expressed as sighting per unit effort in groups of whales per 1,000km for the five sub-areas (Table 1). Overall sighting rates including all regions were 31.7 groups of blue whales per 1,000 km and 46.7 blue whales per 1,000 km. Sighting rates ranged from 169.4 groups of whales per 1,000 km to zero, depending on the area. Relative abundance of blue whales in Northern Los Lagos and west Isla de Chiloé was one order magnitude higher than in other areas.

All aerial survey track lines and sighting locations of each group from 2005-2010 are shown in Figure 2. The relative abundance (SPUE within each 10km^2) and kernel density using effort-weighted data from the 2005 – 2010 aerial surveys are shown in Figure 3. SPUE indicates relative abundance in discrete 10 km^2 grid cells, while the kernel density shows probability contours produced by smoothing the data over a surface. During February – April, the highest probability of finding an individual is off the northwestern coast of Isla de Chiloé and north of the Chacao Channel when blue whales are aggregated in this southern austral summer-autumn feeding ground.

Table 1 - Summary of aerial surveys from 2005 to 2010 for each sub-area and all areas combined

Year	*Effort (km)*					*Number of Groups / Individual blue whales*					*SPUE (groups of whales 1000 km^{-1})*				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
2005	0	227.8	220.4	0	0	-	9/12	11/22	-	-	-	39.5	49.9	-	-
2006	0	94.4	85.2	0	0	-	16/27	4/5	-	-	-	169.4	46.9	-	-
2007	223.0	255.0	255.6	225.9	225.9	0/0	8/11	4/4	0/0	2/3	0	31.4	15.6	0	8.8
2008	155.6	192.6	229.6	70.38	111.1	0/0	4/6	20/31	1/1	0/0	0	20.8	87.1	14.2	0
2009	0	275.9	490.8	107.8	112.2	-	4/5	22/32	0/0	0/0	-	14.5	44.8	0	0
2010	0	202.8	339.3	133.3	118.3	-	8/10	24/32	1/1	0/0	-	39.6	70.7	7.5	0
All years	**378.6**	**1,247.6**	**1,620.8**	**537.5**	**567.6**	**0**	**49/71**	**85/126**	**2/2**	**2/3**	**0**	**39.3**	**52.4**	**3.7**	**5.3**
Overall			**4,352**					**138/203**					**31.7**		

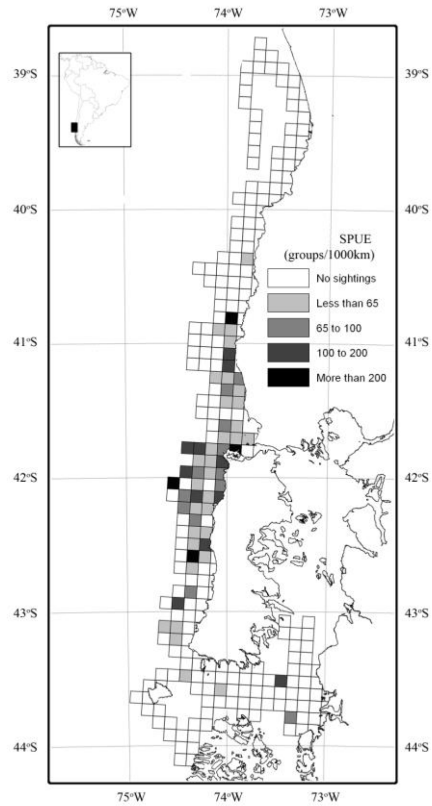
Figure 2 – Aerial surveys 2005-2010: a) tracks and b) sightings of groups of blue whales



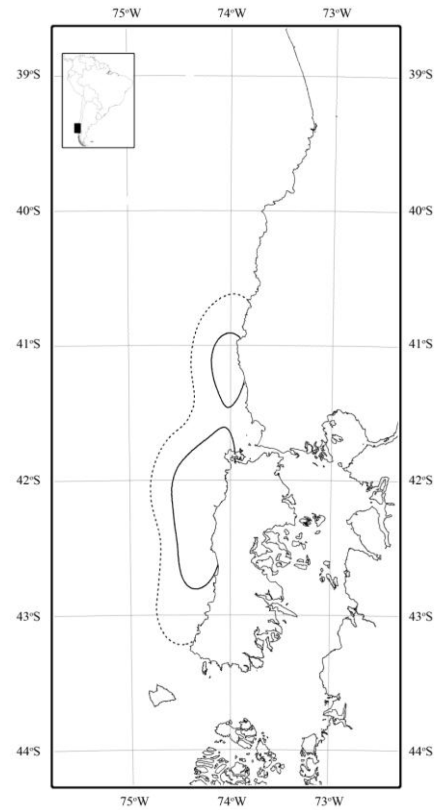
a) black line = aerial survey tracks

b) black dot = sightings of groups of blue whales

Figure 3 – Blue whale relative abundance and distribution probability expressed as (a) SPUE and (b) kernel density using effort-weighted data from 2005-2010 aerial surveys



a) Sighing per unit effort on a 10km grid (groups of whales*1000km^{-1})



b) Density kernel analysis. Thick lines represent 50% and dashed lines represent 90% of the volume of a probability density distribution of blue whales.

Photo-identification

Eighty-five photo-identification surveys totaling 453hr were conducted. A total of 621 blue whale groups was encountered containing 945 individuals. The number of whales encountered does not include animals resighted on the same day. The 2004-2010 CCC catalogue consists of 365 individual blue whales. Eighty-four individuals have been resighted during the same season, including twenty individuals that have been sighted on several occasions. Seventy four individuals were sighted in different years, including thirteen sighted in three different years and three on four years (Table 1).

Table 1 – Photo-ID effort, groups and number of blue whales approached

Year	**Sampling Period (mo/d)**	**Number of surveys**	**Hours of Observation (hrs)**	**Groups of blue whales encountered**	**Number of blue whales encountered**	**Blue whale individuals**		
						New Photo-id	Re-sightings within season	Re-sightings on later years
2004	02/25 – 03/15	2[1]	17:35	2	3	4	0	2
2005	02/01 – 03/15	8	29:13	25	58	11	1	4
2006	02/04 – 04/15	12	67:15	70	112	54	8	27
2007	02/01 – 04/29	17	94:54	142	188	89	26	27
2008	02/01 – 04/30	17	93:33	171	270	76	39	10
2009	02/01 – 04/30	12	68:55	82	124	56	6	4
2010	01/25 – 04/30	17	81:39	129	190	75	25	-
	TOTAL	**85**	**453:04**	**621**	**945**	**365**	**105**[2]	**74**[3]

[1] One marine survey (10.25 hr) in the Corcovado Gulf.
[2] Corresponds to 84 individuals catalogued
[3] Thirteen individuals have been seen in three different years and three on four different years.

From 2005 to 2010, the proportion of individuals observed on multiple days during a season ranged from 8.3% to 37.5%, with a mean residency rate of 19.7% (S.D=11.3%); most of the individuals were resighted one (34.9%) or two times (8.5%). Minimum residency time ranged from 2 to 71 days, with a mean of 17 days (S.D=19 days). In 2008 and 2010, an individual was observed on five occasions over a period of 25 days and 55 days respectively. In 2008, 37.5% of all documented individuals in this season were observed on multiple occasions, the highest residency rate documented to date. By contrast, the lowest residency rate of 8.3% was obtained in 2009.

From 2005 to 2009, the site fidelity to northwestern Isla de Chiloe, expressed as overall annual return rate of individuals, was 31.2% (S.D=18.1%; Range= 7% to 50%). Most between-year sightings occurred off northwestern Isla de Chiloe and corresponded to animals previously sighted in close proximity to the same area. However, one individual first photo-identified in east Corcovado Gulf (43.72°S / 73.11°W) on 13 March 2004 was resighted off northwestern Isla de Chiloe (41.74°S / 74.09°W) on 20 April 2007. Another individual previously photo-identified on 21 December 2006 off Atacama Region (29.03°S / 71.55°W) by Carlos Aguilar, a member of the CCC National Marine Mammal Sighting Network, was resighted off northwestern Isla de Chiloe on 22 February 2007 (41.96°S / 74.21°W) and 26 April 2007 (41.89°S / 74.18°W) (Galletti Vernazzani *et al.*, 2007). Finally, an individual first photo-identified at northwestern Isla de Chiloe on 26 April 2007 (41.90°S / 74.18°W) was resighted on 27 April 2007 (41.86°S / 74.26°W) and again photo-identified on 17 March 2008 off northern Los Lagos (41.12°S / 74.04° W) (Galletti Vernazzani *et al.*, 2008).

Group size and behaviour

Blue whales generally were observed alone (52.1%) or in a group of two (43.5%) individuals. Groups of three whales were sighted on 25 occasions (3.5%) and larger groups of four or six whales represented less than 1% of all observations. In 2005, 2008 and 2009, the number of pairs of blue whales recorded was greater than the number of solitary individuals. Fifty-eight of the 138 sightings during aerial surveys were groups of two or three whales with similar body lengths. Almost all individuals seen during the 2004 to 2010 marine surveys were considered non-calves (i.e. adults or sub adults). The first mother-calf pair was recorded during a marine survey off northwestern Isla de Chiloe on 2 February 2008 and was resighted on 20 February 2008 close to the previous location. The smaller whale was identified as a calf by its size (half the length of the larger whale) and behavior (staying close the other whale and surfacing on alternate sides of it). The mother also was resighted on 8 February without the calf. On 21 February 2009, a second mother-calf pair was observed.

Within a given observation period, whales exhibited one to six different behaviors. The time we spent in the proximity of a group of whales varied from less than a minute up to 30 minutes. We recorded behavior in 321 encounters (67%). The three most frequently observed behaviors were: circling movements (47.0%), fluking up (33.3%), and side-fluking (21.8%). Additional behavioral observations included the whale lifting its head out of the water (10.3%), fast swimming (11.5%), prolonged dive times (8.7%), sub-surface travel (3.4%) and stationary (2.5%). In 25.5% of the cases when we recorded behavior, we also observed light reddish-brown feces. Social behaviors were recorded on 2.2% of all observations. Similar social behavior by blue whales has been recorded in the Gulf of St. Lawrence (Sears *et al.*, 1999) and was first reported off northwestern Isla de Chiloe in 2006 (Galletti Vernazzani *et al*., 2006).

DISCUSSION

Northern Los Lagos seems to represent the upper limit of this austral summer feeding area, although more systematic effort needs to be made in southern Araucania and Los Rios to resolve this question. Sighting rates of blue whales off northwestern Isla Chiloe have been reported to be among the highest in the Southern Hemisphere along with the Madagascar Plateau, south of Madagascar, and off southwestern Australia (Branch *et al.*, 2007b). Gill *et al.* (2011) recently reported 10 blue whales per 1,000 km for the southern Australia coastal upwelling zone. The high sighting rate, number of identified individuals and degree of site fidelity we documented, confirms that the waters off Isla de Chiloe and northern Los Lagos contain the largest aggregation known for this species in Chile and one of the largest aggregations in the Southern Hemisphere.

Over the period of this study, a total of 365 whales was identified by photographs. This number is larger than the abundance estimate of 303 (see discussion below) obtained using a combined standard line-transect and spatial density models with data from a survey conducted in December 1997 (Williams *et al*., 2011). An overall annual return rate of 31% shows high site fidelity off northwestern Isla de Chiloe and highlights the importance of these waters for this population. Photo-identification data were also used to conduct an in-depth analysis of scars and lesions (Brownell *et al*., 2007, 2008) and general health condition (Galletti Vernazzani *et al.*, 2007b, 2008).

Fiedler *et al.* (1998) reported that the dynamics of prey aggregations may be an important factor affecting whale distribution. Between-year resightings of individual blue whales off northwestern Isla de Chiloe that matched individuals identified in east Corcovado Gulf and northern Los Lagos support the idea that the blue whale feeding ground off southern Chile is large and dynamic. However, the physical and ecological processes of "The Pacific Patagonia cold estuarine front" which extend southward (42^{o}S) from Isla de Chiloe to the tip of South America are poorly known (Acha *et al*., 2004).

Behavioral analyses indicate that this area is used as a feeding ground for blue whales and that fluking-up and circling movements may also be associated with feeding behavior. Side-fluking has been considered a feeding behavior and sub-surface feeding has been inferred from frequent short-duration fluke-up dives, with whales resurfacing near the point of diving (Gill, 2002). Our data indicate that circling movements observations, even if whales were not fluking-up, and direct fluking-up observations are significantly related to observations of feces (p-value<0.05) and therefore are attributed to feeding.

The risk of collision is higher in areas where cetacean concentration and vessel traffic frequency are high (Laist *et al*., 2001). In recent years, a number of blue whale strandings have occurred in areas with high densities of whales and commercial vessels off southern California. These strandings have been spatially associated with the location of the shipping lanes and the dead whales had wounds typical of a ship strike (Berman- Kowalewski *et al.* 2010). The high frequency of large vessel transiting the northern Los Lagos region enters the Chacao Channel towards Puerto Montt and other inland water locations. The northern Los Lagos and northwestern Isla de Chiloe, at the west entrance of Chacao Channel also have the highest density of blue whales in Chile. This raises concerns about possible vessel collisions with whales in the region. Therefore, it is critical to monitor any cetacean strandings to determine cause of death and develop mitigation measures to address any emerging threat.

Based on the line-transect surveys conducted from the IWC-SOWER 1997/98 blue whale cruise off central Chile (Findlay *et al*., 1998), Branch *et al*. (2007c) estimated a population abundance of 452 individuals using standard line-transect methods. Williams *et al*., (2011) reanalyzed these data using spatial modeling methods and obtained a new abundance estimate of 303 whales. These authors indicated that their estimate was a minimum because the survey, conducted between18 December 1997 to 1 January 1998, did not covers the waters south of 38˚S, north of 18˚S, waters outside the Economic Exclusive Zone (EEZ), and the inshore waters (east of 12 nm to the coast) in Chile. Williams *et al*. (2011) noted that surveys south and inshore of the SOWER survey area, both before and after SOWER, observed large numbers of blue whales in the inshore waters east of the Isla Chiloe and the Corcovado region (Hucke Gaete *et al*., 2004, Galletti Vernazzani *et al.*, 2006). The 1997/98 El Nino event has been considered one of the strongest ever recorded. Therefore, we believe it is unlikely that many, if any blue whales, were west of the SOWER survey area (outside the EEZ) because the vessels traveled south to north, and blue whales had already moved into coastal waters due to the El Nino Event. Therefore, any blue whales missed during the SOWER survey would have been ones east of the area surveyed (between the coast and out to 12 nm). Also, our survey data since 2004 have shown no records of blue whales in the western coastal waters of Isla de Chiloe in December and early January. Therefore, it is unlikely that blue whales were missed in southern Chilean waters or outside the EEZ at the time of the SOWER survey was conducted.

CONCLUSIONS

Southern Chile is an important feeding ground for this unique blue whale population in the Southern Hemisphere. Therefore, it is essential that long-term photo-identification research, line-transect surveys, and work to determine the cause of death in stranded individuals be continued in Chilean waters to monitor population trends, the health status of individuals and to understand the overall conservation status of this population. We recommend the development of an action plan for the recovery of this species in Chilean waters that includes the protection of critical habitats and the implementation of effective conservation measures to address potential threats such as vessel collisions and habitat degradation.

AKNOWLEDGEMENTS

We wish to thank the Directorate General of the Maritime Territory and Merchant Marine (DIRECTEMAR) from the Chilean Navy and the Ministry of Foreign Affairs for their Official Support to the Alfaguara Project. We would also like to thank the valuable support of Rufford Foundation, Mohamed Bin Zayed Species Conservation Fund, Global Ocean, Marisla Foundation, Cetacean Society International and SAS Software Solutions for the analytical program JPM 7.0. We would also like to express our special gratitude to the northwestern coastal communities of Isla de Chiloé, in particular the Puñihuil community, and our skipper Mr. Jose Aviles as well as the assistant with photo-identification matching work of Ms. Priscila Escobar.

REFERENCES

Abramson, J. and Gibbon, J. 2010. New records of blue whales *Balaenoptera musculus* (Linnaeus, 1758) in winter season in the inlet waters of Chiloé continental - Chile. *Anales Instituto Patagonia* 38(2):107-109

Acha, E. M., Mianzan, H. W., Guerrero, R. A., Favero, M and Bava, J. 2004. Marine fronts at the continental shelves of austral South America physical and ecological processes. *Journal of Marine Systems* 44:83-105.

Aguayo L., A. 1974. Baleen whales off continental Chile. Pages 209-217. *In*: *The Whale Problem: a status report.* W. E. Schevill (editor), Harvard University Press, Cambridge.

Aguayo-Lobo, A., Torres, D. and Acevedo, J. 1998. Los mamíferos marinos de Chile: I. Cetacea. *Serie Científica INACH* (Chile) 48: 19-159.

Berman- Kowalewski, M. et al. 2010. Association between blue whale (Balaenoptera musculus) mortality and ship strikes along the California coast. *Aquatic Mammals* 36(1):59-66.

Branch, T.A., Abubaker, E.M.N., Mkango, S. And Butterworth, D.S. 2007a. Separating southern blue whale subspecies based on length frequencies of sexually mature females. *Marine Mammal Science* 23(4): 803-833.

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

Branch, T. A., Zerbini, A. N. and Findlay, K. 2007c. Abundance of blue whales off Chile from the 1997/98 SOWER survey. Paper SC/59/SH8 presented to the IWC Scientific Committee, May 2007 (unpublished). 9 pp.

Brownell Jr., R.L., Carlson, C., Galletti Vernazzani, B. and Cabrera, E. 2007. Skin lesions on blue whales off southern Chile: Posible conservation implications?. Paper SC/59/SH21 presented to the IWC Scientific Committee, May 2007 (unpublished). 6pp. [Available from the authors]

Brownell Jr., R.L., Carlson, C., Galletti Vernazzani, B. and Cabrera, E. 2008. Skin lesions of blue whales off southern Chile: Posible conservation implications?. Paper SC/60/SH25 presented to the IWC Scientific Committee, June 2008 (unpublished). 8pp. [Available from the authors]

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, London. 446pp.

Cabrera, E., Carlson, C. and Galletti Vernazzani, B. 2005. Presence of blue whale (*Balaenoptera musculus*) in the northwestern coast of Chiloé Island, southern Chile. *LAJAM* 4(1): 73-74.

Cabrera, E., Carlson, C., Galletti Vernazzani, B. and Brownell Jr., R.L. 2006. Preliminary report on the photo-identification of blue whales off Isla de Chiloé, Chile from 2004 to 2006. Paper SC/58/SH18 presented to the IWC Scientific Committee, May 2006 (unpublished). 5pp. [Available from the authors]

Clapham, P.J., Young, S.B. and Brownell Jr., R.L. 1999. Baleen whales: conservation issues and the status of the most endangered populations. *Mamm. Rev.* 29: 35–60.

Findlay, K., et al. 1998. 1997/1998 IWC-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) blue whale cruise, Chile. Paper SC/50/Rep2. Presented to the IWC Scientific Committee, April 1998 (unpublished). 40pp. [Available from the IWC office].

Fiedler, P. C., Reilly, S. B., Hewitt, R. P., Demer, D., Philbrick, V., Smith, S., Armstrong, W., Croll, D. A., Tershy, B. R., and Mate, B. R. 1998. Blue whale habitat and prey in the California Channel Islands. *Deep-Sea Research II*. 45:1781-1801.

Galletti Vernazzani, B., Carlson, C. and Cabrera, E. 2005. Blue whale sightings during the 2005 field season in northwestern Chiloé Island, southern Chile. Paper SC/57/SH14 presented to the IWC Scientific Committee, May 2005 (unpublished). 4pp. [Available from the Office of this Journal].

Galletti Vernazzani, B., Carlson, C., Cabrera, E. and Brownell Jr., R.L. 2006. Blue, sei and humpback whale sightings during 2006 field season in northwestern Isla de Chiloe, Chile. Paper SC/58/SH17 presented to the IWC Scientific Committee, May 2006 (unpublished). 6pp. [Available from the authors]

Galletti Vernazzani, B., Carlson, C., Cabrera, E., and Brownell Jr., R.L. 2007a. Status of blue whales off Isla de Chiloé, Chile, during 2007 field season. Paper SC/59/SH1 presented to the IWC Scientific Committee, May 2007 (unpublished). 7pp. [Available from the authors]

Galletti Vernazzani, B., Carlson, C., Cabrera, E., and Brownell Jr., R.L. 2007b. Status of blue whales off Isla de Chiloé, Chile, from 2004 to 2007. 17th Biennial Conference on the Biology of Marine Mammals. Cape Town, South Africa, 29 November-3 December 2007.

Galletti Vernazzani, B., Carlson, C., Cabrera, E. and Brownell Jr., R.L. 2008. Status of blue whales off Isla de Chiloé, Chile, during 2008 field season. Paper SC/60/SH24 presented to the IWC Scientific Committee, June 2008 (unpublished). 9pp. [Available from the authors]

Gill, P. 2002. A blue whale (*Balaenoptera musculus*) feeding ground in a southern Australian coastal upwelling zone. *Journal of Cetacean Research and Management* 4(2): 179-184.

Gill, P., Morrice, M., Page, B., Pirzl, R., Levings, A.H., Coyne, M. 2011. Blue whale habitat selection and within-season distribution in a regional upwelling system off southern Australia. *Mar Ecol Prog Ser* 421: 243-263.

Hucke-Gaete, R., Osman, L.P., Moreno, C., Findlay, K.P. & Ljungblad D.K. 2004. Discovery of a blue whale feeding and nursing ground in southern Chile. *Proc. R. Soc. Lond. B (Suppl.), Biology Letters* 271: S170–S173.

International Whaling Commission. 2006. Report of the Scientific Committee. Annex H Other Southern Hemisphere Whale Stocks. *J. Cetacean Res. Manage*. 9 (Supp.): 1-498.

International Whaling Commission. 2009. Report of the Scientific Committee. Annex H. Other Southern Hemisphere Whale Stocks. *J. Cetacean Res. Manage*. 11 (Suppl.): In press.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta M. 2001. Collisions between ships and whales. *Marine Mammal Science*, 17(1):35-75

LeDuc, R.G., Dizon, A.E., Goto, M., Pastene, L.A., Kato, H., Nishiwaki, S., Leduc, C.A. and Brownell, R.L. 2007. Patterns of genetic variation in the Southern Hemisphere blue whales and the use of assignment test to detect mixing on the feeding grounds. *J Cetacean Res Manage* 9:73–80

Pastene, L.A. and Quiroz, D. 2010. An Outline of the History of Whaling in Chile. pp. 73-98. In: International Center for Folk Culture Studies (eds.). Human Culture from the Perspective of Traditional Maritime Communities, International Symposium Report No. 1. Kanagawa Shimbun Press, Kanagawa. 199pp.

Rice, D.W. 1998. *Marine mammals of the world, Systematics and distribution*. Society of Marine Mammalogy Special Publication Number 4. +231pp.

Sears, R., Williamson, J.M, Wenzel, F.W., Berube, M, Gendron, D. and Jones, P. 1990. Photographic identification of the blue whale (*Balaenoptera musculus*) in the Gulf of the St. Lawrence, Canada. *Rep. int. Whal. Comm.* (Special Issue) 12:335–342.

Sears, R. Berchok, C. L., Palsbol, P., Doniol-Valcrose, T. and Ramp, C. 1999. Gender related structure in blue whales (*Balaenoptera musculus*) pairs from Eastern Canadian waters. Abstract from: The 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii. Pp. 169.

Williams, R., Hedley, S., Branch, T. A., Bravington, M., Zerbini, A. N., and Findlay, K. 2011. Chilean blue whales as a case study to illustrate methods to estimate abundance and evaluate conservation status of rare species. *Cons. Bio*. 25 (3): 526–535.