Dolphins distributions (Mammalia: delphinidae) in an upwellings zone (Chile)

Distribución de delfines Mammalia: delphinidae) en una zona de surgencias (Chile)

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Abstract

The results of a study on sighting frequency and relative abundance of delphinids along the coast of Northern Chile (18°30'S-25°23'S; from coast to 70°27°W), conducted between March and December 2000 in an area of 207.614,60 km^2 are reported. The following eight species were sighted: Short-beaked Common Dolphin (*Delphinus delphis*), Long-beaked Common Dolphin (*Delphinus capensis*), Short-finned Pilot Whale (*Globicephala macrorhynchus*), Risso's Dolphin (*Grampus griseus*), Dusky Dolphin (*Lagenorhynchus obscurus*), Southern Right Whale Dolphin (*Lissodelphis peronii*), Striped Dolphin (*Stenella coeruleoalba*) and Bottlenose Dolphin (*Tursiops truncatus*). The distribution of dolphins north of Tocopilla showed relationship with the coastal upwelling front of that area, while off the Mejillones Peninsula the relative abundance and diversity of dolphins was associated with the extensive upwelling plume described for this area.

T. truncatus was the most frequently sighted species (44.14% 111 herds) and represented 59.6% of the total observed specimens. *L. peronii* (15.10%) and *L.obscurus* (8.22%) follows numerically. Other species were represented by <4% of the total observed specimens.

The here found species are common to the Peruvian coast. Missing species are *Phocoena spinipinnis*, a more coastal species than the area covered by the present survey and *Pseudorca crassidens*, *Feresa attenuata*, *Peponocephala electra* and *Stenella longirostris*, which are from warmer waters and associated with the Paracas area. This study provides a first estimate of the distribution and relative abundance of small cetaceans of the upwelling ecosystem of Northern Chile.

Key words:

Delphinus delphis, Delphinus capensis, Globicephala macrorhynchus, Grampus griseus, Lissodelphis peronii.

Resumen

Se comunican los resultados de un estudio de frecuencias de avistamiento y abundancias relativas de delfínidos a lo largo de la costa norte de Chile (18°30'S-25°23'S; desde la costa hasta 70°27°O), realizado entre marzo y diciembre de 2000 en un área de 207.614,60 km^2. Las siguientes especies fueron avistadas: delfín común de rostro corto (*Delphinus delphis*), delfín común de rostro largo (*Delphinus capensis*), ballena piloto de aleta corta (*Globicephala macrorhynchus*), delfín gris (*Grampus griseus*), delfín oscuro (*Lagenorhynchus obscurus*), delfín liso (*Lissodelphis peronii*), delfín listado (*Stenella coeruleoalba*) y trursión (*Tursiops truncatus*). La distribución de delfines al norte de Tocopilla mostró

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estar relacionada con el frente de surgencia de ese sector, mientras que frente a la Península de Mejillones las abundancias relativas y la diversidad de delfines estuvieron asociadas con la extensa pluma de surgencia descrita para dicha área.
T. truncatus fue la especie más frecuentemente avistada (44,14% de 111 rebaños) y representada por 59,6% del total de individuos observados. *L. peronii* (15,10%) y *L. obscurus* (8,22%) siguen numéricamente, mientras que otras especies solo presentaron <4% del total de individuos estudiados. Las especies aquí encontradas son compartidas con las costas de Perú. Especies faltantes son *Phocoena spinipinnis*, una especie más costera que el área cubierta en el presente estudio, y *Pseudorca crassidens*, *Feresa attenuata*, *Peponocephala electra* y *Stenella longirostris*, que son de aguas más temperadas y asociadas al área en torno a Paracas. Este estudio representa la primera estimación de abundancias relativas de pequeños cetáceos para ecosistema de surgencias del norte de Chile.

Palabras clave:
Delphinus delphis, Delphinus capensis, Globicephala macrorhynchus, Grampus griseus, Lissodelphis peronii .

INTRODUCTION

The Humboldt Current System (HCS) is one of the most productive marine ecosystems on Earth (Barnes & Hughes, 1988; Escribano & McLaren, 1999) and extends from Southern Chile (~42°S) up to Ecuador and the Galapagos Islands (Thiel *et al.* 2007), characterized by dominant equatorward alongshore wind stress, offshore Ekman transport and coastal upwelling of cold, nutrientrich subsurfase water into the photic zone. The primary production can reach up to 9.3 g C m^{-2} d^{-1} (Daneri *et al.* 2000).

Upwelling in Northern Chile (north of ~42°S) appears to vary little with season and is a year-round feature (Morales *et al.* 1996), but related to local winds at periods about 3-10 days (Shaffer *et al.* 1997; Torres *et al.* 1999).

The coastal topography (*e.g.* points, capes) and bottom topography also affects the coastal upwelling circulation (Graham & Largier, 1997; Trowbridge *et al.* 1998), generating at a mesoscale important upwelling centers along the 18-22°S study area that can be identified as Península Mejillones, Punta Patache, Punta Chucumata, Punta Pisagua, Punta Camarones (Lagos *et al.* 2002; Marín & Moreno, 2002; Marín *et al.* 2003; Escribano *et al.* 2002, 2009).

The upwelling plumes of these centers can extend up to 50 km offshore (case of Mejillones Peninsula: Rodríguez *et al.* 1991; Marín *et al.* 2001; Sobarzo & Figueroa, 2001) and its interaction with the poleward Peruvian Counter-Current (PCC) may influence and exert a southward flow in Peruvian and northern Chilean waters up to 100–300 km from the coast (Silva, 1983; Strub *et al.* 1998), resulting in areas offshore and south of the upwelling focus that are relatively productive for oceanic feeders (Rendell *et al.* 2004) and creating a particularly productive habitat for fish spawning, eggs and larvae (Rojas *et al.* 2002) and in consequence feeding grounds for sea mammals.

This system is considered to be the most productive in terms of fish biomass, estimated to support a long-term production twenty times higher than the Benguela and Canary current systems (Marzloff & Tam, 2011) and supports the Chilean pelagic fishery, principally based on landings of anchovy, mackerel and pilchard, with total annual landings up to 6,9 million T between 18°25'S – 56°30'S (Thiel *et al.* 2007). But anchovy landings are most important in Northern Chile (Administrative Regions XV, I and II) with annual landings up to 2 million T in 1994-95 and around 0,5-1 annual T in last decades (SUBPESCA, 2016), with frequent interactions and incidental capture of top depredators, mainly otariids, but also in lower rates sea birds, sea turtles and small cetaceans (Böhm *et al.* 2017).

The knowledge of small odontocetes in the HCS, particularly delphinids, is inadequate (Clarke, 1962; Cárdenas *et al.* 1986; Aguayo-Lobo, 1999), although there are numerous studies that provide valuable local background on small cetaceans (Aguayo, 1975; Gallardo & Pastene, 1983; Guerra *et al.* 1987 b; Van Waerebeek & Guerra, 1987, 1988; González *et al.* 1989; Cárdenas *et al.* 1991; Canto *et al.* 1992; Sanino *et al.* 2003a, b; Sielfeld *et al.* 2003).

In the Chilean sector of the HCS (south of 18°S), Delphinidae is represented by nineteen

species (Aguayo, 1975; Sielfeld, 1983; Cárdenas *et al.* 1986; Guerra *et al.* 1987a, b; Canto *et al.* 1992; Aguayo-Lobo *et al.* 1998a; Hucke-Gaete, 2000), eight of which inhabit the neritic-littoral zone. Abundance indexes off Chile have only been calculated for few of these species (Aguayo-Lobo *et al., op. cit*), but the population size of most part of these species in the southeast Pacific is unknown.

Estimates of cetacean abundance and population density are key to assessing potential effects of anthropogenic perturbations on cetacean populations (Carretta *et al.* 2006) and in understanding the ecological role of cetaceans in marine ecosystems (Trites *et al.* 1997). However, there is little published information on current abundance to evaluate direct anthropogenic impacts on cetacean species and to estimate their food requirements (Barlow & Forney, 2007), aspects currently fundamental to regulate the by catch, the incidental death and other direct damages associated with the anchovy purse seine fishing of Northern Chile, the food needs of top depredators to ensure the implementation of the "ecosystem management concept" adopted by the "Nueva Ley de Pesca y Acuicultura de Chile" (Ley 18.892 y modificaciones de la Ley 21.134 del 16/02/2019) (Chilean Fishing Law), and to support the Protection programs for the various vulnerable and/or endangered species (sea turtles, birds, sea mammals).

Consequently the present paper focuses on the presence and relative abundances of delphinid species off Northern Chile, to contribute to understand the distribution and abundance of small cetacean in the northern part of the Humboldt Current ecosystem, comprising the following objectives: 1) identify the species, 2) evaluate their distribution, 3) analyze the species relative abundances and 4) the relationship with the upwellings.

MATERIALS AND METHODS

Study area

The cruise was off Northern Chile (18°30'S-25°23'S; from coast to 70°27°W) (Fig. 1). This areas is influenced by the Mejillones Peninsula that impacts the spatial distribution of winds and currents, reinforces the coastal upwelling and modifies the latitudinal distribution of the Ekman transport (Letelier *et al.* 2012) and defined as a local biogeographic unit of the transitional zone between Northern and Central Chile, whose southern limit is 30°S (Camus, 2001). It also represents the southern distribution limit for various coastal fishes (Sielfeld *et al.* 2010) and fishing stocks as the case of the anchovy (CCTPP, 2014). The coastline north of the Mejillones Peninsula (23°S) is relatively straight, and aligned primarily in a north-south direction and a large part of the biological productivity develops in a narrow strip along the coast (Fig. 2), particularly in areas of active upwelling between 18° - 35°S (Fonseca & Farías, 1987; Fonseca, 1989; Vergara, 1991, 1992; Strub *et al.* 1998).

Equipments

The data were collected from the 13 m sailing vessel "Balaena" from March to December 2000 (Appendix 1). The surveys used acoustic searching with an omni-directional hydrophone (Benthos AQ4 with Ithaco pre-amplifiers). During daylight (7:00 -18:30 =11.5h) only, visual searching by a staff of three independent observers ordered in three shifts of 4 hr. Date, hour and geographic position were recorded automatically every 5 min using a Trimble Transpak and Garmin 65 GPS navigator.

Cruises

The present study corresponds with an annex result of the Project of Sound Recording on Sperm whale (Rendell *et al.* 2004). Details of the general navigation track were given by Whitehead (2003) and Rendell *et al.* (*op. cit.*) and totaled 158 days at sea during 9 cruises (Table 1) at monthly intervals during year 2000.

Due to operational reasons related to supply and base port the survey area was divided in the following sectors: following 18°30›-19°59'S (Sector 1: Arica-Pisagua), 20°-22°29'S (Sector 2: Iquique-Tocopilla), 22°30›-23°59'S (Sector 3: Mejillones-Antofagasta) and 24°-25°,30°S (Sector 4: El Cobre-Taltal) (-Figs. 1, 3; Appedix 1).

During navigation straight segments between georeferenced start and end points were considered as "transects", with length expressed in km. Hundred and two of these units were surveyed, totaling 9.703,2

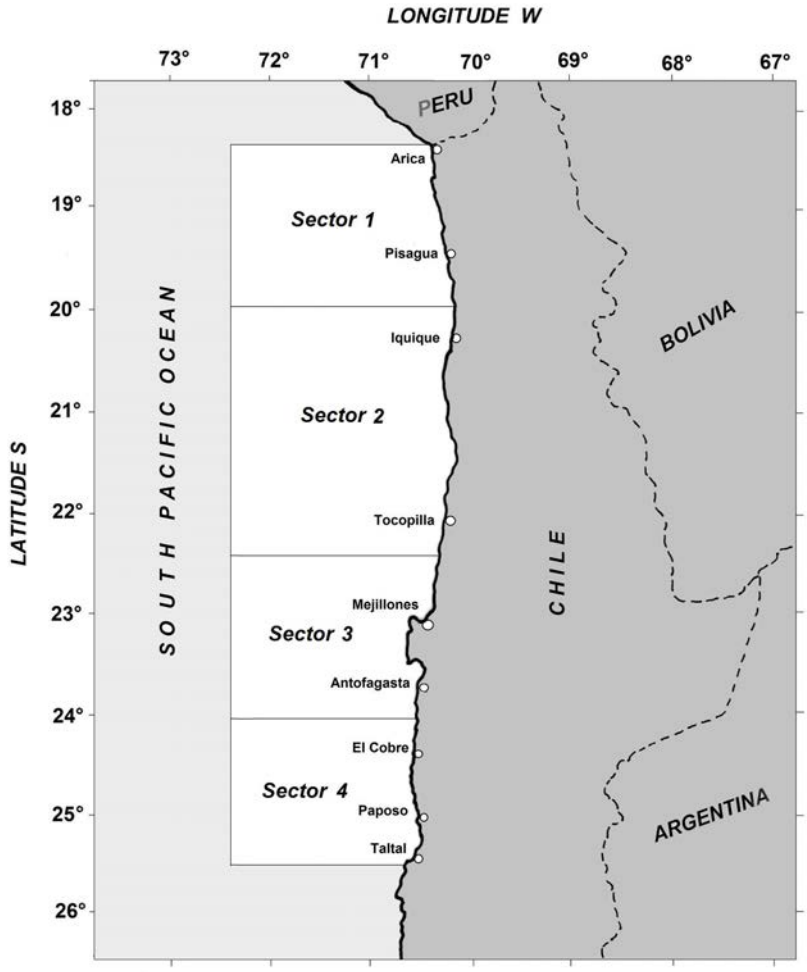

Fig. 1. Study area (in white) and transect grouping sectors (Zones 1-4).

km (= 5.239,3 nautical miles). Fig. 3 shows navigation track and transects. The distance (Km) between points was estimated using the Vincenty equation (1975) to calculate distances on spheroidal surfaces in geodesy. For distribution data analyses the transects were ordered north south by geographical degree.

T.obs. = total observation hours; M.day = mean of daily observation time; T.obs.b. = total observation hours during good conditions; b = daily mean with good sea and weather conditions.

Species

Taxonomic identification of individuals was corroborated following the *Review of Small Cetaceans* of Culik (2004) and *The Sierra Club Handbook of Whales and Dolphins* of Leatherwood *et al.* (1983). Special attention was given to the short-beaked *Delphinus delphis* and the long-beaked *D. capensis* that were distinguished by the less crisp and colorful colour pattern of the first one (Perrin, 2002). The nomenclature used followed Aguayo-Lobo *et al.* (1998a).

Sightings

Species identification and group size were recorded independently by each of the three observers of the corresponding shift. The raw data expressed in Appendix 1 represent a numerical average between the records of the three observers. The sightings were assisted with 10X50 binoculars and a Canon EOS

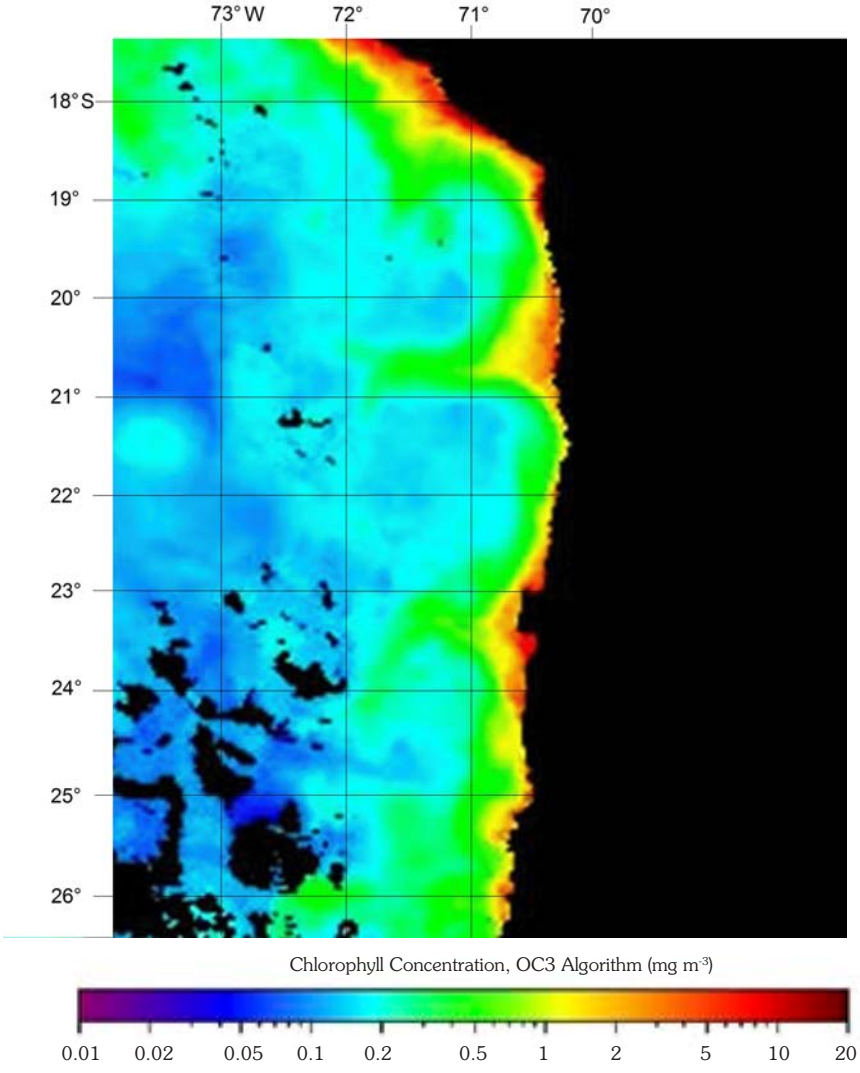

Fig. 2. Chlorophyll concentration during March 2000 off the north coast of Chile. Composition of monthly data. Source: NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group; (2014): Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Ocean Color Data, NASA OB.DAAC. https://doi.org/10.5067 / ORBVIEW-2 / SEAWIFS_ OC.2014.0. Accessed on 2019/04/17.

Table 1. Sighting effort by sighting trip between March and December 2000 off Northern Chile.

Campaigns	Dates	Days (n)	T.obs.	M.day	T.obs.b.	M.day b.
1	28/03 - 17/04	21	241.5	11.5	188.5	8.98
2	25/04 - 16/05	21	241.5	11.5	184.5	8.79
3	24/05 - 14/06	22	195.5	11.5	171.5	10.26
4	26/06 - 09/07	14	184.0	11.5	110.0	6.88
5	14/07 - 03/08	21	241.5	11.5	215.5	10.26
6	18/08 - 05/09	19	195.5	11.5	137.5	8.09
7	26/09 - 17/10	12	230.0	11.5	177.5	8.88
8	26/10- 13/11	9	195.5	11.5	127.5	7.50
9	22/11 - 10/12	19	218.5	11.5	184.0	9.68
TOTALS	28/03 - 10/12	158	1,943.5	11.5	1,496.5	8.70

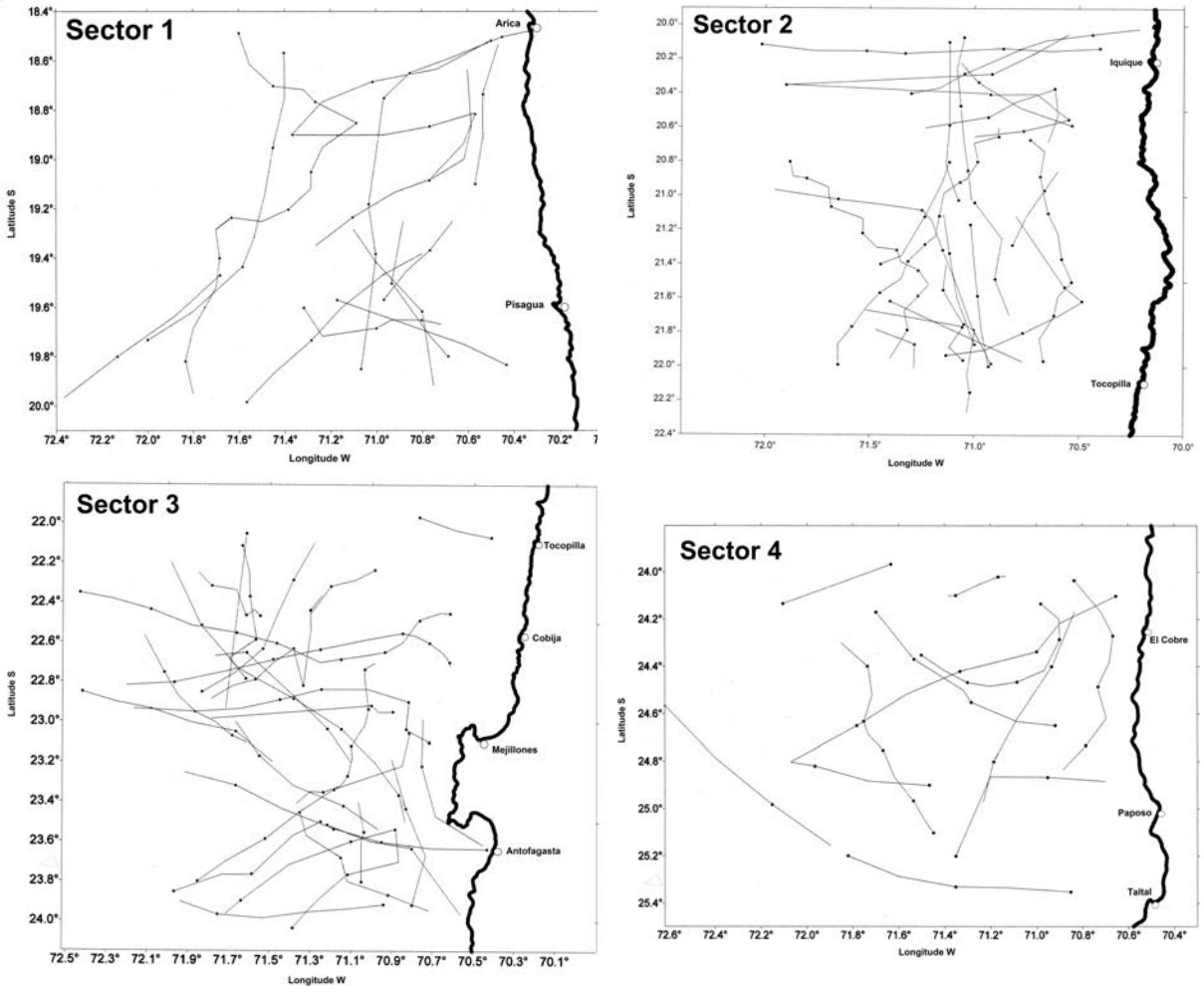

Fig. 3. Navigation tracks and sighting transects: Sector 1: Arica–Pisagua (18.4-20.0°S/70.4 -72.4°W); Sector 2: Iquique–Tocopilla (20.2-22.4°S/70.5-72.0°W); Sector 3: Mejillones-Antofagasta (22.0-24.0°S/70.5-72.5°W); Sector 4: El Cobre Taltal (24.0-25.4°S/70.6-72.6°W).

3000 camera with a 75-300 zoom, and digitalized with Surfer Software (WIN 32), version 6.04. Total sightings during the complete cruise are summarized in Table 1 and sightings for each transect in Table 2. Each sighting consisted in: 1) species identification, 2) herd size and 3) estimated distance to first observation point. The sightings were expressed as Sighting Rate (individuals a/o herds/day).

Statistical analyses

Using average effort (hours of observation with good observation conditions/days at sea = ≤ Beaufort 4 and calm to moderate breeze) (Table 1) an "sighting (or encounter) rate" was calculated for each species following Aguayo-Lobo *et al.* (1998b) and Hucke-Gaete (1998), expressed in sightings/day (times a species was sighted each day) and animals/day (individuals of each species sighted during a day). The estimation of these values was considered important by allowing comparisons with the results presented by the previous authors.

Interpretation of species distribution patterns was supported by Kernel distribution maps (Gaussian Function; 95% concentration ellipses level) from PAST 2.17 Statistical Programme (Hammer, 2018).

RESULTS

Species observed

Small cetacean herd sightings were made, corresponding to 5.841 individuals of 8 dolphin species: Short-beaked Common Dolphin (*Delphinus delphis*) (*Dd*), Long-beaked Common Dolphin (*Delphinus capensis*) (*Dc*), Short-finned Pilot Whale (*Globicephala macrorhynchus*) (*Gm*), Risso's Dolphin (*Grampus griseus*) (*Gg*), Dusky Dolphin (*Lagenorhynchus obscurus*) (*Lo*), Southern Right Whale Dolphin (*Lissodelphis peronii*) (*Lp*), Striped Dolphin (*Stenella coeruleoalba*) (*Sc*) and Bottlenose Dolphin (*Tursiops truncatus*) (*Tt*) (Appendix 1).

Association between species

The 21.62% of the recorded specimens (1.263 of 5.841 ind.) integrated herds of more than one species. Nineteen herd sightings (17.12%) and 269 specimens (4.61%) were observed in association with sperm whales (*Physeter catodon*) and 2 groups (44 individuals) were found with *Otaria byronia* (Appendix 1).

Seven groups (565 individuals) were associated with sea birds, of which 505 were *Lp* from the sector in front of Mejillones (23°24-38'S) (Appendix 1, Table 1).

Associations between delphinid species were mainly represented by associations with *Tt*: 1 case with *Gg* off Arica (18°49'S), 1 case with *Sc* off Mejillones (23°45'S), 1 case with *Lo* off Mejillones (23°03'S) and 5 cases with *Gm* between 21°55'-24°27'S (Appendix 1).

Sightings

Tt was the most frequently sighted species (44.14%; 49 of the 111 herds) and represented 59.6% of the total observed specimens (3.481 out of a total of 5.841). *Lp* (n = 882; 15.10%) and *Lo* (n = 480; 8.22%) follows numerically. Other species were represented by <4% of the total observed specimens (Table 2).

Latitudinal distribution of species

The principal dolphin sightings were around 21°00'-21°59'S (12.7%) in sector 2 and 23°00'-23°59'S (68.6%) in sector 3 (Table 2; Fig. 4a). Other sectors were represented by ≤ 5%. Regarding herd sightings 39.6% around 23°00'-23°59'S (Table 2).

The sighting of specimens per species in the latitudinal perspective (18-25°S) (Table 2) shows that *Dd* was concentrated mainly around 18°00'-18°59'S (48.8%) and 21°00'-21°59'S (34.2%), *Dc* concentrated around 21°00'-21°59'S (92.6%), *Gm* and *Gg* respectively concentrated 85.6% and 92.3% of their observations between 21°00›-23°59'S (Fig. 4c), *Lo* 88.5% at 23°S, *Lp* 100% at 23°00›-24°59'S. *Tt* was the only species represented along the entire latitudinal gradient, however with 61.3% of individuals sighted at around 23°00'-23°59'S (Fig. 4b). The only sighting of *Sc* was also made in that sector.

This trend is also repeated if herds are considered (Table 2), where the highest percentages of herd sighting of *Gg*, *Gm*, *Lp*, *Lo*, *Sc* and *Tt* is coincident with the sectors indicated for specimen numbers. Exceptions are *Dd* and *Dc* where the respective higher abundances were in the 18° and 21° sector, resulting from the existence of greater herds in that sectors.

Latitudinal species assemblage composition changes

The species structure (%) expressed by geographical degree (Table 3) shows *Tt* (59.6%) and *Lp* (15.1%) as the most sighted species. Along the latitudinal gradient (18°-25°S) the predominant species was *Tt*, except around 18°00›-18°59'S in which *Dd* stood out (> 75%) and around 24°00'S-24°59'S where it is surpassed by *Lp* (58.3%).

The 18°00›-18°59›S sector with a predominant presence of *Dd* (75.2%), 19°-23° *Tt* (44.7-84.7%) and 23°00'-24°59'S, presence of *Lp* (18.4-58.9%) and in general by greater number of species. The sightings expressed in number of herds is not consistent with the above, except *Tt* that stands out with 30.0-62.5% over the sighting of herds of the other species.

Sighting Rates (specimens and/or herds/day)

For the total sighting records *Tt* showed the highest sighting rate (22.0 ind./day; 0.31 herds/day). The remaining species had values ≤ 0.05 herds/day and ≤ 5 ind./day (Table 4).

Table 2. Sightings (herds and individuals) expressed as % and arranged by degree of latitude.

Individuals							
Species	18°00'-18°59'	19°00'-19°59'	20°00'-20°59'	21°00'-21°59'	22°00'-22°59'	23°00'-23°59'	24°00'-24°59'
D. delphis	48.78	2.44		34.15			14.63
D. capensis		2.47		92.59			4.94
G. macrorhynchus	5.93			14.41	25.42	45.76	8.47
G. griseus	7.75			38.76	6.98	46.51	
L. obscurus			8.33		3.13	88.54	
L. peronii						83.22	16.72
S. coeruleoalba						100.00	
T. truncatus	0.46	4.60	4.60	11.26	6.55	70.96	1.58
Indet.		5.42	11.92	16.26	4.34	61.25	0.81
Total	2.28	3.24	4.18	12.65	5.09	68.21	4.35

Herds							
Species	18°00'-18°59'	19°00'-19°59'	20°00'-20°59'	21°00'-21°59'	22°00'-22°59'	23°00'-23°59'	24°00'-24°59'
D. delphis	25.00	25.00		25.00			25.00
D. capensis		33.33		33.33			33.33
G. macrorhynchus	11.11			11.11	22.22	44.44	11.11
G. griseus	16.67			33.33	16.67	33.33	
L. obscurus			11.11		11.11	77.78	
L. peronii						77.78	22.22
S. coeruleoalba						100.00	
T. truncatus	4.08	4.08	20.41	18.37	16.33	30.61	6.12
Indet.		4.76	23.81	14.29	9.52	38.10	9.52
Total	4.50	4.50	14.41	15.32	12.61	39.64	9.01

Campaign 8 (October/November = spring) standed out with the highest sighting rate (313.7 ind./day) and campaign 4 (June/July = winter) with the lowest value (7.1 ind./day) (Table 4) mainly due to the dominant presence of *Tt* (2.341 individuals; 82.9% of all individuals in the campaign).

Herd size

Aggregations were generally quite variable, ranging from 1 individuals (*Tt*) to 250 individuals (*Lp*) (Table 5). The species with the largest herds was *Lp* (average=122,5 individuals), though herd size for this species varied considerably (ranging from 1 to 250; SD=112,06). Large aggregations were also noted for *Tt* (2-160 ind.; average 36,1 ind.) and *Dd* (8-150 ind.; average 52,6 ind.). The numerically most important herds (*Tt* 2.470, *Lp* 734, *Lo* 425) (Appendix 1) were observed around 24°00›-24°59›S.

DISCUSSION

The recorded species are the same found by Van Waerebeek *et al.* (1988) for the littoral zone of Peru, with the exceptions of *Phocoena spinipinnis* (typical of coastal habitats, and incompletely covered by the present survey), *Pseudorca crassidens*, *Feresa attenuata*, *Peponocephala electra* and *Stenella longirostris*, which are from warmer waters and associated with the Paracas area and/or the northern region of Peru.

All these species have been previously cited for the study area by Aguayo (1975)

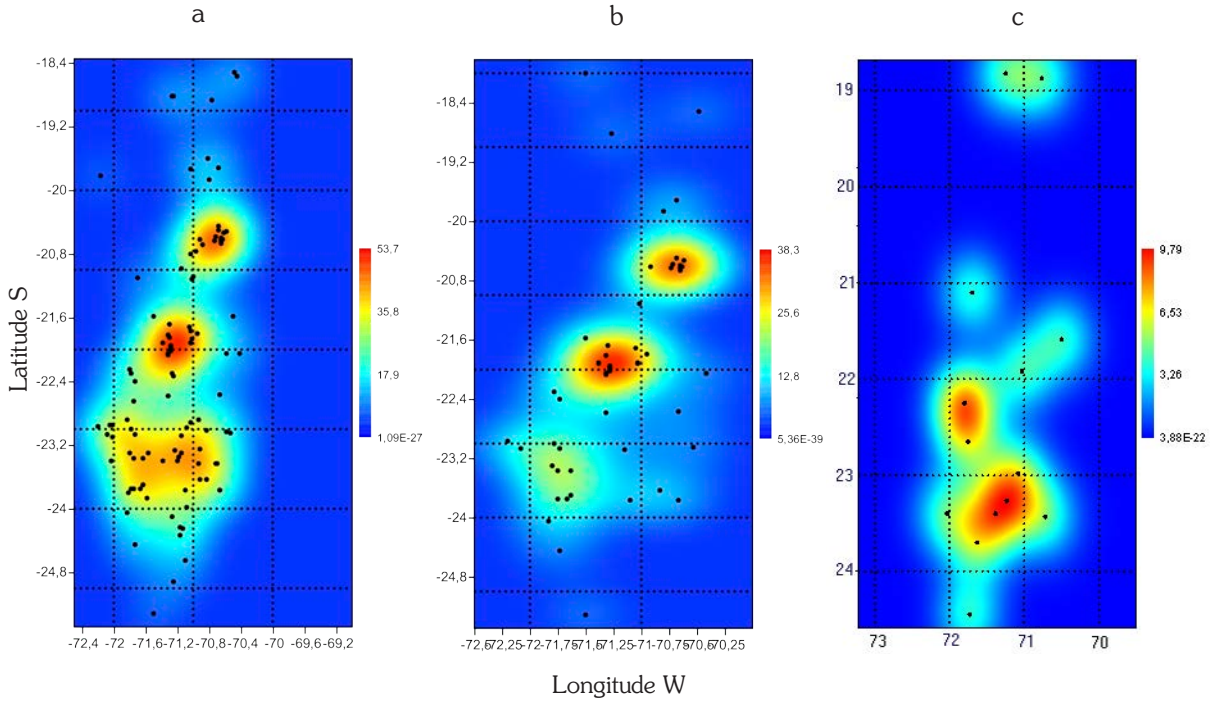

Fig. 4. Kernel density maps (Gaussian function, concentration ellipses level 95%):
a. all species; b. *Tursiops truncatus*; c. *Globicephala macrorhynchus* and *Grampus griseus*.

and Aguayo-Lobo *et al.* (2002). Aguayo-Lobo *et al.* (1998 a,b) cited *Delphinus capensis*, *D. delphis*, *Feresa attenuata*, *Globicephala macrorhynchus*, *Globicephala melas, Grampus griseus*, *Lagenorhynchus obscurus*, *Lissodelphis peronii*, *Orcinus orca*, *Pseudorca crassidens*, *Stenella coeruleoalba*, *Steno bredanensis* and *Tursiops truncatus* for the northern area of Chile. The lack of observations of *Feresa attenuata* in the present study is probably explained by its preference for subtropical and tropical waters, as noted by Hoyt (1999).

All the present *Globicephala* sightings were positively identified as *G. macrorhynchus*. *Globicephala melas*, the most abundant dolphin in the Humboldt Current System (Clarke *et al.* 1978), was not sighted in the present study, probably due to its preference for colder waters (Aguayo-Lobo *et al. op. cit.*).

The only record of *Steno bredanensis* for Chile comes from an individual sighted in the area of Botija (24°30'S), off Antofagasta Region (Van Waerebeek & Guerra, 1988) most probably corresponding to the Peruvian population, that extends to the south, particularly during "El Niño" events (Aguayo-Lobo *et al.* 1998a), penetrating Chilean waters in search of food. The present study took place during a cold, "Inter-El Niño" period, explaining the species absence.

The distribution of the small cetaceans indicates a close relationship with the oceanographic conditions of the upwelling system described by Hormazábal *et al.* (2001) for the study area.

Accordingly, the distributional scheme north of Tocopilla corresponds precisely with the upwelling zone characterized by Fuenzalida (1992) and Blanco *et al.* (2001), while off the Mejillones peninsula the abundance and diversity of the dolphins is associated with the intense upwelling plume of this area (Castilla *et al.* 2002). The effect of the Mejillones upwelling on the distribution and feeding of the sperm whale (*Physeter macrocephalus*) was analyzed previously by Rendell *et al.* (2004) and Flores (2005).

The ocean environment west of the upwelling fronts (west of 71°W) displayed lower densities of groups and species of dolphins, here interpreted as response to the lower productivity of these more oceanic areas (Wyrtki, 1964; Fonseca & Farías,

Table 3. Latitudinal species composition (%) changes.

Individuals								
Species	18°00'-18°59'	19°°00'-19°59'	20°00'-20°59'	21°00'-21°59'	22°00'-22°59'	23°00'-23°59'	24°00'-24°59'	Total
D. delphis	75.19	2.65		9.47			11.81	3.51
D. capensis		2.12		20.30			3.15	2.77
G. macrorhynchus	5.26			2.30	10.07	1.36	3.94	2.02
G. griseus	7.52			6.77	3.02	1.51		2.21
L. obscurus			16.39		5.03	10.67		8.22
L. peronii						18.42	58.27	15.10
S. coeruleoalba						0.38		0.26
T. truncates	12.03	84.66	65.57	44.52	76.51	62.00	21.66	59.60
Indet.		10.58	18.03	9.12	5.37	5.67	1.18	6.32

Herds								
Species	18°00'-18°59'	19°°00'-19°59'	20°00'-20°59'	21°00'-21°59'	22°00'-22°59'	23°00'-23°59'	24°00'-24°59'	Total
D. delphis	20.00	20.00		5.88			10.00	3.60
D. capensis		20.00		5.88			10.00	2.70
G. macrorhynchus	20.00			5.88	14.29	9.09	10.00	8.11
G. griseus	20.00			11.76	7.14	4.55		5.41
L. obscurus			6.25		7.14	15.91		8.11
L. peronii						15.91	20.00	8.11
S. coeruleoalba						2.27		0.90
T. truncatus	40.00	40.00	62.50	52.94	57.14	34.09	30.00	44.14
Indet.		20.00	31.25	17.65	14.29	18.18	20.00	18.92

1987; Morales *et al.* 1996; Hormazábal *et al.* 2001; Hormazábal & Shaffer, 2002; Schneider *et al.* 2003; Fuenzalida *et al.* 2007).

The here found species and their abundances coincide in their specific structures as much as in relative abundances with the species assemblage cited by Van Waerebeek *et al.* (1988) for the Peruvian coast, including the subsequent additions of *Lissodelphis peronii* made by Lazarte & Valdivia (1998)) and Van Waerebeek *et al.* (1991). *Peponocephala electra*, a strongly oceanic species scarce off the Peruvian coast (Van Waerebeek *et al. op cit*.) was not found off the Chilean coast. *Stenella attenuata* and *S. longirostris*, tropical species that do not reach south of 21,5°S (Perrin, 1975) were also not found in the study area.

Therefore, the here found species assemblage is part of the same species group common to the Peruvian coast, characterized fundamentally by the abundance of *Tursiops truncatus* (over 40% of the sightings and over 60% of the individuals sighted) (Van Waerebeek *et al.* (1991) for Peruvian data and present Table 3 for Chilean data).

The conservation status of most of the here involved species is "insufficiently known" (*Delphinus delphis, D. capensis, Globicephala macrorhynchus, Grampus griseus* and *Lagenorhynchus obscurus*), the coastal ecotype of *Tursiops truncatus* is "in danger" and the resting population of the same species "insufficiently known" (Ministerio de Medio Ambiente, 2020).

The present sighting rates (sightings/day) of *L. obscurus, L. peronii* and *T. truncatus* showed higher sighting rates (1,02, 1,02 and 5,58 sightings/day respectively), as compared

Table 4. Sighting rates of herds (herds/day) and specimens (specimens/day) off Northern Chile.

Specimens/day											
Campaign	Dates	Days	*Dd*	*Dc*	*Gm*	*Gg*	*Lo*	*Lp*	*Sc*	*Tt*	indet.	Totals
1	28/03 - 17/04	21	1.43	0.38		1.43	0.92			0.95	5.62	10.76
2	25/04 - 16/05	21	0.24		0.33		1.43			17.14	1.62	20.76
3	24/05 - 14/06	22	4.55				1.82			3.68	0.05	10.09
4	26/06 - 09/07	14					1.29	5.21	1.07	9.29	7.14	7.14
5	14/07 - 03/08	21			0.71	1.43		12.05		0.05	0.05	14.29
6	18/08 - 05/09	19			3.42	0.47				13.53		17.42
7	26/09 - 17/10	12		12.83		5.00	0.17	37.92		1.58	0.83	58.33
8	26/10- 13/11	9			3.44		38.89	11.22		260.11		313.67
9	22/11 - 10/12	19	3.68				1.05			14.32	5.53	24.58
Totals	28/03 - 10/12	158	1.30	1.03	0.75	0.80	3.04	5.58	0.095	22.03	2.34	36.97

Herds/day											
Campaign	Dates	Days	*Dd*	*Dc*	*Gm*	*Gg*	*Lo*	*Lp*	*Sc*	*Tt*	indet.	Totals
1	28/03 - 17/04	21	0.05	0.05		0.10	0.05			0.05	0.28	0.57
2	25/04 - 16/05	21	0.05		0,.05		0.14			0.62	0.19	1.05
3	24/05 - 14/06	22	0.05				0.05			0.36	0.05	0.50
4	26/06 - 09/07	14					0.07	0.14	0.07	0.36	0.36	1.00
5	14/07 - 03/08	21			0.05	0.05		0.10		0.05	0.05	0.29
6	18/08 - 05/09	19			0.21	0.05				0.21		0.47
7	26/09 - 17/10	12		0.17		0.17	0.08	0.25		0.25	0.08	1.00
8	26/10 - 13/11	9			0.33		0.11	0.22		0.01		1.56
9	22/11 - 10/12	19	0.05				0.05			0.32	0.16	0.58
Totals	28/03 - 10/12	158	0.03	0.02	0.06	0.04	0.06	0.06	0.01	0.31	0.13	0.70

Table 5. Herd size by species.

Species	Herds (n)	Range (specimens)	Mean ($\bar{X}$)	Standar desviation (std)
Gm	9	5 – 25	12.0	9.06
Gg	6	9 – 30	14.7	8.62
Tt	49	1 – 1500	36.1	45.76
Dd	4	5 – 105	51.3	21.75
Dc	3	4 – 150	54.0	67.90
Lo	9	2 – 350	22.6	9.94
Sc	1	15	-	-
Lp	9	1 – 250	122.5	112.06

to values of 0.13, 0.13 and 0.76 sightings/day respectively for the same species, indicated by Aguayo-Lobo *et al. (op. cit.).* Making a difference *D. delphis* with 1.01 sightings/day for the Valparaíso-Easter Island sector (Aguayo-Lobo *et al.* 1998b) is less abundant in the present study area (0.34 sightings/day).

T. truncatus, the most abundant species off the northern part of Chile (20°11'S-32°13'S), reached up to 306.940 animals/day comparable to 309.20 animals/day found by Hucke-Gaete (1998) for the coast of central Chile and by Aguayo-Lobo *et al.* (1998a) between Valparaíso and Easter Island.

The sighting rate of *L. obscurus* in the present study area (38,96 animals/day, Cruise 8) than values reported for the littoral zone of central Chile (Aguayo-Lobo *et al*. 1998a; Findlay *et al.* 1998). The maximum sighting rate here found for *L. peronii* (37.9 animals/day, Cruise 7) compared with previous research data: 180 animals/day (January 1998, south of 40° latitude) (Findlay *et al. op. cit*.) and 122,6 animals/day (Aguayo 1966) is consequent with the appreciation of Aguayo (*op. cit*.) suggesting that the species would be most abundant in the area south of the country.

These comparisons are not strictly comparable due to different years between this work and previous research. Also the present campaigns were carried out in autumn, winter and spring, while Hucke-Gaete (1998) did it in summer and Aguayo-Lobo *et al.* (1998b) in winter for the Valparaíso to Easter Island section. Therefore, it must be considered that new studies and future surveys in upwelling areas will corroborate or modify the present conclusions.

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APPENDIX 1. Sightings of delphinids during the navigation campaigns.

Campaigns	n°	Date	Time	Species	Specimens (n)	Latitude	Longitude	Observations
1	1	29-03-2000	1715 h	Delphinids indet.	20	19°44'S	71°02'W	with *Physeter catodon*
	2	04-04-2000	1255 h	*Grampus griseus*	20	21°35'S	70°30'W	
	3	07-04-2000	1503 h	Delphinids indet.	1	24°15'S	71°08'W	
	4	07-04-2000	1420 h	*Delphinus delphis*	30	24°14'S	71°10'W	
	5	07-04-2000	1600 h	*Delphinus capensis*	8	24°20'S	71°10'W	
	6	12-04-2000	1948 h	Delphinids indet.	2	24°55'S	71°15'W	
	7	13-04-2000	1705 h	*Lagenorhynchus obscurus*	20	23°15'S	70°55'W	
	8	13-04-2000	2320 h	Delphinids indet.	30	22°53'S	70°56'W	detected with hydrophone
	9	14-04-2000	0659 h	*Grampus griseus*	10	22°59'S	71°05'W	
	10	14-04-2000	0825 h	Delphinids indet.	25	22°55'S	71°02'W	
	11	14-04-2000	1250 h	*Tursiops truncatus*	20	22°34'S	70°40'W	
	12	15-04-2000	1136 h	Delphinids indet.	40	21°05'S	71°00'W	
2	1	26-04-2000	0945 h	*Globicephala macrorhynchus*	7	18°52'S	70°46'W	
	2	27-04-2000	1420 h	*Tursiops truncatus*	150	19°43'S	70°41'W	
	3	28-04-2000	1940 h	Delphinids indet.	10	20°27'S	70°41'W	
	4	29-04-2000	0200 h	Delphinids indet.	3	20°41'S	70°53'W	detected with hydrophone
	5	29-04-2000	0400 h	Delphinids indet.	6	20°46'S	70°58'W	detected with hydrophone
	6	30-04-2000	2020 h	Delphinids indet.	15	20°31'S	70°35'W	detected with hydrophone
	7	03-05-2000	0715 h	*Lagenorhynchus obscurus*	15	22°03'S	70°35'W	
	8	03-05-2000	0915 h	*Tursiops truncatus*	40	22°03'S	70°25'W	Associated with sea birds and southern sea lion
	9	06-05-2000	0930 h	*Lagenorhynchus obscurus*	5	22°57'S	72°01'W	
	10	06-05-2000	0950 h	*Lagenorhynchus obscurus*	10	22°57'S	72°03'W	
	11	11-05-2000	0922 h	*Tursiops truncatus*	15	20°40'S	70°39'W	
	12	11-05-2000	1000 h	*Tursiops truncatus*	15	20°38'S	70°39'W	

Campaigns	n°	Date	Time	Species	Specimens (n)	Latitude	Longitude	Observations
	13	11-05-2000	1141 h	*Tursiops truncatus*	10	20°32'S	70°37'W	
	14	12-05-2000	1325 h	*Tursiops truncatus*	25	20°37'S	70°55'W	
	15	12-05-2000	1555 h	*Tursiops truncatus*	20	20°38'S	70°44'W	
	16	12-05-2000	1700 h	*Tursiops truncatus*	30	20°38'S	70°39'W	
	17	12-05-2000	1730 h	*Tursiops truncatus*	10	20°37'S	70°38'W	
	18	12-05-2000	1755 h	*Tursiops truncatus*	10	20°36'S	70°39'W	1 calf
	19	12-05-2000	1845 h	*Tursiops truncatus*	10	20°35'S	70°43'W	
	20	12-05-2000	1915 h	*Tursiops truncatus*	15	20°30'S	70°41'W	
	21	13-05-2000	1726 h	*Tursiops truncatus*	10	19°52'S	70°48'W	
	22	15-05-2000	1130 h	*Delphinus delphis*	5	19°49'S	72°10'W	
3	1	30-05-2000	1125 h	*Delphinus delphis*	100	18°34'S	70°27'W	
	2	01-06-2000	1120 h	*Lagenorhynchus obscurus*	40	20°48'S	71°02'W	
	3	01-06-2000	1454 h	*Tursiops truncatus*	50	21°07'S	71°01'W	
	4	02-06-2000	1600 h	Delphinids indet.	1	22°20'S	71°15'W	
	5	04-06-2000	0820 h	*Tursiops truncatus*	3	22°04'S	71°19'W	with *Physeter catodon*
	6	04-06-2000	0848 h	*Tursiops truncatus*	6	22°03'S	71°19'W	with *Physeter catodon*
	7	04-06-2000	0950 h	*Tursiops truncatus*	7	22°01'S	71°17'W	with *Physeter catodon*
	8	04-06-2000	1050 h	*Tursiops truncatus*	5	22°00'S	71°17'W	with *Physeter catodon*
	9	04-06-2000	1145 h	*Tursiops truncatus*	2	21°58'S	71°17'W	with *Physeter catodon*
	10	04-06-2000	1224 h	*Tursiops truncatus*	3	21°57'S	71°17'W	with *Physeter catodon*
	11	04-06-2000	1700 h	*Tursiops truncatus*	5	21°49'S	71°19'W	with *Physeter catodon*
4	1	20-06-2000	1531 h	*Tursiops truncatus*	12	18°31'S	70°29'W	with *Physeter catodon*
	2	22-06-2000	1320 h	*Tursiops truncatus*	20	21°43'S	71°03'W	with *Physeter catodon*
	3	22-06-2000	1349 h	Delphinids indet.	10	21°46'S	71°02'W	
	4	22-06-2000	1505 h	Delphinids indet.	10	21°52'S	71°01'W	

Campaigns	n°	Date	Time	Species	Specimens (n)	Latitude	Longitude	Observations
	5	28-06-2000	1132 h	*Tursiops truncatus*	25	24°03'S	71°50'W	
	6	30-06-2000	1332 h	Delphinids indet.	30	23°38'S	70°50'W	
	7	01-07-2000	0800 h	Delphinids indet.	45	23°59'S	71°05'W	
	8	03-07-2000	1800 h	*Lagenorhynchus obscurus*	18	23°21'S	71°11'W	
	9	04-07-2000	0724 h	Delphinids indet.	5	23°48'S	71°49'W	
	10	04-07-2000	0915 h	*Tursiops truncatus*	35	23°45'S	71°45'W	with *P. catodon* and *S. coeruleoalba*
	11	04-07-2000	0915 h	*Stenella coeruleoalba*	15	23°45'S	71°47'W	with *P. catodon* and *T. truncatus*
	12	04-07-2000	1145 h	*Tursiops truncatus*	38	23°45'S	71°40'W	
	13	04-07-2000	1733 h	*Lissodelphis peronii*	25	23°52'S	71°35'W	with *Physeter catodon*
	14	05-07-2000	0900 h	*Lissodelphis peronii*	48	24°06'S	71°16'W	with *Physeter catodon*
5	1	21-07-2000	1620 h	*Grampus griseus*	30	21°06'S	71°42'W	
	2	27-07-2000	1033 h	*Lissodelphis peronii*	250	23°24'S	71°12'W	with sea birds
	3	31-07-2000	0414 h	Delphinids indet.	1	23°18'S	71°09'W	detected with hydrophone
	4	31-07-2000	1403 h	*Globicephala macrorhynchus*	15	23°16'S	71°14'W	1 calf; with *P. catodon*
	5	01-08-2000	1828 h	*Tursiops truncatus*	1	23°46'S	71°06'W	
	6	02-08-2000	2035 h	*Lissodelphis peronii*	3	23°26'S	70°56'W	
6	1	19-08-2000	0750 h	*Tursiops truncatus*	35	23°42'S	71°38'W	with *G. macrorhynchus*
	2	19-08-2000	0755 h	*Globicephala macrorhynchus*	18	23°42'S	71°38'W	2 calfs; with *T. truncatus*
	3	20-08-2000	1125 h	*Grampus griseus*	9	22°39'S	71°45'W	with *P. catodon*
	4	21-08-2000	0750 h	*Tursiops truncatus*	145	22°24'S	71°44'W	1 calf
	5	21-08-2000	0936 h	*Globicephala macrorhynchus*	25	22°15'S	71°48'W	with *T. truncatus*
	6	21-08-2000	0941 h	*Tursiops truncatus*	2	22°18'S	71°47'W	with *G. macrorhynchus*
	7	21-08-2000	1054 h	*Globicephala macrorhynchus*	5	22°15'S	71°48'W	
	8	01-09-2000	1040 h	*Tursiops truncatus*	75	21°55'S	71°02'W	with *G. macrorhynchus*

Campaigns	n°	Date	Time	Species	Specimens (n)	Latitude	Longitude	Observations
	9	01-09-2000	1041 h	*Globicephala macrorhynchus*	17	21°55'S	71°02'W	2 calfs; with *T. truncatus*
7	1	26-09-2000	1627 h	*Lissodelphis peronii*	250	23°38'S	70°55'W	with sea birds
	2	29-09-2000	1114 h	*Tursiops truncatus*	12	21°35'S	71°30'W	
	3	30-09-2000	0600 h	Delphinids indet.	10	20°59'S	71°09'W	detected with hydrophone
	4	01-10-2000	1827 h	*Delphinus capensis*	4	19°36'S	70°49'W	with *P. catodon* and otariids
	5	02-10-2000	0830 h	*Grampus griseus*	10	18°49'S	71°15'W	with *T. truncatus*
	6	02-10-2000	0830 h	*Tursiops truncatus*	4	18°49'S	71°16'W	with *G. griseus*
	7	05-10-2000	1240 h	*Delphinus capensis*	150	21°48'S	70°57'W	
	8	06-10-2000	0826 h	*Grampus griseus*	50	23°26'S	70°43'W	1 calf; with *L. peronii*
	9	06-10-2000	0826 h	*Lissodelphis peronii*	5	23°26'S	70°42'W	with *G. griseus* and sea birds
	10	10-10-2000	0826 h	*Lissodelphis peronii*	200	23°01'S	70°50'W	
	11	11-10-2000	1809 h	*Tursiops truncatus*	3	23°03'S	70°32'W	with *L. obscurus* and sea birds
	12	11-10-2000	1809 h	*Lagenorhynchus obscurus*	2	23°02'S	70°35'W	with *T. truncatus* and sea birds
8	1	26-10-2000	1607 h	*Lagenorhynchus obscurus*	350	23°46'S	70°40'W	with *L. peronii*
	2	26-10-2000	1607 h	*Lissodelphis peronii*	1	23°46'S	70°40'W	with *L. obscurus*
	3	27-10-2000	1756 h	*Globicephala macrorhynchus*	10	24°27'S	71°44'W	with *T. truncatus*
	4	27-10-2000	1756 h	*Tursiops truncatus*	15	24°27'S	71°44'W	with *G. macrorhynchus*
	5	29-10-2000	1330 h	*Lissodelphis peronii*	100	24°39'S	71°06'W	
	6	31-10-2000	1617 h	*Globicephala macrorhynchus*	15	23°24'S	72°02'W	with *P. catodon*
	7	04-11-2000	1349 h	*Tursiops truncatus*	6	22°58'S	72°12'W	
	8	04-11-2000	1740 h	*Tursiops truncatus*	60	23°04'S	72°05'W	
	9	05-11-2000	0640 h	*Tursiops truncatus*	100	23°18'S	71°48'W	
	10	05-11-2000	0858 h	*Tursiops truncatus*	150	23°22'S	71°45'W	
	11	08-11-2000	1702 h	*Globicephala macrorhynchus*	6	23°24'S	71°23'W	
	12	09-11-2000	1516 h	*Tursiops truncatus*	10	23°38'S	70°50'W	

Campaigns	n°	Date	Time	Species	Specimens (n)	Latitude	Longitude	Observations
	13	10-11-2000	1223 h	*Tursiops truncatus*	500	23°05'S	71°09'W	
	14	12-11-2000	1945 h	*Tursiops truncatus*	1500	23°04'S	71°44'W	
9	1	25-11-2000	2025 h	*Tursiops truncatus*	2	23°00'S	71°47'W	
	2	25-11-2000	2300 h	Delphinids indet.	50	22°53'S	71°50'W	detected with hydrophone
	3	26-11-2000	1755 h	*Tursiops truncatus*	20	22°35'S	71°19'W	with *P. catodon*
	4	27-11-2000	0300 h	Delphinids indet.	15	22°18'S	71°16'W	detected with hydrophone
	5	27-11-2000	1350 h	*Tursiops truncatus*	25	21°55'S	71°23'W	
	6	27-11-2000	1745 h	*Delphinus delphis*	70	21°51'S	71°18'W	
	7	27-11-2000	2200 h	*Tursiops truncatus*	200	21°41'S	71°18'W	
	8	29-11-2000	1745 h	*Tursiops truncatus*	10	23°22'S	71°38'W	
	9	01-12-2000	0912 h	*Lagenorhynchus obscurus*	20	23°28'S	71°34'W	
	10	03-12-2000	1349 h	*Tursiops truncatus*	15	25°19'S	71°30'W	with sea birds
	11	08-12-2000	1030 h	Delphinids indet.	40	23°06'S	72°01'W	
				TOTAL	5841			