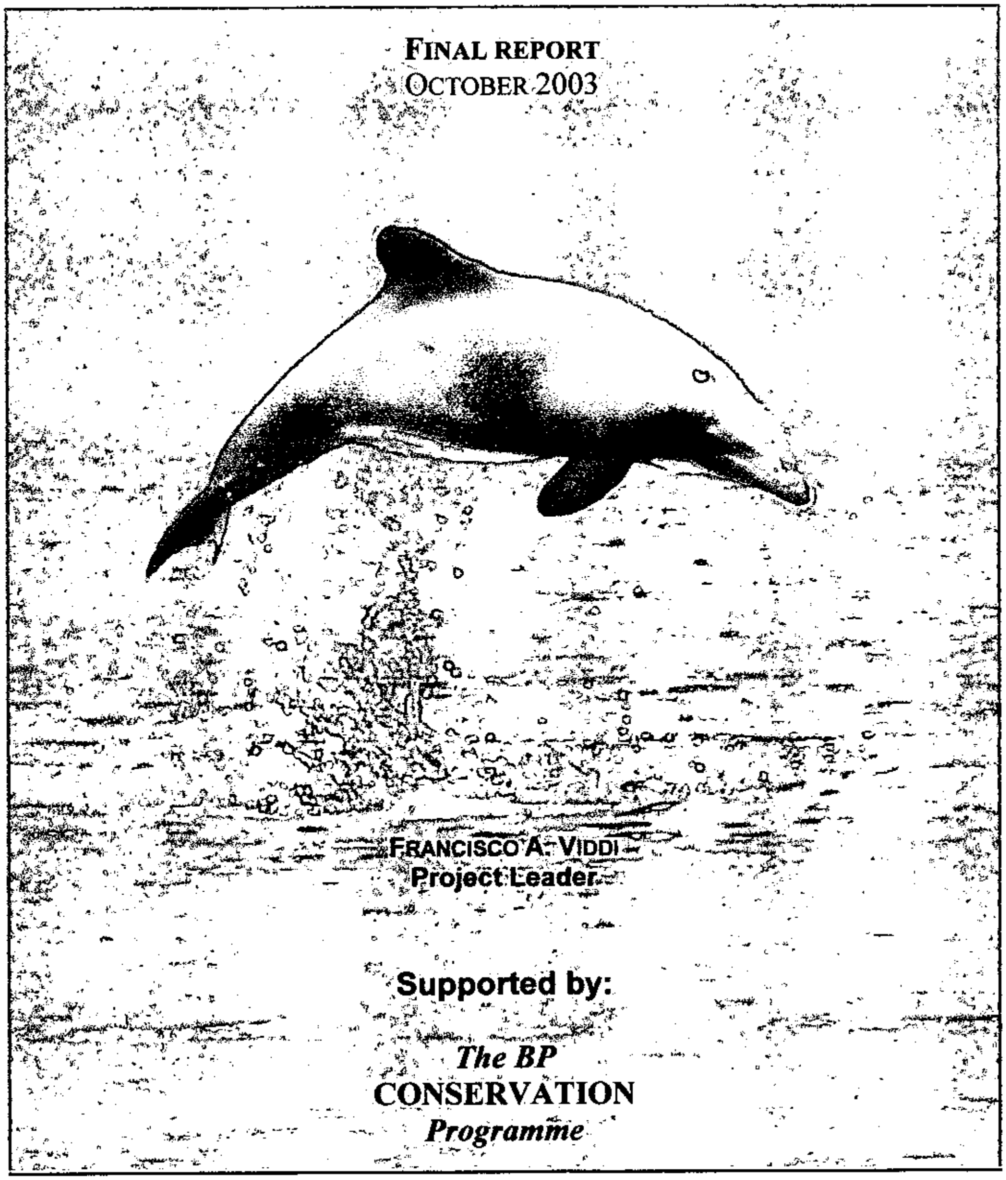
THE CHILEAN DOLPHIN PROJECT

ECOLOGY AND CONSERVATION OF THE CHILEAN DOLPHIN IN SOUTHERN CHILE



FINAL REPORT
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Project Leader

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CONTENTS

PREFACE

Most of the planet is covered by ocean waters, far the largest ecosystem on Earth. Of this great ecosystem only a small percentage are costal habitats. Situated at the confluence of land, sea and air, the coastal ocean- its structure and processes composed of terrestrial, freshwater, marine and atmospheric elements- is exploited by humans for food, recreation, transport, waste disposal, and other needs. For these reasons and others, roughly 60% of the world's human population resides close to a coast. The high actual density and the projected increases in population have caused and will threaten the seas by the diverse range of human-derived impacts such as depletion of natural resources from over exploitation and fishing, alteration of physical habitat, chemical pollution and eutrophication, invasion of exotic species, increased boat traffic and global climate change.

Marine biodiversity has been threatened to the point of bringing some species to extinction, while many others remain under severe conservation threats. Because they are usually much less readily observed, marine species status is in general more difficult to assess and monitor than terrestrial ones.

One group considered of special concern as a whole are marine mammals, the archetypal "charismatic megafauna" of the sea. Some species belonging to this group are also one of the best-known cases of overexploitation; they were intensively killed and hunted during last century for their fur, blubber and meat. In the present, one of the main concerns for coastal cetaceans is the loss of critical habitats, important areas for highly essential biological activities, due to the exponential increase of human population in coastal areas. Chile is not an exception of this environmental problem, has also a very important cetacean diversity, with the Chilean dolphin (*Cephalorhynchus eutropia*) as the only endemic species, found restricted to coastal waters.

In this final report, we are pleased to present the results of the beginning of a long-term programme on the conservation of marine ecosystems, considering dolphins as flagship species, especially the Chilean dolphin; an ambitious project, where international students, graduates, professionals and volunteers came together and played an important role.

As new scientists, environmentalists and conservationist, we have all an important responsibility to take action and search for answers and solutions within a wider multidisciplinary approach.

Empirical information is essential, strong fundaments and scientific basis is of great importance for the recommendation of conservation actions. Science plays a central role in marine ecosystem conservation; nevertheless, this information needs to be brought to the general public in the form of education and dissemination, work close to governmental agencies and local NGOs in order for it to reach all its potential.

In the following pages our dreams of many years can be finally seen materialized. The project team sincerely thanks the *BP Conservation Programme* for the opportunity given. Your support was wholly essential to our work and will be vital for the years to come. Many more dreams will be dreamt.

Thank you so much

Francisco A. Viddi
Project Leader, October 2003

SUMMARY

After five months of field work, in probably one the most beautiful and isolated spots on Earth, where cold waters forming fjords and channels meet the mountains, dense and deep forest, our team achieved more than 600 hours at sea, in a cooperative work which had as main goal the conservation of coastal marine ecosystems focusing on the Chilean dolphin (*Cephalorhynchus eutropia*) and through research and environmental education in local communities.

The Chilean dolphin (*Cephalorhynchus eutropia*) is within the most unknown species in the dolphin family. It is a species restricted to coastal waters of southern South America, endemic of Chile (the only endemic cetacean in Chile). Due to its near shore and restricted distribution, this species is prone to direct and indirect anthropogenic threats. The specific objective of this project was to obtain relevant information on important areas for this dolphin species at different spatio-temporal scales, identify current and potential conservation threats to dolphins and their habitat, and raise public awareness on marine conservation issues through environmental education considering this dolphin species as flagship species. Habitat selection of dolphins was studied for the identification of important and critical areas. A model of habitat selection and movement patterns at a spatio-temporal scale, identifying core areas and home range size, as well as abundance estimates will be performed as part of the long-term aim.

The information presented here brings together the results from the first long run cooperative work on the understanding and conservation of coastal dolphins from three different areas in the tenth Region (Region de Los Lagos), southern Chile, which focused in its beginnings on the Chilean dolphin.

Important areas were recognized for Chilean dolphins in two of the areas, many mother-calves pairs, high residency of identified individuals and a very specific habitat selection pattern. Potential human impacts were also identified in the research areas, such as extensive aquaculture farming for mussels and salmon, which are taking place in all areas surveyed and overlapping greatly with dolphin distribution. These farms produce high levels of pollution and cause increased boat traffic and garbage, factors that could negatively impact dolphin populations, both directly and indirectly.

The Chilean dolphin was the coastal dolphin species recognized initially to be potentially affected by anthropogenic activities and hence, used as flagship species for marine ecosystem conservation due to its attribute of umbrella and charismatic species. During the course and progress of this project, other three small cetacean species were also identified in the study area. Due to the important occurrence of one of these with relation to the Chilean dolphin and the aquaculture activities, Peale's dolphin (*Lagenorhynchus australis*) was also included in the analysis and used as flagship species towards the conservation of coastal habitat.

These dolphin species showed important habitat selection patterns, but at the same time extremely interesting habitat segregation between them. Our results are of great importance since the information gathered showed a very important diversity of small cetaceans at such small scale.

INTRODUCTION

A full three quarters of the area of our blue planet lies underwater, and the whole of the worlds' ocean is theoretically capable of supporting life, so that the terrestrial component of the biosphere is far smaller than the marine one, an environment of extraordinary value and complexity (Sullivan Sealey and Bustamante, 1999; Groombridge and Jenkins, 2000). From the edge of the polar sea to the tropics, the sea looks homogeneous to anyone viewing it from a low angle. Only differences in colour hint at the diversity of marine topography and overlying waters. This heterogeneity is crucial, however, because different physical settings favour different kinds of organisms, that is, ecosystem diversity. Life in the sea is diverse, exciting and provides a myriad of services to humanity, many of which we barely even comprehend. Diversity at high taxonomic levels (Phyla and Classes) is much higher in the oceans than on land or in fresh water, in contrast, known species diversity in the sea is much lower than on land. Some 250000 species of marine organisms are currently known, compared with more than 1.5 million terrestrial ones (Groombridge and Jenkins, 2000; Roberts and Hawkins, 2000).

Human activities, directly and indirectly, now pose serious threats and are the primary cause of changes to the ocean biodiversity and their capacity to support productive fisheries, recreation, water purification and other services we take for granted (Groombridge and Jenkins, 2000; Roberts and Hawkins, 2000). Throughout the globe, humans represent the greatest threat to the marine environment, degrading marine ecosystems and reducing the capacity of estuaries and oceans to thrive, and possibly threatening the very physical and biological dynamics of ocean ecosystems (Sullivan Sealey and Bustamante, 1999). A large proportion of the world's coastal habitats are in various stages of degradation, and regardless of biogeographic province, the litany of abuse of coastal habitats is similar, with similar key problems identified: eutrophication, coastal development (including aquaculture), habitat modification and destruction, disruption of coastal hydrological cycles, point and nonpoint source release of toxins and pathogens, introduction of exotic species, fouling by plastic litter, build-up of chlorinated hydrocarbons, shoreline erosion, unsustainable exploitation of resources, noise pollution, disturbance by boat traffic and global climate change and variability (Alongi, 1998).

Until recently by far the most important human activity affecting marine species was uncontrolled exploitation. This is the case of many marine mammal species, for which some species suffered catastrophic declines (Groombridge and Jenkins, 2000). This is a group for which there is worldwide concern. Their large size and the fact that they spend a considerable amount of time at the sea surface make them more likely to be noticed by people. Furthermore, marine mammals remind us of ourselves, being homeothermic, air-breathing creatures that bear few live young, have long parental-care periods and complex social structures, and exhibit behaviours sometimes attributed to intelligence and altruism. Another seldom articulated, but ecologically more important reason is that marine mammals can serve as "strong interactors" or keystone species in marine ecosystems. In fact, marine mammals are major consumers of production at most trophic levels from primary production (*i.e.* manatees and dugongs) to predatory fish and even to other marine mammals (*i.e* orcas and polar bears) (Bowen, 1997). Because their large body size and abundance, they are thought to have a major influence on the structure and function of some marine communities (Estes, 1979; Harwood, 2001). Hence, developing a better understanding of the role of marine mammals in marine ecosystems will surely assist conservation and management actions, however, this understanding will likely come slowly; the product of long term interdisciplinary research (Bowen, 1997).

Marine ecosystem conservation might be approached by the design of different strategies, which include both biodiversity and ecosystem concepts and instrumental values (which is a measure of how valuable or useful a species or ecosystem is): economic; spiritual; scientific and educational; ecological; strategic; realized versus potential; and genetic (Hunter, 1999). One strategy for bringing up concern and develop solutions and actions on marine ecosystem conservation is using the concept of flagship and umbrella species. Flagship species are literally charismatic species that win the hearts of the general public, while umbrella species refers to the idea that some species have such broad habitat requirements and large home ranges that if one protects their populations, one would inevitably protect many other elements of biodiversity as well (Hunter, 1999). Furthermore, marine mammals as the ocean's top predators are environmental indicators, which can tell much of the health and fitness of the ecosystem (Bowen, 1997; Hunter, 1999).

Resources in the marine environment tend to be patchily distributed, the high heterogeneity of ecosystems, ecological processes and patterns, brings as result that within a species distribution, resources (food and space) are clumped rather than distributed randomly or systematically (Samuel *et al.*, 1985; Karczmarski *et al.*, 2000; Stevick *et al.*, 2002). Hence, although marine mammals are found widely across the world's ocean and fresh water bodies, their distribution is patchy, and some areas are more frequently used than others, evidencing a process of habitat selection (Harwood, 2001). These preferred areas are probably particularly important for survival and reproduction, and changes to these areas are most likely to affect their distribution and abundance (Harwood, 2001). An adequate identification at different spatio-temporal scales of key habitats within a population's home range, and core areas where biologically and socially important behaviours concentrate, is an important part of the understanding the species' ecology and crucial for the conservation and management of any wild animal population and their habitats (Karczmarski *et al.*, 2000).

Although in Chile there is a poor perception of nature, threatened biodiversity is recognized among the environmental problems in the country (Simonetti, 1994). In Chile there are 41 cetacean species (whales, dolphins and porpoises) inhabiting its waters, which represent 47% of all species in the world. From these, sixteen belong to the dolphin family (Delphinidae) and two belong to the porpoise family (Phocoenidae) (Aguayo *et al.*, 1998). Despite this very important cetacean diversity, little is known about the biology of these animals and hence little is what it can be said about their conservation status. From this very important diversity, the Chilean dolphin (*Cephalorhynchus eutropia*) is the only endemic species in Chile, distributed from Valparaiso (33° S) to Navarino Island, Cape Horn (55° S). It is a coastal species, inhabiting sheltered bays, channels, fjords and exposed coast (Oporto, 1984; Oporto, 1986; Goodall *et al.*, 1988; Goodall, 1994). The current conservation status of *C. eutropia* listed by the IUCN is of Data Deficient (Hilton-Taylor, 2000) and it is within the smallest and most unknown dolphin species (Goodall, 1994;

Reeves and Leatherwood, 1994). It is also listed in the Appendix II of CITES (Convention of the International Trade of Endangered Species), CMS (Convention for Migratory Species) and IWC (International Whaling Commission) (Schlatter and Hucke-Gaete, 1999)
Basic knowledge on its biology and ecology are still very scarce and there is no data available on abundance, population structure and dynamics, home range size and movement patterns (Goodall *et al.*, 1988; Goodall, 1994). Only until recently, some studies on the ecology have been initiated (Heinrich, 2001; Perez-Alvarez and Aguayo-Lobo, 2002; Ribeiro *et al.*, 2002).
Anecdotal information suggest that between 1930, and specially between 1970 and 1990, the abundance of the Chilean dolphin, together with other species, were severely reduced due to extensive hunt for use as bait in the king crab, *Lithodes xantolla,* and false king crab, *Paralomis granulosa,* industry in southern Chile (Cardenas *et al.*, 1987; Oporto, 1992; Lescrauwaet and Gibbons, 1994), but also for the local small scale fishery in the tenth region, specially in Chiloe Island (Goodall *et al.*, 1988). Since the early 1990's, directed takes in these fisheries seem to have declined due to protective legislation and changes in fisheries practices. However, these activities and implementation of protective regulation have not been enforced (Manzur and Canto 1997).
In the present, the main concern for the conservation of *C. eutropia,* as well as for other coastal dolphin species, is the incidental catch in local fisheries and the progressive destruction of potential critical areas, mainly due to aquaculture activities (for mussel and salmon), which have expanded rapidly in the sheltered bays, channels and fjords of southern Chile (Buschmann *et al.*, 1996; Sullivan Sealey and Bustamante, 1999).

One major response to the growing crisis in marine capture fisheries has been the rapid raise in various forms of aquaculture, the latter defined as the rearing in water of organisms in a process in which at least one phase of growth is controlled or enhanced by human action (Groombridge and Jenkins, 2000). Two main types of marine-based aquaculture come into potential conflict with marine mammals (and, in some areas, with marine birds and turtles): extensive raising of shellfish, such as oysters, mussels and shrimp; and intensive raising of finfish, such as salmon, sea bass and sea bream (Würsig and Gailey, 2002). Since its implementation in Chilean waters in the 1980s, the aquaculture industry has increased in more than 140 times its initial production, especially in the tenth region, which is responsible for more than 90% of the national production (Clasing *et al.*, 1998; Claude and Oporto, 2000; SERNAPESCA, 2001). In the present, Chile is the first salmon producer in the world (505000 tons/yr), and even though mussel (*Mytilus chilensis*) production is much less than salmon culture (35000 tons/yr), is considered one of the most representative in the southern hemisphere (SERNAPESCA, 2001; Kemper *et al.*, 2003).
Mussel is cultured massively, it takes up space in near shore waters, but does not require nets or cages that can entangle or otherwise hurt air-breathing vertebrates. It does not require supplementary feeding, however it can generate an intense organic enrichment of the water column and sea bottom due to the high biodeposition rates (faeces and pseudofaeces) and frequent detachment of individual mussels from suspended systems, altering the sediment composition and reducing the amount of oxygen available (Dahlback and Gunnarson, 1981; Grant *et al.*, 1995; Würsig and Galey, 2000). Consequently, the benthic community is modified, as well as the local biodiversity (Navarro *et al.*, 1995; Stenton-Dozey *et al.*, 1999; Chammberlaim *et al.*, 2001). The intensive, but more localized farming of salmon requires external supplementary feeding (rich in phosphorus and

nitrogen) and an important quantity of antibiotics (Mirto *et al.*, 2000; Naylor *et al.*, 2000), all of these causing significant impacts on the environment (Wu, 1995; Buschmann *et al.*, 1996; Naylor *et al.*, 1998). In summary, the potential impacts of the aquaculture industry are many, impacting local coastal environments by misuse of important areas, eutrophication from over input of nutrients into the environment from faeces and pellets, antibiotics, exotic diseases, alteration of native fish communities from escaped salmon, negative interaction with marine mammals and birds, chemical and solid residues pollution (pellet plastic bags) and increased boat traffic (Claude and Oporto, 2000; Würsig and Galey, 2000).

In the present report, we detail the information gathered and analysed from a cooperative work in three different areas in southern Chile, on the ecology and conservation of the Chilean dolphin. It was the coastal dolphin species recognized initially to be potentially affected by anthropogenic activities and hence, used as flagship species for marine ecosystem conservation due to its attribute of umbrella and charismatic species. During the course and progress of this project, Peale's dolphins (*Lagenorhynchus australis*) were also identified in the study area and, due to their important occurrence with relation to the Chilean dolphin and the aquaculture activities, were also included in the analysis and used as flagship species towards the conservation of coastal habitat. Peale's dolphin has also a very restricted coastal distribution, inhabiting the waters of only Argentina and Chile, in southern South America, ranging from Valparaiso, Chile (33° S), around Tierra del Fuego up to Golfo San Matias, Argentina (38° S).
Data is mainly analysed from one season (2002/03), but due to the importance of the fine spatial scale of one of the studies undertaken during the previous field season, it was also included in this report.

OBJECTIVES

Overall Aim

To obtain scientific understanding of the ecology of Chilean dolphins and identify the conservation threats they face, allowing in this way the building up of environmental awareness on marine ecosystems in local communities and authorities through environmental education, considering the Chilean dolphin as flagship species.

Specific Objectives

a. Describe geographic distribution patterns and movements of Chilean dolphins.
b. Identify critical habitats for dolphins in the study area, describing Chilean dolphin habitat selection at different spatial scales
c. Raise public awareness on conservation issues regarding the marine environment, considering the Chilean dolphin as a flag species.
d. Provide field training to graduate students and local community members.

The objectives above were then also developed for Peale's dolphins

PROJECT AREA

The project was developed in southern Chile, mainly in three subareas: Yaldad bay (43°08'S, 73°44'W), Comau fjord (42°22'S, 72°24'W) and Reñihue fjord (42°34'S, 72°30'W) (Figure 1). The three sub-areas sum in total more than 500km^2.
Yaldad Bay is localized in southern Chiloe Island, Chile (Figure 2). Its coastline is mainly constituted by pebbly beaches, while its central deepest portion is constituted by soft bottom (sand and mud) (Navarro *et al.*, 1993). The bay's average depth is about 13.4 m, with a maximum of 32 m. The average declivity is 2.3% (SD = ±1.7%) and the maximum is of 12%. Tide cycle is semidiurnal, with the high tide ranging from 3 to 5 m (SHOA, 1999). The water temperature varies between 9° to 16° C (in winter and summer, respectively) (Winter *et al.*, 1982; Navarro and Jaramillo, 1994). The average salinity is 30‰, but values of 25‰ might be measured after rain seasons (Navarro *et al.*, 1993; Classing *et al.*, 1994). An extensive area of Yaldad bay is used for growing the mussel *Mytillus chilensis*, which exists at great scales since the end of the 80s (Bushmann *et al.*, 1996; Clasing *et al.*, 1998). Recently, salmon farms have also been set up in the area.

The fjord area presents part of the intricate array of inner passages, abrupt coast, channels, fjords and archipelagos of southern Chile (Figure 2). It is also characterized by unique features of cold-temperate marine environments, with strong tidal currents, fresh water influence of glacier melt and pluviosity, and an average sea surface temperature ranging from 6-12°C during summer.

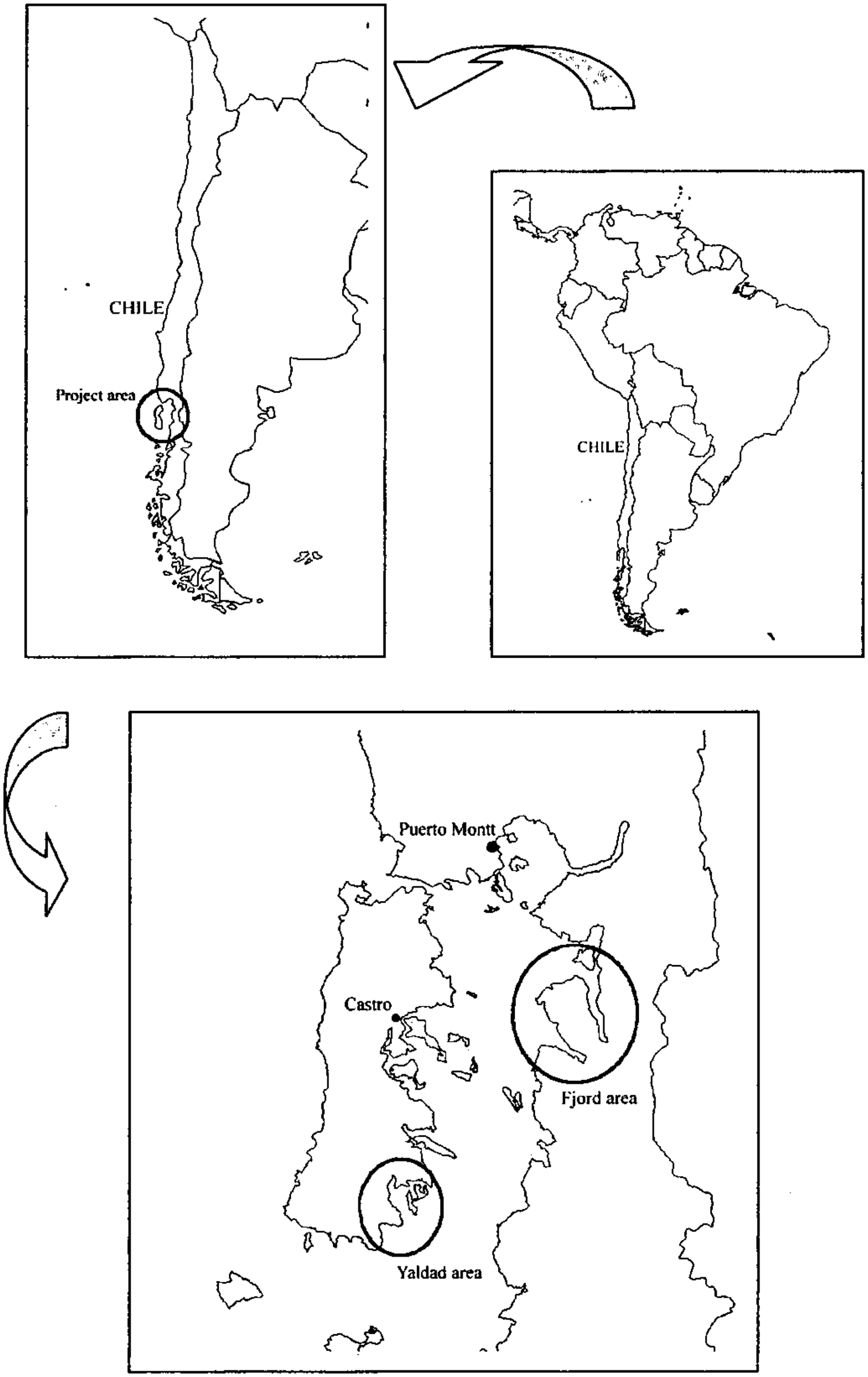

Figure 1. Study areas where the project was carried out, southern Chile, South America.

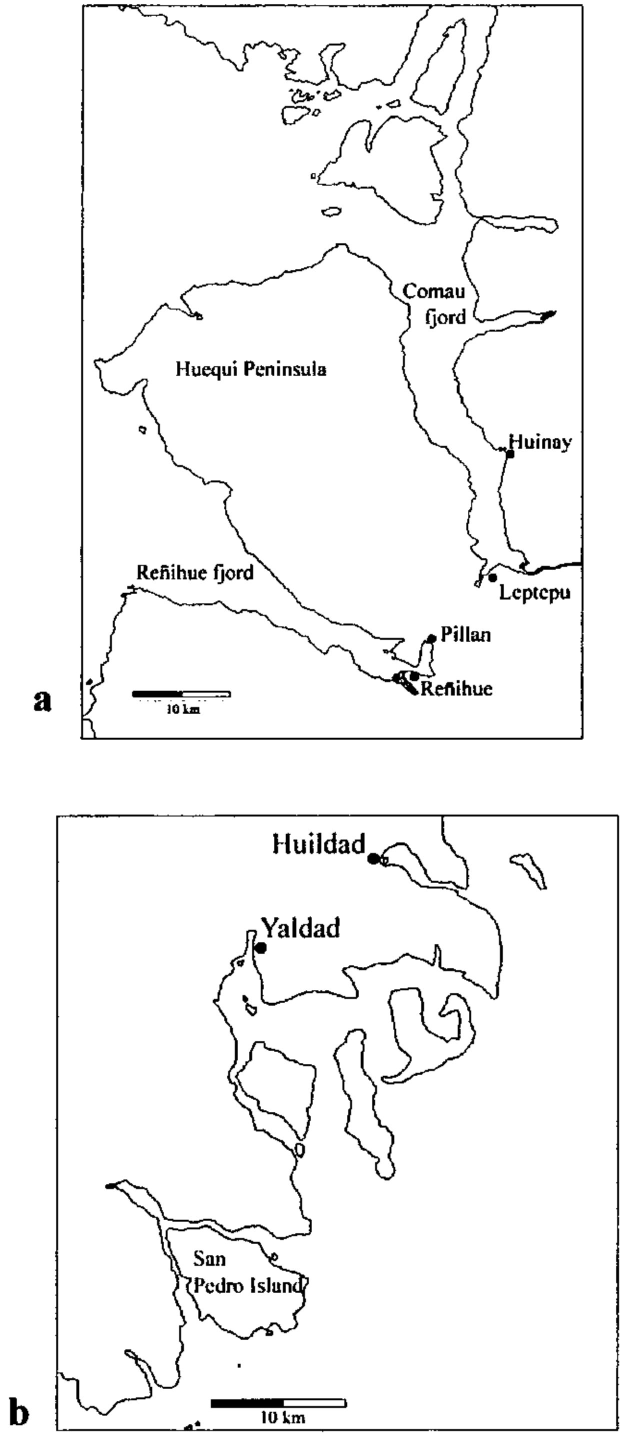

Figure 2. Detail of study areas. a) Fjords and b) Yaldad area

METHODOLOGY

Fieldwork was conducted from December 2002 through April 2003 and included marine surveys in the three areas selected for this study as well as land-based observations (theodolite tracking) in Yaldad area, during January-April 2002. This latter study, even though developed the preceding season by Sandra Ribeiro, it is considered extremely important due to the fine spatial scale of the results and conclusions obtained.

Marine Surveys

Survey refers to encountering groups or individual dolphins for brief periods to census the number of animals and record location, identification and probable behaviour state (Mann 1999, 2000). Marine linear transect surveys were undertaken by two to three observers on a 3.5 m inflatable boat with an outboard two stroke engine Yamaha 25 Hp (in Yaldad area) and on a 4.5m semi rigid boat with an outboard four stroke engine Honda 50 Hp (fjord area). Observers were looking for dolphins by naked eye or binocular 7x50 covering a strip of about 500m looking ahead to 90° on each side, at searching speed of 8 to 10 knots. At the beginning of each survey, and thereafter every 15 minutes, an effort sheet was filled recording date, time, geographical coordinates, weather conditions (sea state, cloud cover, wind direction and relative strength) as well as oceanographic variables (sea surface temperature and water visibility). Data on human activities such as salmon farms locations, boat traffic and floating garbage distribution was also recorded. Field observations were restricted to Beaufort sea states three or less.

Whenever dolphins (a group or a solitary individual) were sighted, the transect track was interrupted in order to record dolphin geographical position with a Magellan Meridian GPS, group size, angle of sighting and distance estimation. Data on oceanographic variables as well as weather conditions were recorded after every sighting. A "group" of dolphins was defined as any aggregation of more than one dolphin (including all age classes) observed close to each other within a radius of 100m (Mann 1999, 2000).

Data was also obtained on behavioural states following the definitions below:

-Foraging: A variety of behaviours distinguished by such events as repeated and asynchronous dives in varying directions in one location. It could occasionally be seen prey being captured.

-Travelling: Consisting of persistent movement in one direction. Travelling animals move as a unit, with all group members diving and surfacing regularly.

-Socializing: Some or all group members in almost constant physical contact with one another. Characterized most of the time (but not always) by a high level of activity, often displaying surface behaviours like slaps and leaps. It might include actual mating taking place.

-Forage/Travelling: Moving steadily in one direction while presumably hunting or seeking prey (and therefore some changes in direction are seen).

-Resting: Characterized by low levels of activity during which almost no forward movement is observed, very slow movements or drifting in one direction may also be observed.

During dolphin encounters, photo- and underwater video identification, as well as skin-swabbing sampling (for genetic analysis), were performed as long as it was possible for up to 30 minutes, then the transect track was continued (data presented in this report from fjord area only). Photographs of dorsal fin pigmentation patterns, scars, deformations, edge detail, incrustations, and imperfections were used to identify individuals within the population. A well-marked individual is recognised by a matrix of marks, which form a distinctive 'face' for the individual (Würsig and Jefferson, 1990). The photo-identification was complemented with underwater video of bow riding dolphins, which helped in the identification from body pigmentation and scars when dorsal fins were not well marked.
Every photograph, taken with a digital camera Nikon coolpix 5700, was stored digitally into a database along with essential information on date, time, group composition, geographical position and behavioural state. Video footages were obtained by using a digital MDV Sony 330V video camera with an underwater housing. These images were then played in the computer and captured according to image quality and possibility of identifying individual dolphins. Important behaviours were also recorded.
Marine surveys were developed in order to get independent data on dolphin group distribution and in this way get the best of information on habitat selection and use. Dolphin sightings, salmon farm position, boat traffic and garbage distribution were first recorded into a GPS, which were then downloaded into the computer using *GPS Utility* software (© *Allan Murphy*). All geographical positions were mapped (plotted) into a digitized chart (IGM map, Chilean Military Geographic Institute) for later geostatistical analysis into a GIS database ArcView (ESRI, Environmental Systems Research Institute). The software *SSPS* and *STATISTICA* were used for the main statistical tests utilized for data analysis.

Land based study

Between January and April 2002, land based observations were performed from a fixed vantage point of 102.78 m high (above sea level) with a wide angle of vision of the bay (Figure 3). Dolphin and boat positions were determined using a digital theodolite Pentax ETH-10D (10'' precision and 30X telescope). This equipment measures horizontal angles in relation to a reference point (zero point) and vertical angles in relation to the Earth gravitational centre. Knowing the theodolite geographical position and zero reference point, the precise instrument's height above sea level (considering tide fluctuation), horizontal and vertical angles can be converted to x/y map coordinates (Würsig *et al.*, 1991), which was achieved using the software *PYTHAGORAS* (© *Glenn Gailey, Texas A&M University*).
Since 1979 theodolite tracking from shore has been widely used in many cetacean studies, principally to describe movement and habitat use patterns (Würsig and Würsig, 1979a; Würsig and Würsig, 1979b; Smith, 1993; Yin, 1999; Bejder and Dawnson, 2000; Quick, 2001) and to evaluate behavioural responses to boat traffic (Kruse, 1991; Bejder *et al.*, 1999; Yin, 1999; Williams *et al.*, 2002). This method, in addition to precision, has the particular advantage of not affecting the animal's behaviour as observations are always from a high vantage point away from the water surface (Würsig *et al.*, 1991).
Two to thee observers, using binoculars 7x50 and spotting scope (60X), scanned the entire bay looking for dolphins. Once sighted, dolphins were followed and monitored maximizing

time the groups of animals (through groups follows and focal group sampling, after Mann 1999, 2000). To evaluate the patterns of dolphin habitat use in relation to aquaculture activities, the areas covered by mussel and salmon farms, as well as boat track, were also mapped determining their position with the theodolite. By performing a spatial analysis through the GIS software package *IDRISI 3.2*, variables such a depth, declivity, distance to the coast, rivers and aquaculture structures were extracted for correlation of dolphin habitat use patterns. The entire area was divided into 100x100 m quadrants for further analysis.

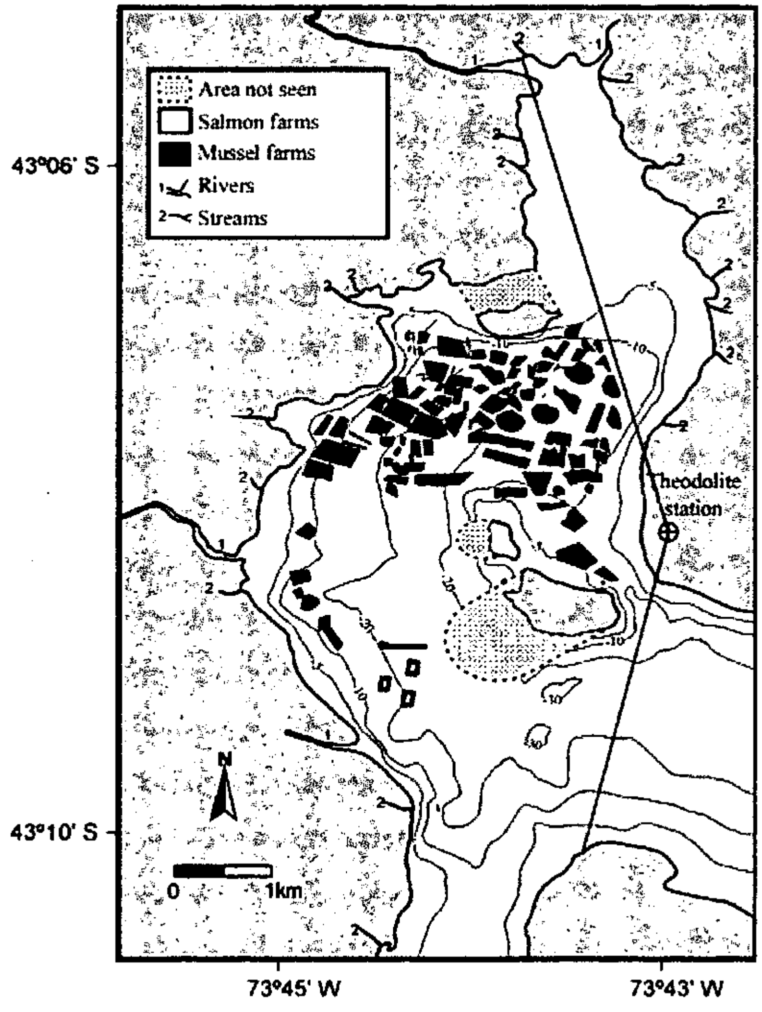

Figure 3. Yaldad Bay, area of the fine scale study on Chilean dolphins. Angle of vision (—) and theodolite station (⊕) are shown.

RESULTS

Effort and sighting data

More than 650 hours of marine survey effort were achieved in all areas. 331 effort hours were made in the fjord area, with 258 dolphin sightings; 84 Chilean and 174 Peale's dolphin. In Yaldad area 95 sightings of Chilean and 36 sightings of Peale's dolphin were obtained, totalling 131 sightings.

In the fjord area there was no significant difference in effort hours when comparing among months (*ANOVA*, F=0.604, df=4, p=0.661), but there was a significant difference in sighting rate taking into consideration the two species observed (*Kruskal-Wallis ANOVA*, KW=10.12, df=4, p=0.038) (Figure 4).

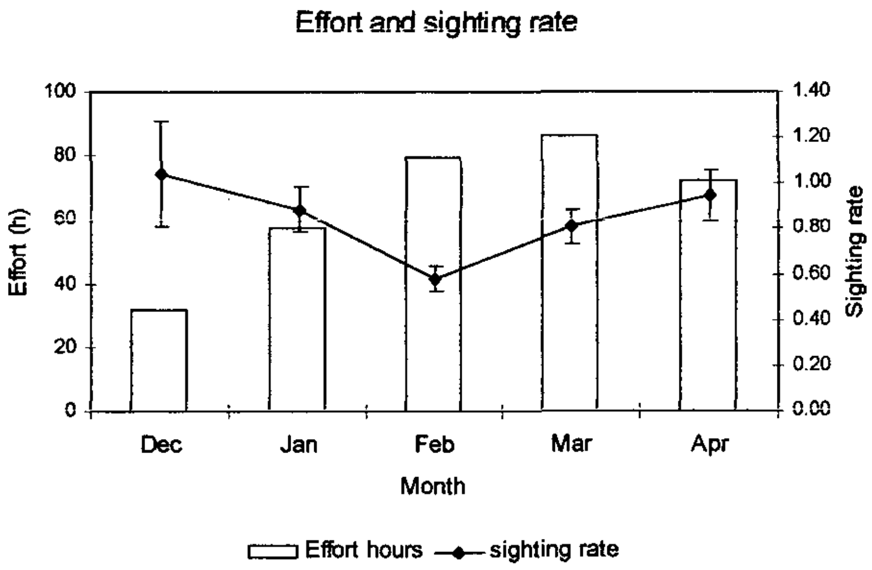

Figure 4. Effort hours and sighting rate of dolphins seen in the fjord area

Peale's dolphins were significantly more frequently seen than Chilean dolphins (*T test*, T=3.0, p=0.004). Finally, for both dolphin species, sightings were not correlated with Beaufort sea sate (*Pearson*, r =0.150, p=0.227).

During the fine scale study on habitat selection (theodolite) developed in Yaldad, 293.5 hours of effort were made, with an effective rate of 23% (effectively following dolphin groups). 192 dolphin groups were followed, achieving 3659 theodolite readings. Observation effort was significant similar for all months (*ANOVA*, F=1.56, df=3, p=0.21), but there existed a significant difference in the effective rate among months (*ANOVA*, F=3.45, df=3, p=0.02) (Figure 5). Dolphin occurrence in Yaldad bay was greater during

January-February than during March-April (*T test*, T=3.14, p=0.003), suggesting a possible seasonal dolphin movement pattern.

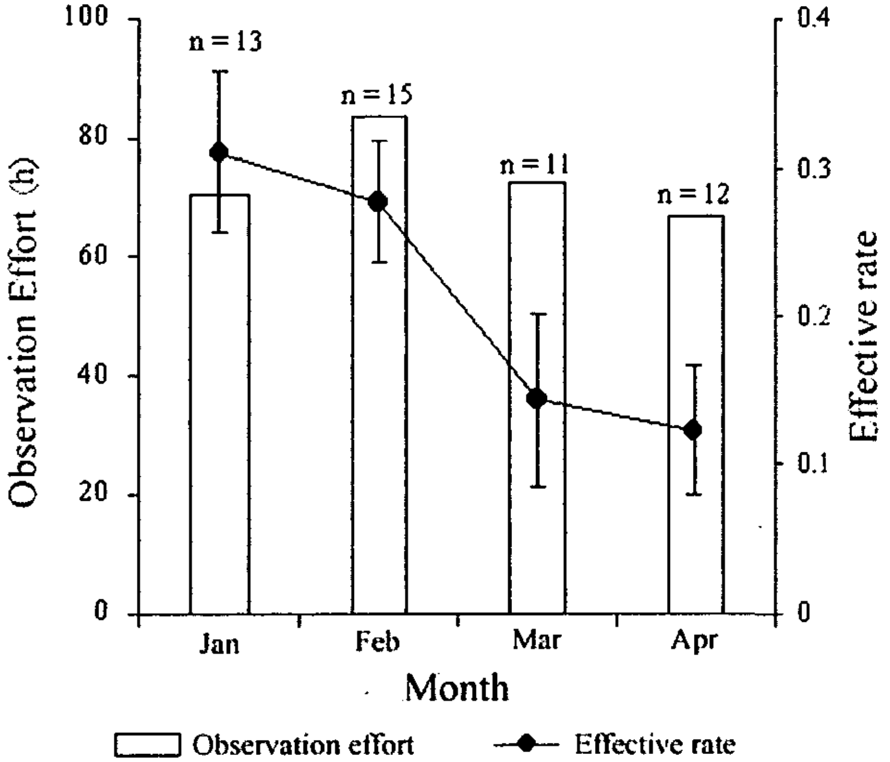

Figure 5. Observation effort and effective rate during the months of study at Yaldad bay (fine scale habitat selection study). Effective rate represents the total time following dolphins in relation to the observation time. *n* indicates days of effort achieved in that particular month.

Diversity and spatial distribution of marine mammal species

During the study and within the area, six species of marine mammals were registered. Four species of small cetaceans (three dolphin species and one porpoise) and two pinnipeds (sea lions and elephant seal) (Table 1).

Practically all species were seen in Reñihue fjord, except for the single sighting of a group of orcas (*Orcinus orca*); which were observed in Comau fjord. Sea lions were seen in all areas, but the rookeries were only registered in Reñihue fjord and consisted of about 450 animals and one rookery in Comau fjord (approximately 250 animals). Both rookeries do not appear to be reproductive (Figure 6).

Table 1. Diversity of marine mammals registered in all areas surveyed during the study period

Common name	Scientific name	Area where species were observed
South American sea lion	*Otaria flavescens*	Comau, Reñihue and Yaldad
Southern elephant seal	*Mirunga leonina*	Reñihue
Orca	*Orcinus orca*	Comau
Peale's dolphin	*Lagenorhynchus australis*	Comau, Reñihue and Yaldad
Chilean dolphin	*Cephalorhynchus eutropia*	Reñihue and Yaldad
Burmeister's porpoises	*Phocoena spinipinnis*	Reñihue

Four sightings of elephant seals were recorded (however, we strongly believe it was always the same seal), all of them in Reñihue fjord. These sightings are very important, since these animals, whose distribution includes these areas, are rarely seen (Figure 7).
Six sightings of Burmeister's porpoises were made, all of them in Reñihue fjord (Figure 11). These were encountered between February and April. Group size varied from 3 to 8, and only one calf was seen (in the biggest group). These are very timid animals and difficult to see. Only last year, the first pictures ever of free ranging animals were taken (S. Heinrich) and this year more pictures were taken in Reñihue. Maybe one of the most important events was obtaining the first video footage, both from the boat and underwater, which are the first in their class for this species (Figure 8).
Peale's dolphin was the species that presented more overall sightings, with a greater number in Comau fjord (n=161) (Figure 9 and 11). This species was seen almost all over this fjord, nevertheless, its distribution in Yaldad area and Reñihue fjord was much restricted. On the other hand, Chilean dolphins were only registered in Reñihue fjord and Yaldad area (Figure 10 and 11).

Figure 6. South American sea lions seen in all areas. Colony shown is from Reñihue fjord

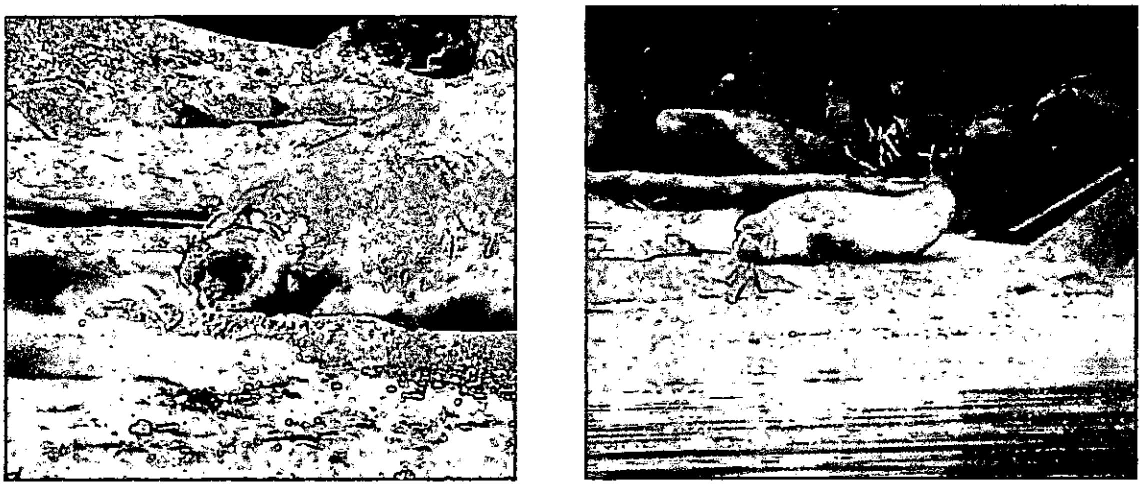

Figure 7. Southern elephant seal registered in fjord Reñihue.

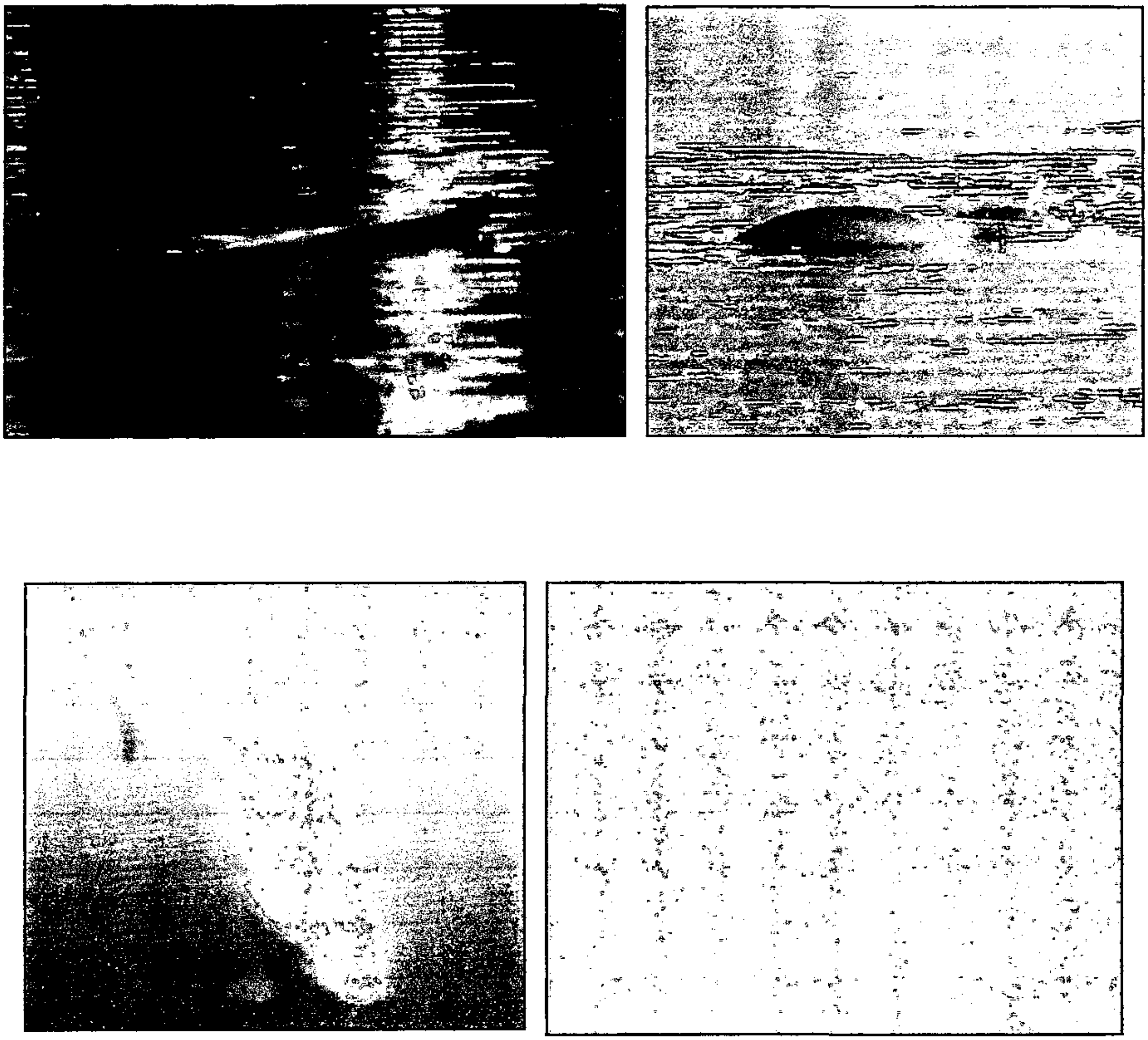

Figure 8. Burmeister's porpoise observed in Reñihue fjord. The team members of this project possess the first pictures and video footage ever (above and underwater) of free raging animals of this species.

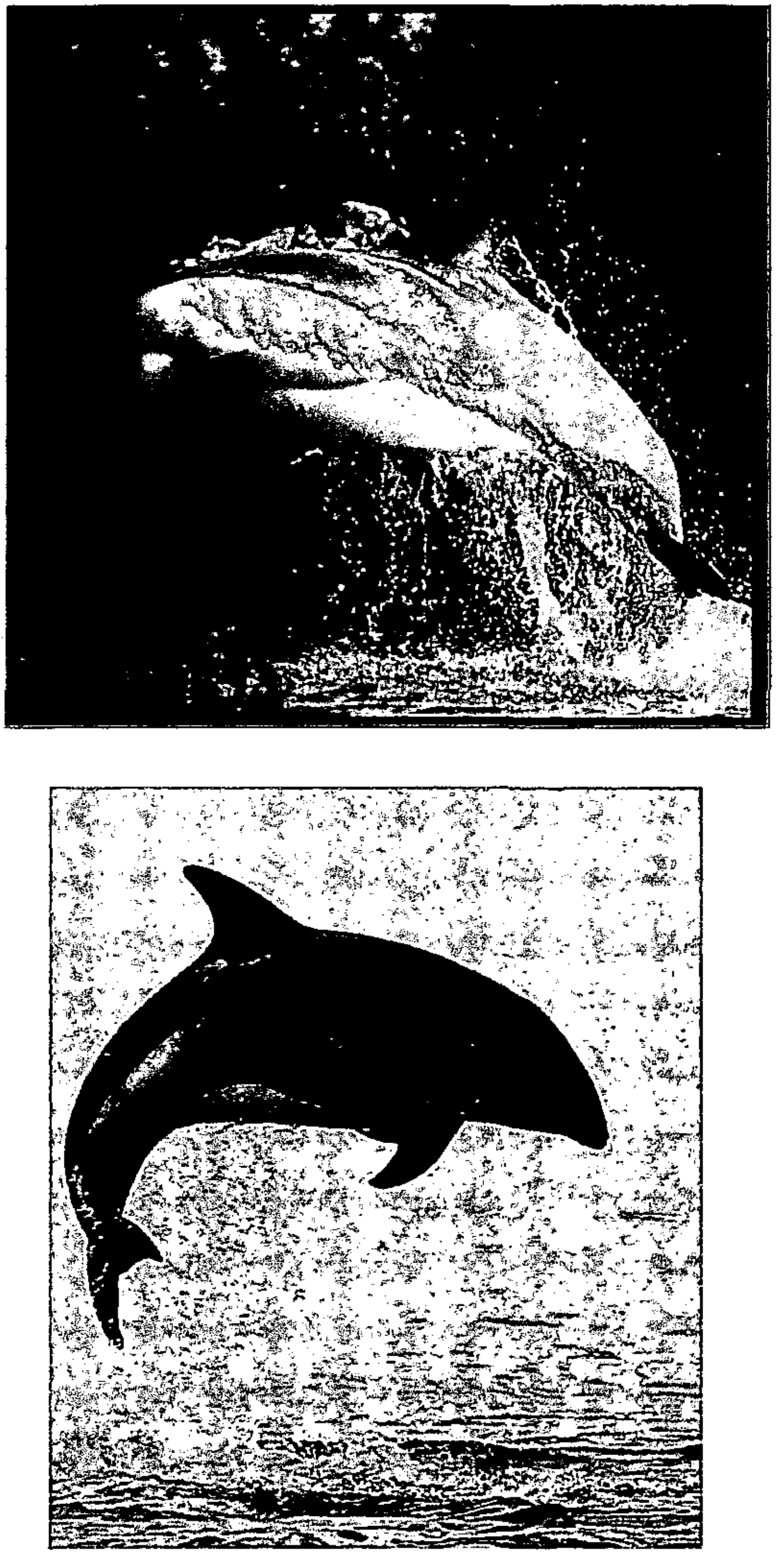

Figure 9. Peale's dolphins sighted in all areas

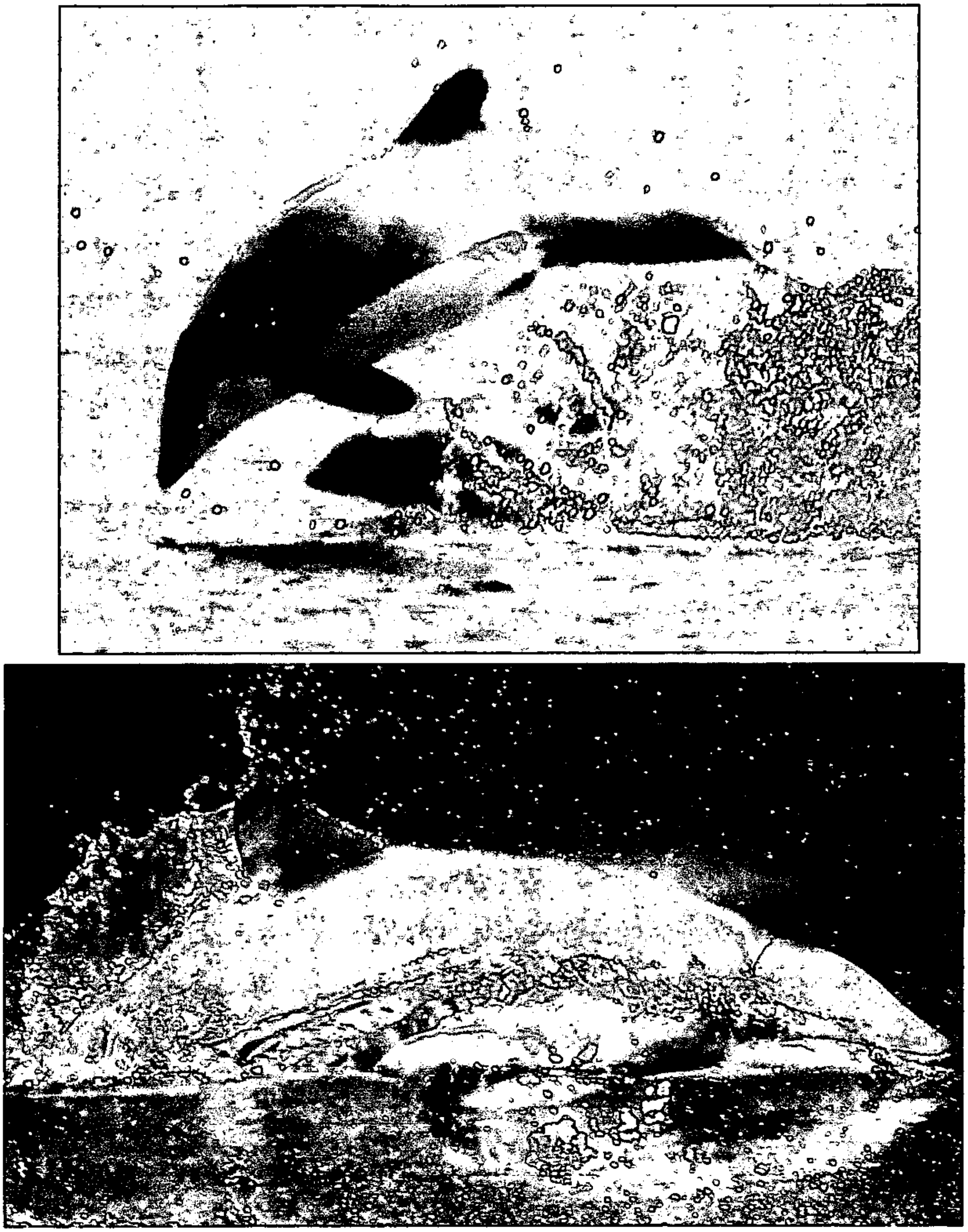

Figure 10. Chilean dolphins sighted in Reñihue fjord and Yaldad area

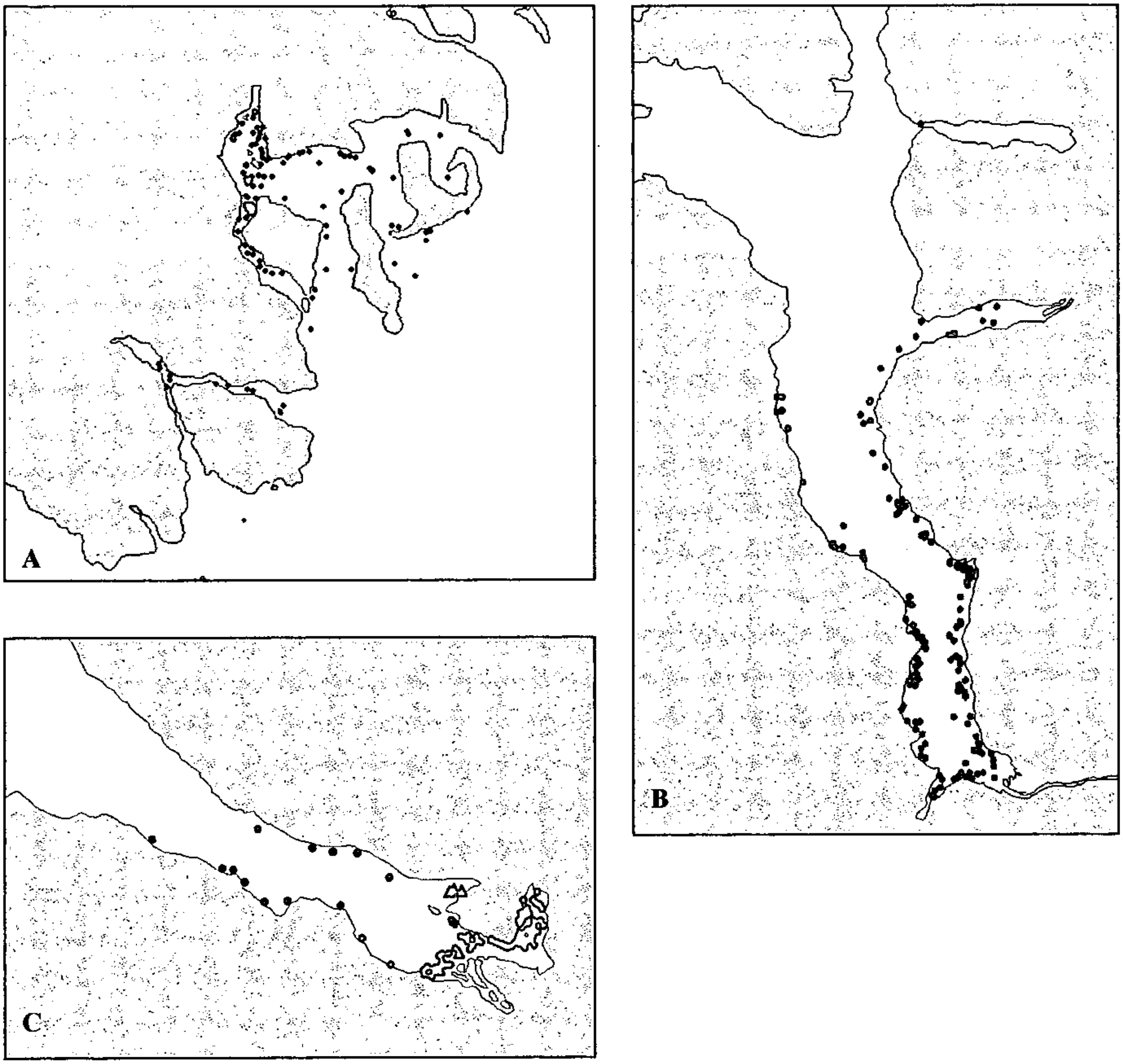

Figure 11. Species spatial distribution in all areas studied. Red circles represent Chilean dolphin sightings; blue circles represent Peale's dolphin and green triangle represent Burmeister's porpoises. A) Yaldad area, B) Comau fjord, and C) Reñihue fjord.

Habitat selection

From a general large scale, there seems to be a marked habitat segregation between dolphins species and porpoises. Burmeister's porpoises were mainly seen in a small bay called Fiordo Largo, where the other dolphin species were never seen. Twice, porpoises were seen near Chilean dolphins, but they never mixed. Although the general geographical distribution described for both Chilean and Peale's dolphins overlaps, at the smaller scale, habitat selection seems to be interestingly segregated and specific for both species (Figure 11). Within the potential home range, Chilean dolphins seemed to select certain habitats, which we could consider as core.

From the whole area surveyed in Reñihue fjord (divided into 29 line-shore sections of approximately 1 km), Chilean dolphins were not evenly distributed (χ^2=360.48, *df*=28, p<0.001). They concentrated their activities significantly in only five sections, which means that only 17.2% of the area was principally used (D_{max}=0.7881, p<0.001) (Sections 1, 2, 4, 5 and 6) (Figure 12)

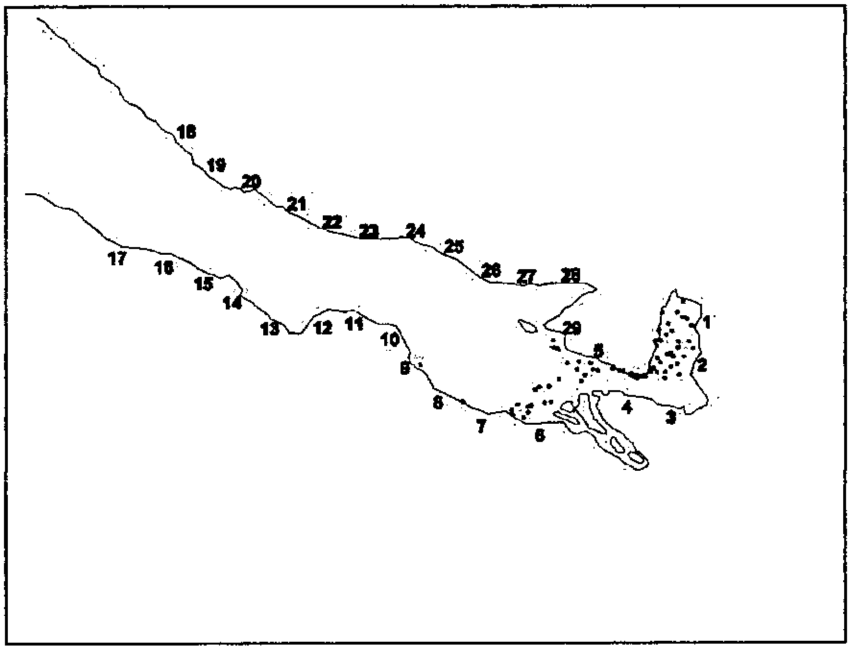

Figure 12. Habitat selection of Chilean dolphins in Reñihue fjord. Red circles represent dolphin sightings and numbers correspond to aprox. 1 km sections of coastline.

Even though Peale's dolphin showed a more wide-ranging distribution in Comau fjord, there was still a significant difference in their distribution in the area (divided into 49 line-shore sections of approximately 1 km) (χ^2=148.86, *df*=49, p<0.001). They concentrated their activities significantly in 18 sections, which means that 36.7% of the area was principally used (*K-S* D_{max}=0.3771, p<0.001) (Sections 1, 2, 5, 6, 7, 8, 12, 14, 16, 20, 39, 41, 43, 44, 45, 46, 47 and 48) (Figure 13). Peale's dolphins did not show any preference for any area in Reñihue fjord.

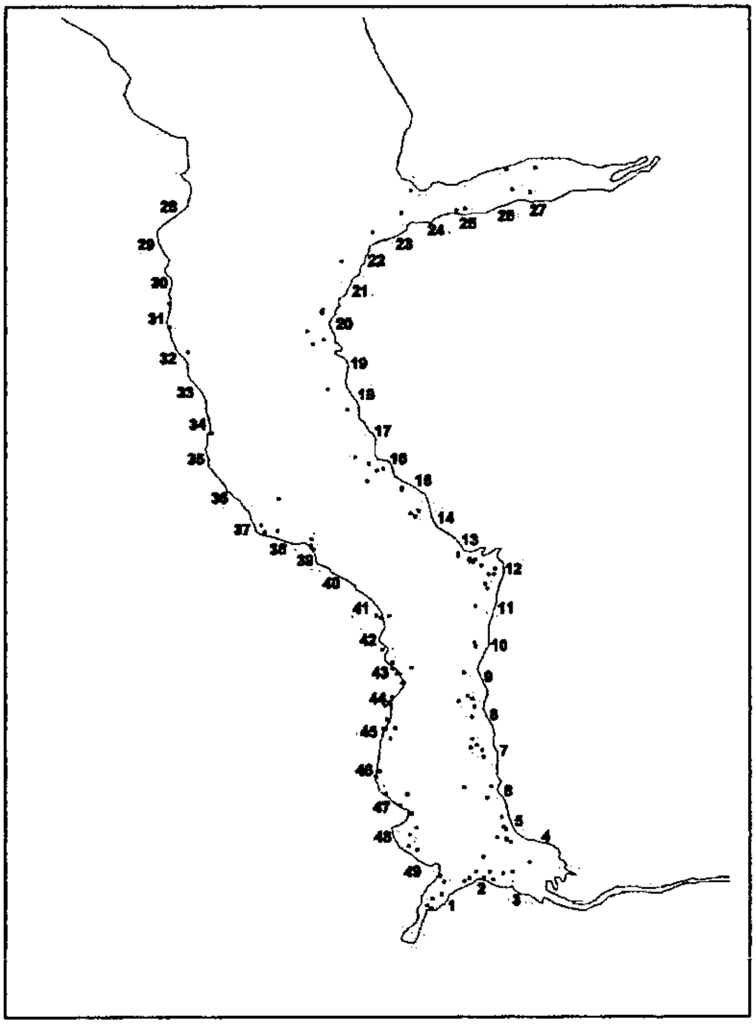

Figure 13. Habitat selection of Peale's dolphins in Comau fjord. Blue circles represent dolphin sightings and numbers correspond to aprox. 1 km sections of coastline.

In relation to environmental variables, Chilean dolphins seemed to prefer colder surface waters when comparing with Peale's dolphin, for both fjord areas, as well as for Yaldad area; nevertheless, a greater difference was seen in the fjords (*T test*, t=4.87, df=218, p<0.001 for fjord area; and t=-2.08, df=89, p=0.04 for Yaldad area). In addition to this, Chilean dolphins showed a very marked preference for turbid waters, both in the fjords and in Yaldad area, but again, the difference was stronger in the fjords (*T test*, t=5.47, df=170, p<0.001 for fjord area; and t=2.15, df=106, p=0.034 for Yaldad area) (Figure 14).

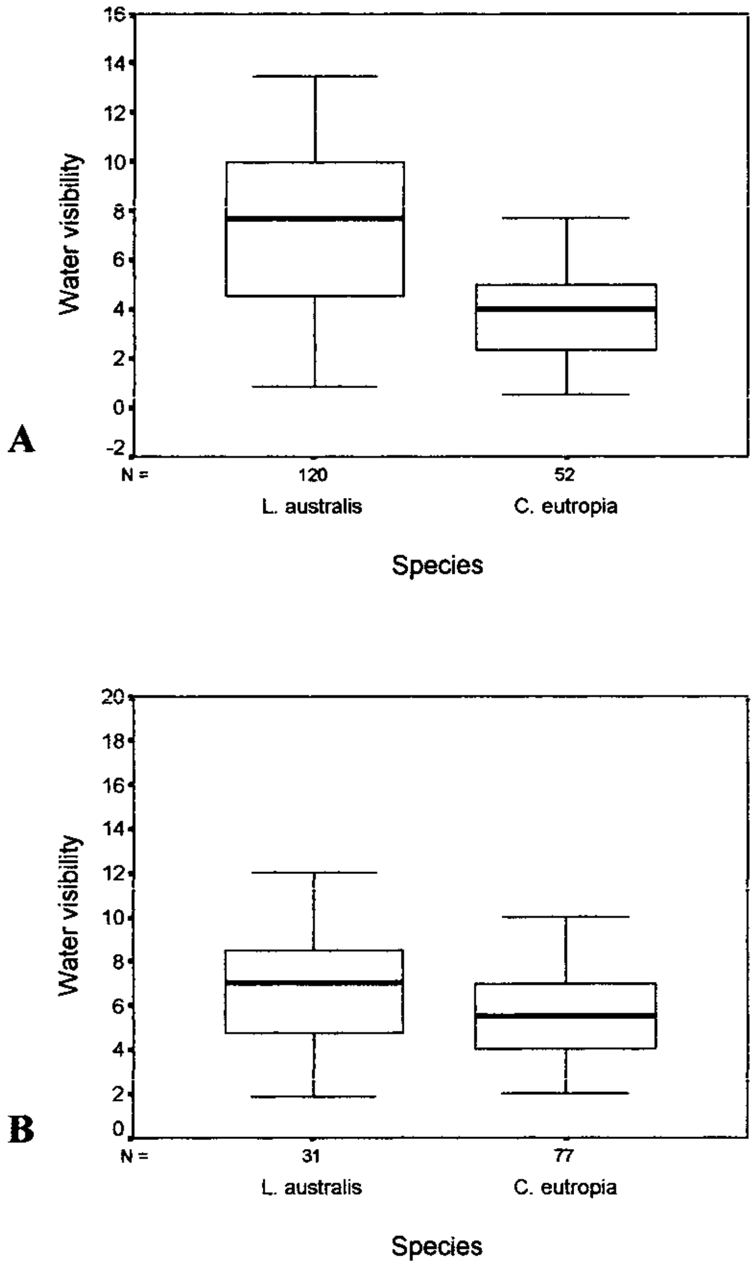

Figure 14. Preference of water clarity (in meters) for Chilean and Peale's dolphin in the fjords (A) and Yaldad area (B)

When bringing together all variables, environmental as well as the ones extracted from GIS analysis, a Principal Component Analysis (PCA) was carried out; which resulted in three components (more than 65%) explaining the habitat selection of dolphins in the fjords. Chilean dolphin habitat selection was mainly related to turbid waters and short distance to rivers, away from salmon farms and boat routes (Table 2)

Table 2. Principal Component Analysis for Chilean dolphins in the fjord area. (Rotation method: Quartimax with Kaiser Normalization).

	Component		
	1	2	3
Water visibility	.103	-.718	-.259
Sea surface temperature	-.148	5.799E-02	.834
Distance to coast	4.315E-02	.850	-.152
Distance to big rivers	-.807	2.320E-02	.321
Distance to streams	.966	8.448E-02	-7.864E-02
Distance to salmon farms	.953	-.143	6.957E-02
Distance to boats	.662	3.142E-02	.545

On the other hand, Peale's dolphin habitat selection was related to clearer and warmer waters than Chilean dolphins, but also close to shore and close to big rivers (Table 3)

Table 3. Principal Component Analysis for Peale's dolphins in the fjord area. (Rotation method: Quartimax with Kaiser Normalization).

	Component		
	1	2	3
Sea surface temperature	.846	-3.545E-02	-.186
Water visibility	.851	8.150E-03	.103
Distance to coast	8.739E-02	.468	-.427
Distance to big rivers	8.812E-02	.901	.134
Distance to streams	.375	-.583	.112
Distance to salmon farms	-7.875E-02	-.248	.676
Distance to boat routes	8.441E-02	.324	.844

Hence, the possible habitat segregation might be given by water clarity and/or sea surface temperature as is shown in a principal component analysis (PCA) diagram, where a two plot-cloud pattern can be seen, representing a separation of variables preferred by the different species (Figure 15).

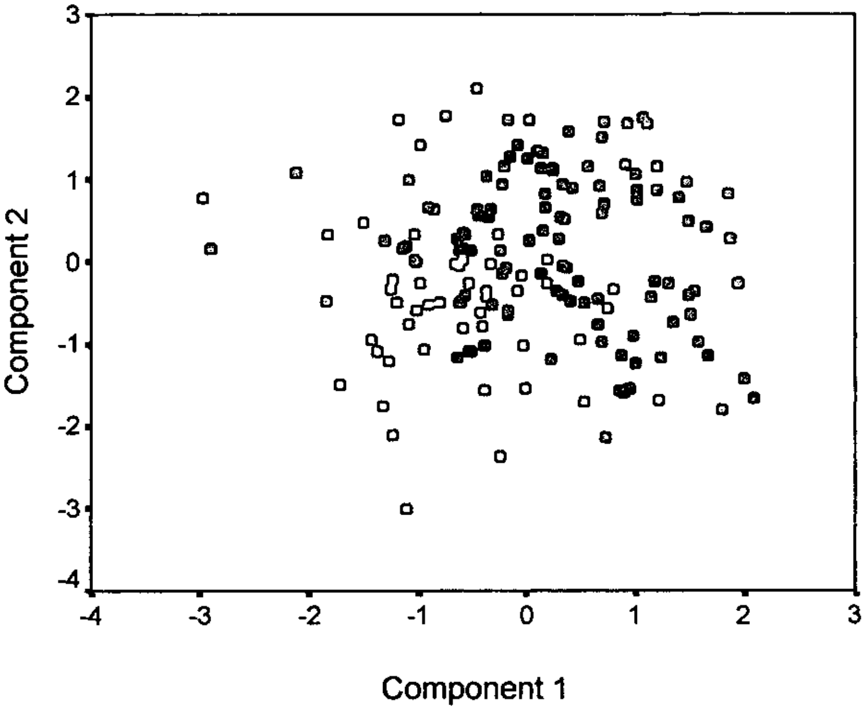

Figure 15. Principal Component Analysis scatter plot graph showing a pattern of two different clouds of plots, representing each one of the dolphin species (Chilean dolphins represented by red and Peale's dolphin by blue)

Extremely important was to observe that habitat selection was given at different scales. At relative large scale (approximately 60 km of coastline and an area of 120 km^2 for Chilean dolphin surveys in Reñihue) dolphins select a small area of the potential home range, but at the relative fine scale (approximately 10 km of coastline and an area of 22 km^2 for Chilean dolphin land based surveys in Yaldad bay), dolphins were also restricted to a very small area, utilizing significantly only 21% of the entire bay ($K\text{-}S\ D_{max}$=0,707 p<0,001), mainly a narrow strip close to shore (Figure 16). Dolphins used this area for 91% of the total time groups were monitored

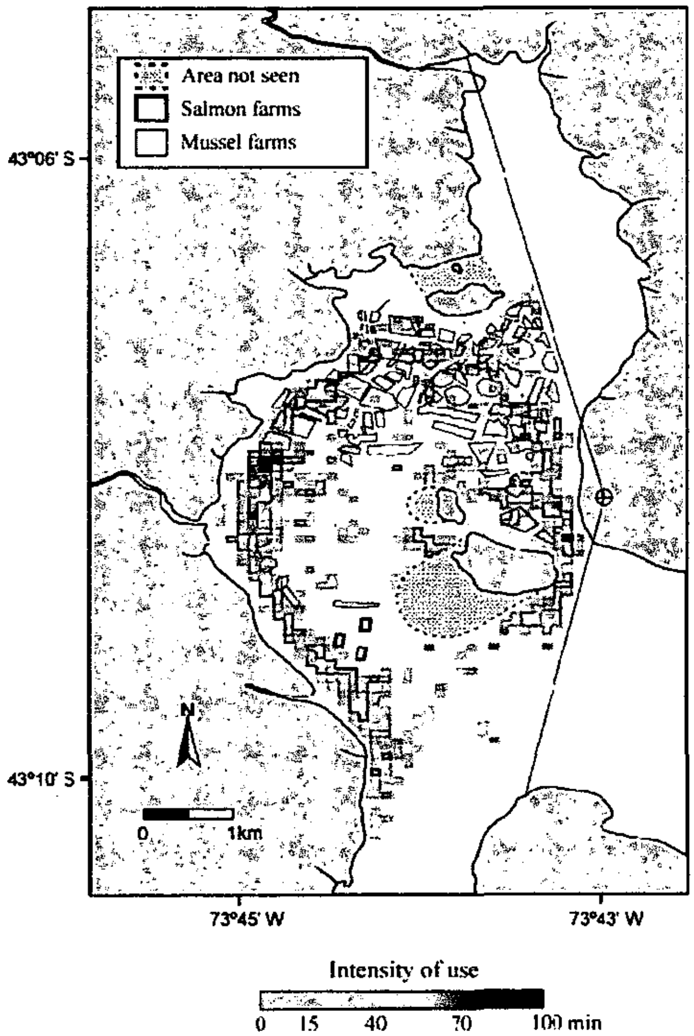

Figure 16. Fine-scale habitat selection of Chilean dolphins in Yaldad Bay (shown as intensity of use in minutes).

The association between the intensity of dolphin habitat use and the environmental variables (extracted through GIS) (Table 4) was analysed through Correspondence Analysis and showed that dolphins were significantly selecting certain factors of their habitats. In areas used (Figure 17), a gradient among the selected categories can be seen, from a lower to a greater intensity, with some characteristics in common for areas with *little*, *medium* and *high* intensity of use. Areas close to coast (up to 500m) (categories 1 and 2, Table 4), with depth range of 5-10m (category 6) and intermediate distances to rivers and streams (14 and 17, respectively), were the environmental variables selected by dolphins, independently if used with *little, medium* or *high* intensity.

Areas close to rivers and streams (categories 13 and 16, respectively) constituted the main factor for *high* intensity of use, while areas more than 500 m from the coast (categories 3 and 4), depth greater than 20 m (9), with no declivity (10), more than 1 km from rivers (15) and more than 750 m from streams (18) were associated to areas *absent* of dolphins (variables not selected by the animals) (Figure 17).

Table 4. Categories of variables extracted from GIS analysis used in the Correspondence Analysis. The intensity of use by Chilean dolphins is categorised in four classes, according to the amount of time in each quadrant.

Variable	Category	
Intensity of use (min)	0	Absent
	1-10	Little
	10-25	Medium
	> 25	High
Environmental variables		*Numeric code*
Distance to coast (m)	0-250	1
	250-500	2
	500-1000	3
	> 1000	4
Depth (m)	0-5	5
	5-10	6
	10-15	7
	15-20	8
	> 20	9
Declivity (%)	0	10
	1-5	11
	> 5	12
Distance to rivers (m)	0-500	13
	500-1000	14
	> 1000	15
Distance to streams (m)	0-350	16
	350-700	17
	>700	18
Distance to salmon farms (m)	0-250	19
	250-500	20
	>500	21
Mussel farm coverage (%)	0	22
	1-30	23
	30-60	24
	> 60	25

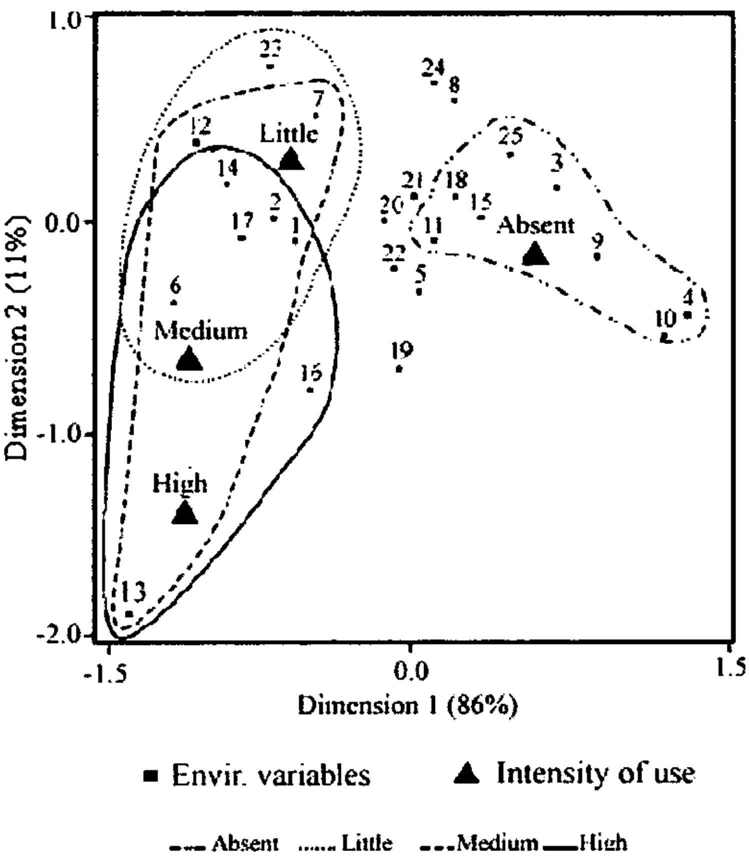

Figure 17. Percentage graph of Correspondence Analysis between environmental variables and intensity of use by Chilean dolphins in Yaldad bay. The lines discriminate the significant associations obtained by fitted residual analysis ($p<0.05$)

Behavioural patterns and group size

Chilean dolphin mean group size in the fjords (Reñihue) was 5.92 ($SD=3.32$, $n=77$) and ranged from 1 to 17 animals per group; while in Yaldad the mean group size was 6.63 ($SD=4.03$, $n=93$) and ranged from 1 to 25 animals per group. Chilean dolphin mean group size did not differ significantly with the value for Peale's dolphin for both the fjord area and Yaldad (*T test*, $t=-0.078$, $df=242$, $p=0.94$ for the fjords and $t=-1.95$, $df=125$, $p>0.05$ for Yaldad area). Peale's dolphin mean group size was 5.88 in the fjords ($SD=4.13$, $n=167$, ranged from 1 to 22) and 5.18 in Yaldad area ($SD=2.72$, $n=34$, ranged from 1 to 12).
In the fjords, Chilean dolphin activities were not observed uniformly ($\chi^2=67.17$, $df=4$, $p<0.001$), with feeding and travelling the most important activities (Figure 18). Peale's dolphin presented similar results, activities were not uniformly observed ($\chi^2=121.43$, $df=4$, $p<0.001$), with travelling and socializing as the most frequent activities (Figure 18).

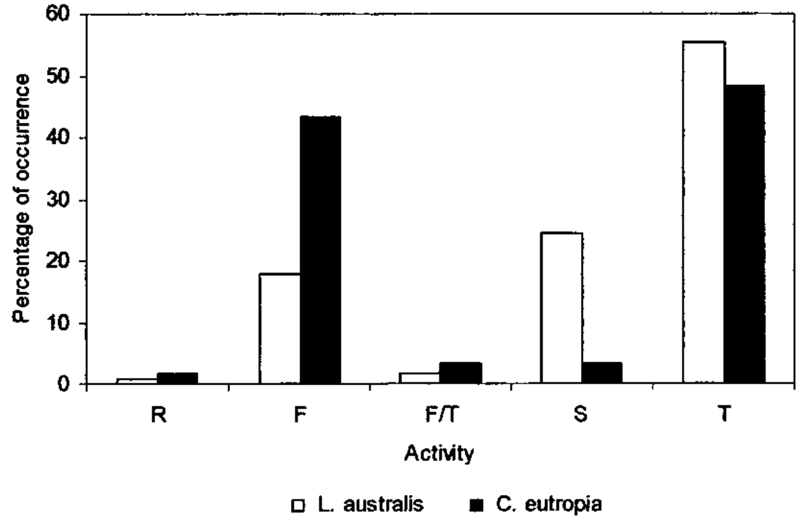

Figure 18. Activity pattern observed for Chilean and Peale's dolphin in the fjords (R: resting; F: feeding; F/T: feeding/travelling; S: socializing; T: travelling)

For both species, dolphin behavioural patterns were significantly different in relation to dolphin's mean group size (*ANOVA*, F=6.38, df=2, p=0.003 for Chilean dolphins (Figure 19) and F=17.49, df=2, p=0.001 for Peale's dolphins (Figure 20)). For both species, travelling was the activity that explained the difference, with less number of animals per group (Only feeding, socializing and travelling were considering for this analysis).

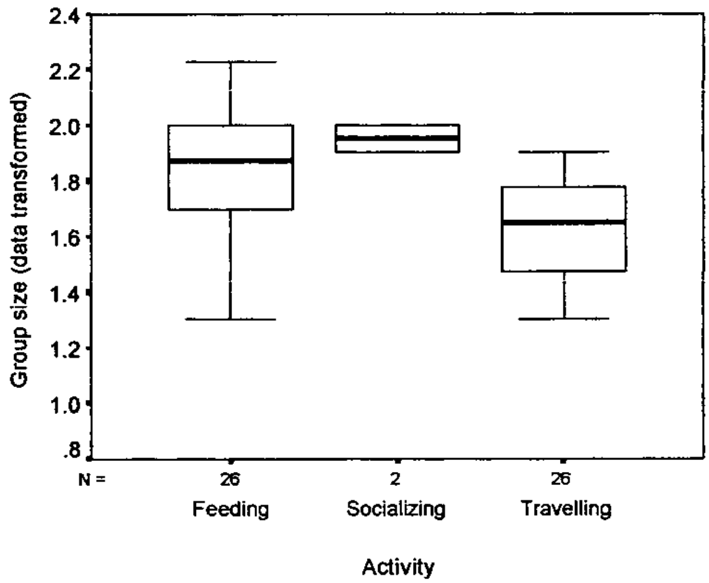

Figure 19. Activity patterns in relation to mean group size for Chilean dolphins.

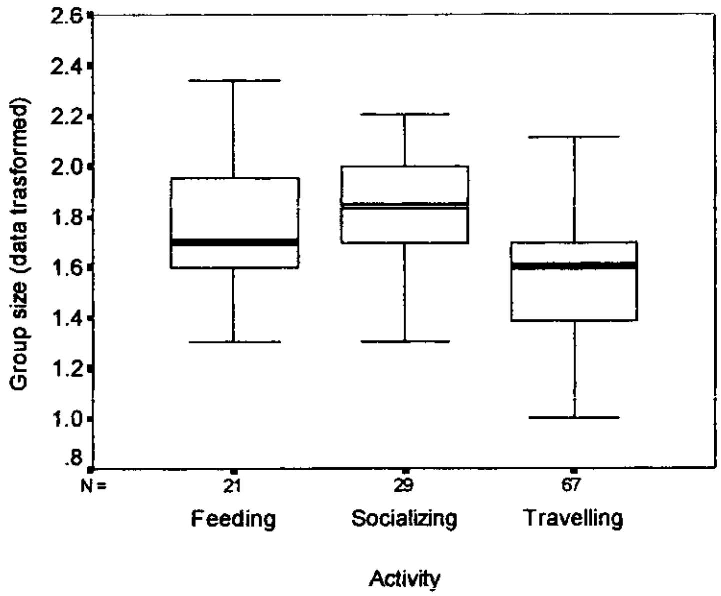

Figure 20. Activity patterns in relation to mean group size for Peale's dolphins.

Photo-identification

Approximately 2500 photographs were randomly taken of dolphins that surfaced in close vicinity of the research boat. From preliminary results from this photo-identification, about 12 Chilean and 35 Peale's dolphins have been identified so far in the fjords (see Appendix 1 for example of dolphin catalogue). Both digital photography and underwater video have been used for this purpose. Some animals seemed to be resident, while others seem to be transient. The furthest two sightings of an individual (Peale's dolphin) were 50 km apart, nevertheless, this distance represents the limits of the study where this dolphin has been sighted. There is one special case for an identified Chilean dolphin ("Viejito") that was sighted 16 times (different days) within an area of less than 20 km^2 in five months. This dolphin is one the best examples we have obtained of high residence and site fidelity. Once the photo-identification analysis concludes, there might be more dolphins with such fidelity and residency.

Threats identified on dolphins

Due to the coastal distribution of these dolphin species, they are exposed to direct and indirect threats. One of the main conservation problems affecting dolphins in the present is the progressive destruction of habitat, which might be of great importance or even critical. The explosive expansion of aquaculture activities might be causing potential impacts on resident populations.

Within the study area in the fjords, eight salmon farms have been set up so far, while there are other facilities constructed related to the salmon industry. These not only use suitable areas for dolphins and other animals, but there is also increased boat traffic in the whole fjord, increased land-shore occupation (offices, housing and warehouse), and chemical and organic pollution (eutrophication, garbage disposal, etc.) (Figure 21 and 22). Unfortunately, much of these activities are in areas where high occurrence of dolphins has been observed. Important areas for Chilean dolphins both in Reñihue and Yaldad are been used for high aquaculture activities (salmon and mussel production).

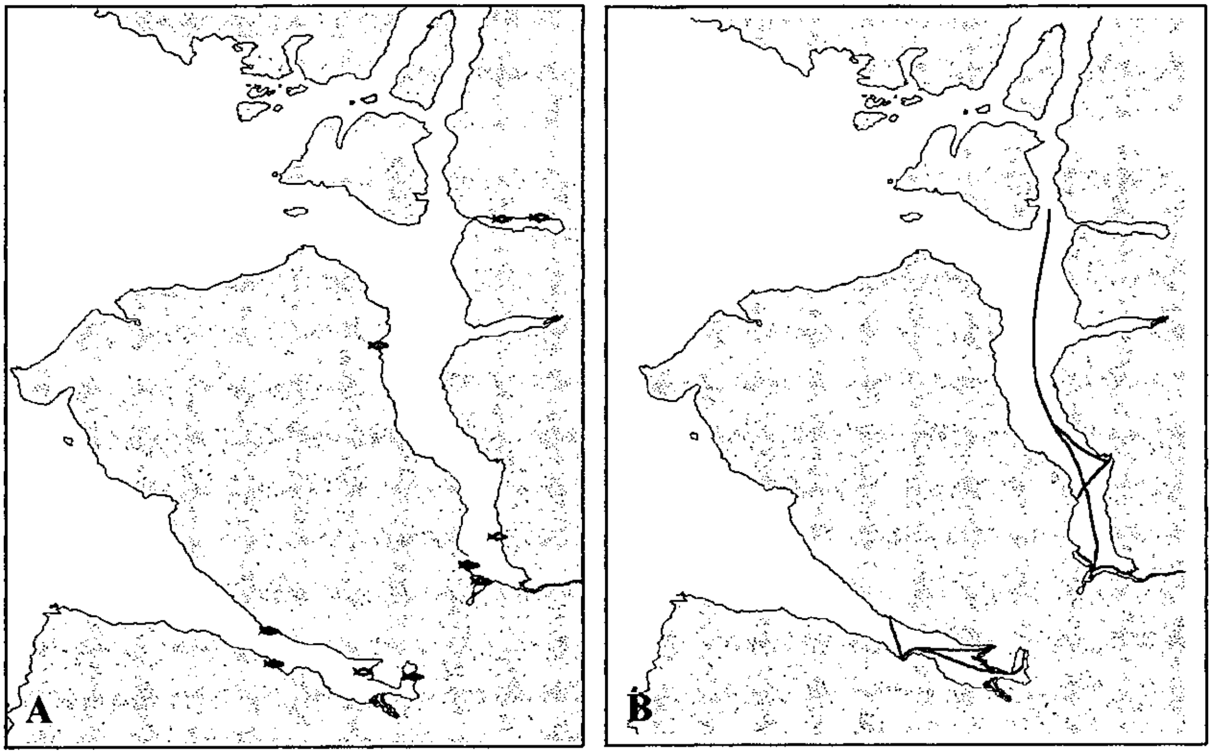

Figure 21. Threats identified on dolphin in the fjord area. A) Distribution of salmon farm structures. "Blue-fish" represent structures where salmon is been cultivated. "Red-fish" represent structures related to salmon farm activities, but no fish in cultivated (i.e. old abandoned cages, floating warehouses, etc.). B) Main boat routes

In Yaldad bay, it was seen that the high coverage of mussel farming is restricting dolphins of using available space (see Figure 16). Dolphins were absent from areas where mussel coverage was higher than 60%.

Human impact is not only driven by the aquaculture activities, a great amount of garbage was recollected during surveys. This came in part from aquaculture activities, but also from fishing gear and domestic sources (plastic and glass bottles, bags, rope, etc.) (Figure 22).

Intense boat traffic was seen to affect dolphin normal behavioural patterns. From the fine-scale land based survey in Yaldad, it was possible to recognize negative reaction from dolphins towards the presence of boats. Behavioural responses were analysed for each dolphin activity, during boat encounter and post encounter. When foraging and approached by a vessel, dolphins increased significantly their orientation rate, while their speed did not show any significant variation. Instead, when travelling, dolphins reacted to boats by increasing significantly their directional speed, while the orientation rate did not differ significantly. After encounters, dolphins seemed to go back quickly to normal behavioural patterns when travelling, whereas it took longer time to establish normal patterns when foraging. Group dispersion analyses showed that when boats approached foraging dolphins, they became significantly more cohesively grouped. Dolphins reacted negatively to boat presence in Yaldad bay, but these responses were different depending on the dolphin behavioural activities prior to boat encounters.

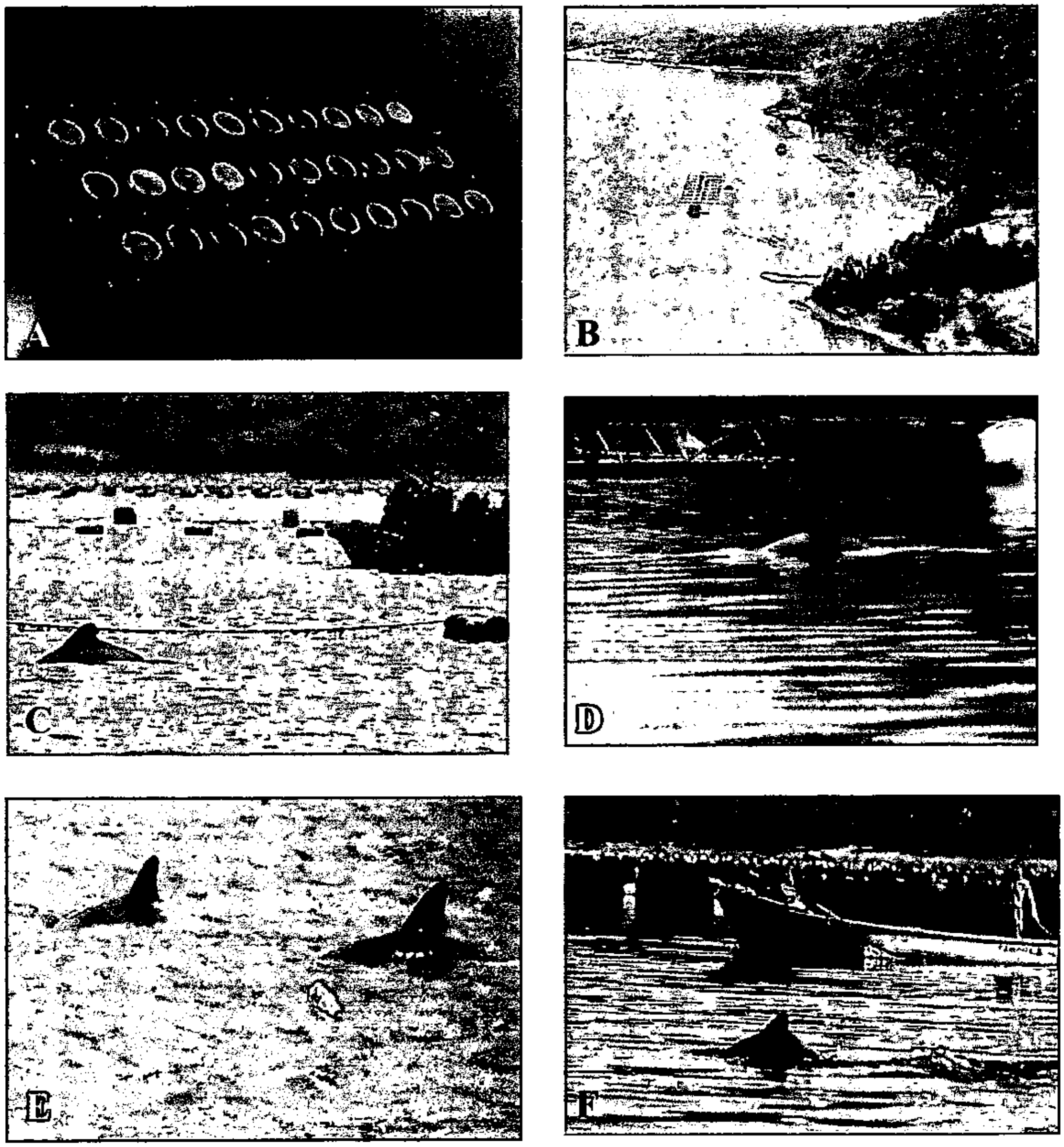

Figure 22. Different threats to dolphins. A) and B) salmon farms in Comau fjord and Reñihue, respectively; C) and D) Chilean dolphins close to mussel and salmon farms, respectively; E) Peale's dolphins swimming close to a plastic bottle in Comau; F) Chilean dolphin swimming near a boat in Yaldad

An important threat might have been found in Reñihue fjord. A Chilean dolphin calf was photographed presenting rare and dramatic wounds on its body. Even though the cause and the real explanation to such injury is still unclear, at first it was thought to be a tattoo disease, a particular documented disease on cetaceans caused by a poxvirus. Nevertheless, it is presently thought that the injury might be caused by a fungus species (Figure 23).

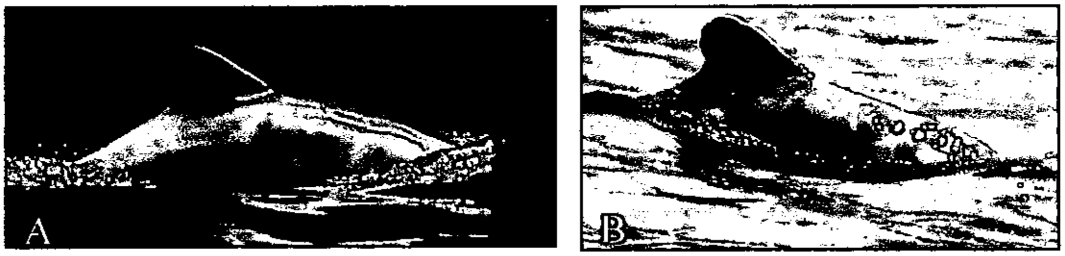

Figure 23. Chilean dolphin calves. A) normal healthy calf; and B) injured calf

PUBLIC AWARENESS

During September 2002 through June 2003, work on public awareness and training was done in four areas: at Universidad Austral de Chile and a scientific meeting in Valdivia; at the school and Fundacion San Ignacio del Huinay facilities in Huinay village (Comau fjord); at the Pumalin Park facilities in Reñihue; and school in Yaldad.

Presentations

The main objectives of general presentations and talks were to present the project's objective to general and specialized public, dissemination of current results, update of fieldwork progress and conclusions.
At Universidad Austral de Chile in Valdivia, talks and presentations were carried out mainly focused for students and teachers from disciplines of biology and veterinary. In total more than 100 people, students and teachers, assisted to the presentations before and after fieldwork. During October 2002, the team members as a new NGO in Chile (*Centro Ballena Azul* (The Blue Whale Centre), established officially under the Chilean law at the end of 2002) coordinated and organized the *10th Reunion of Specialists on Aquatic Mammals in Latin America*, which was held in Valdivia. During this important international meeting, team members presented previous work on dolphin species and the The Chilean Dolphin project.
Presentations at the facilities of the Fundacion San Ignacio del Huinay (Chilean foundation which established a marine ecology station in Comau fjord) counted for three formals presentation and many informal talks. Formal presentations were carried out for regional authorities (i.e. major, provincial governor), company managers and workers (i.e.

ENDESA) and tourists (i.e. kayakers and sailors). Informal talks were spontaneous and organized for visitors.
One formal talk was organized for ONG officials (Land Conservation Trust), company managers and workers (i.e. Agricola Reñihue Limited) and general public in the facilities of Parque Pumalin, Reñihue fjord.
We estimate that more than 200 people attended our presentations, which all included videos made and pictures taken by the project team members.

Environmental education

The main objective of the environmental education component in this project, is to begin a long term programme to raise public awareness at the local, regional and national level on marine conservation issues considering the dolphin species as flagship and umbrella species. Raising as well awareness about their locally resident dolphin populations, the environment they live in and the threats that they might be facing.
Specific objectives are to give an understanding on basic marine ecosystem processes, marine ecology, links to the terrestrial environment and coastal conservation. The focus of the classes and workshops were on the role that every organism plays in the marine environment, how the human activities (anthropogenic) have influenced and affect ecological processes and the importance of conservation and respect towards all living creatures. Workshops, classes, talks and outdoors activities were developed for schoolchildren and teachers from Comau fjord (rural boarding school in Huinay village) and Yaldad.
The main indoor activities, divided into two to three sessions, involved a general presentation through Power Point, blackboard drawings and big cardboard graphics about marine processes, marine biodiversity and dolphin general biology. All sessions were always very interactive, with children participating throughout much of every seminar and talk. Children were asked to mention how they identified themselves with the ocean; to define what a dolphin was; to distinguish between the two dolphin species (Chilean and Peale' dolphins); and to mention marine conservation threats. To our surprise, children were very conscious and aware about what type of things were affecting the seas, like oil spills, garbage disposal, wars, global climate change and general pollution. After we had a good idea of deficiencies, we focused stronger on those topics. Children helped to design first a general marine food web (which ended up a food net) and then they helped designing a food web for the local area they live in (Yaldad bay or fjords) and then discussed the interactions of the different organisms such as plankton, molluscs (with emphasis of mussels in Yaldad), crustaceans, fish and higher vertebrates.
A specific session was developed to work and talk only about marine mammals, especially dolphins. We addressed dolphin biology and habitat requirements and the local environment in more detail. Specific emphasis was placed on the uniqueness of the local dolphin populations and sources of threats to them (e.g. entanglement in gillnets, habitat encroachment due to expanding mussel and salmon farms, effects of toxic algae blooms). We also discussed about our own work with dolphins, the projects' objectives and how we go about studying wild dolphins in their environment to understand their habitat requirements and social characteristics. We used examples from our photo-identification catalogue to illustrate how we can follow individual dolphins with a non-invasive method

and are able to learn more about their residency, ranging and social patterns. In Yaldad we intend to extend this individual dolphin-based approach into an "adopt-a-dolphin" scheme where children choose responsibility for an identifiable dolphin and follow its movements and socialization patterns based on our observations.

Finally, an outdoor workshop component encompassed short field excursions to walk along the local beaches for the identification of animals and features that make up the "local environment" and a boat excursion to be closer with dolphins. The latter activity was probably the one that left stronger positive feelings towards dolphins. After this session we perceived very different attitudes towards marine life in general.

Training

The main goal of the training component of this project was to prepare future students and community members for conservation work, both in research and environmental education and dissemination. In total 11 volunteers/assistants participated in this training programme, mainly from Universidad Austral de Chile and Universidad de Valparaiso. Three students will write their undergraduate thesis in marine biology. One of them on the micro-geographical distribution of dolphins in the fjords; another student from Colombia developed a basic land-based study on Peale's dolphin in Comau fjord; and the other one in social patterns of identified dolphins in Yaldad. Also two students assisted in the field as part of their "*professional practice*", a practical placement in a research or industry-oriented venture of 4 weeks duration. This placement is required as part of the undergraduate study of marine biology in Chilean universities.

Chilean as well as International volunteers participated energetically in this project, whose contribution was incredible important.

Training of field assistants usually included a pre-field work preparation stage, data collection in the field, insights into data entry and data analysis approaches. Each student was given a list of selected references about the biology of Chilean and Peale's dolphins and a detailed description of the fieldwork protocol. On site, the principal investigator provided a detailed briefing on the background of the project, the objectives, field protocol as well as training sessions on the tasks that the students were to fulfil during the fieldwork. These included an introduction to the research vessel, a 3.8 m inflatable boat with a 25 hp outboard engine or a 4.5 semirigid boat with a 50 hp outboard four stroke engine (boat safety instructions, theoretical and practical lessons on handling the research vessel during surveys and how to approach dolphins with minimal disturbance); introduction to the data collection protocol; and introduction to data entry and analysis

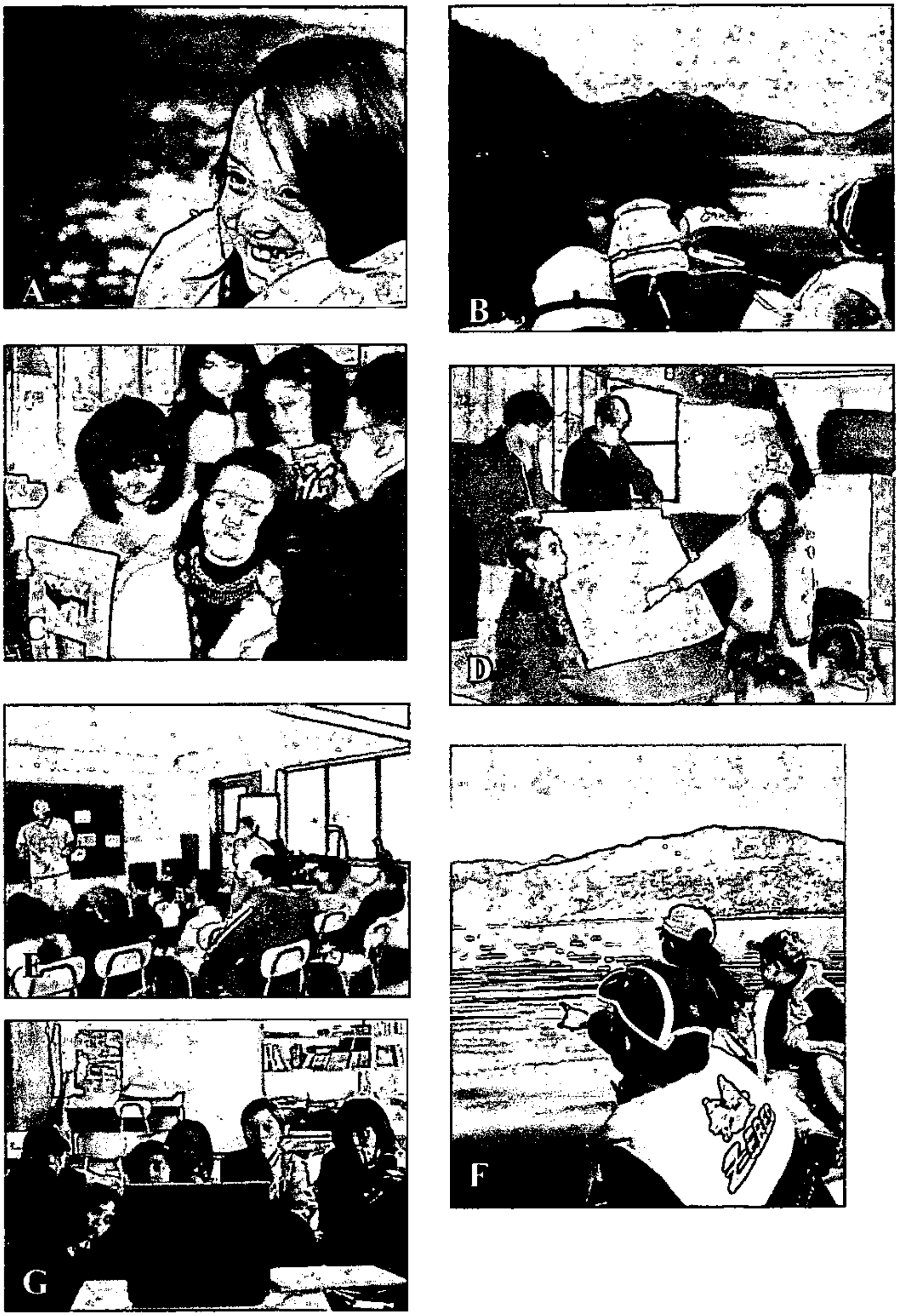

Figure 24. Environmental education programme. a), b) and f) Outdoor activities looking for dolphins in Comau fjord; c) and d) talks in Yaldad elementary school; and e) and g) talks in Huinay boarding school, Comau fjord.

Institutional work

General dissemination is still in course through the design of our web page. This page will have the overall aims and missions of our new NGO, as well as our projects' objectives, goals and results. Our dolphin project established cooperative work with the Conservation Land Trust (which manages the most important and largest private park in Chile), the World Wildlife Fund (WWF) in Chile and San Ignacio del Huinay Fundation. All these organizations have already preliminary reports. A formal document was also given to CONAMA (Governmental institution, National Committee for the Environment), where we gave bases and recommendation for the establishment of marine protected areas taking into consideration cetacean species.

DISCUSSION

Although the Chilean dolphin was, at the beginning of the project, the target species to monitor and use its charismatic characteristic as flagship species for marine ecosystem conservation, other five species of marine mammals were registered in the study areas. Reñihue fjord was the area with the greatest diversity, with five species occurring in an area of less than 80 km^2. Three of these five marine mammals were small cetaceans: Peale's and Chilean dolphins and Burmeister's porpoises. These results are of great importance since the information gathered showed a very important diversity of small cetaceans at such small scale. This particular area (Chiloensis Province, (Sullivan Sealey and Bustamante, 1999)) is probably one of the most important sites or hot spot for marine mammal diversity, as well as other marine biota, in Chile.

Peale's dolphins were the most abundant and common of all small cetaceans registered, with more sightings in Comau fjord and more restricted in Yaldad and Reñihue. Interestingly, no Chilean dolphins were encountered in Comau fjord, but where Peale's had a more restricted distribution, Chilean dolphins were present. Hence, we were able to find very marked habitat segregation between these two species. Chilean dolphins used a small portion of 17.2% of the total area surveyed in Reñihue fjord, while Peale's dolphin used 36.7% of the total area in Comau fjord. These percentages are here considered as areas of importance, high concentration of dolphins or core areas.

Both in Yaldad and in the fjords, Chilean dolphins had a preference for more turbid waters, lower sea surface temperatures when compared to Peale's dolphins. Nevertheless, both species presented selection for areas close to rivers.

At the finer scale in Yaldad bay, Chilean dolphins presented a very restricted habitat selection, concentrating their activities in areas of shallow waters (5-10m), close to shore and rivers; which represents only 21% of the entire study area. Tide cycle, which probably determines fine scale oceanographic processes in the bay and prey diurnal cycles, also influenced the habitat use patterns.

The results from our work (at both fine and large scale) correlate well with results from other works for the same species and others. Heinrich (2001) observed in Chiloe Island that 92% of Chilean dolphin groups sighted were within 500 m from shore at mean depth 12.8

m. In the fjords, Oporto (1984) observed that dolphins were more frequently seen at depth range 3 to 15 m; and in the northern portion of the Chilean dolphin distribution Perez-Alvarez and Aguayo-Lobo (2002) found that the animals were often seen near river mouths. Although information on the ecology of this species is still limited, its association to shallow waters seems to correspond to a pattern (Goodall, 1994), as seen for other species of the same genus such as *C. commersonii* (Lescrauwaet *et al.*, 2000) and *C. hectori* (Slooten and Dawson, 1994; Bedjer and Dawson, 2000).
Most studies on coastal dolphins suggest that habitat use and selection patterns occur principally in function to the distribution, movement and abundance of their prey species (Ballance, 1992; Bonin, 2001; Karczmarski *et al.*, 2000; Viddi and Lescrauwaet, 2001) and secondarily in pursue of refuge and protection against predators (Wells *et al.*, 1980; Evans, 1993). One of the activities most often seen made by dolphins was feeding and travelling (at the different spatial scales), the first highly localized in the selected areas, suggesting that these areas had some prey availability or patch predictability. Würsig (1986) points put that dolphins seem to return to areas where previously they found food; an adaptive behaviour that minimizes energetic costs of food searching. The association between feeding and travelling activities are well documented for several species. Animals tend to move or travel rapidly in areas poor of resources and stay longer in rich areas (Ballance, 1992; Defran *et al.*, 1999; Barco *et al.*, 1999; Gubbins, 2001; Cremer, 2000; Karczmarski *et al.*, 2000; Bonin, 2001, Stevik *et al.*, 2002; Viddi, 2002). The greater the resource predictability, more evident will be the movement patterns (Stevik *et al.*, 2002).

The activities derived from aquaculture both in Yaldad and fjord area seem to be negatively affecting movement, distribution and behavioural patterns, representing a potential threat to the local dolphin populations. While the mussle (*Mitylus chilensis*) is a native species, the many species of salmon cultured in Chile, all of them were introduced in Chile in the twentieth century. The mussel farming in Yaldad seems to restrict Chilean dolphins of using potential important habitat. The exclusion from core areas, in addition to the very restricted, high site fidelity distribution of this species, could be severely affecting important biological and social activities, as observed for other species (Würsig and Galley, 2002). It was observed that dusky (*Lagenorhynchus obscurus*) and Hector's dolphins (*Cephalorhynchus hectori*), tend to avoid mussel farming areas in New Zealand (Clement *et al.*, 2001; Würsig and Galley, 2002). These authors suggest that these farms are not attractive for dolphins due to the great amount of lines and buoys, which might turn difficult or even impossible to forage efficiently.
The main environmental impact from the culture of mussel and salmon is the organic enrichment of the water and sediment, which modifies the primary productivity and benthonic community (Wu, 1995; Stenton-Dozey *et al.*, 1999, Naylor *et al.*, 2000). The effects of this impact could be reflected in the trophic chain and affect prey availability for a top predator, such as dolphins (Quick, 2001). In Yaldad for example, Navarro *et al.* (1995) observed that there was an increased in the amount of nutrients, both in the water column and sediment, which affected significantly the benthonic community, reducing species diversity. The environmental impacts resulting from escaped salmon are very severe, such as disease transmission, habitat and prey competition, as well as predation on native fish, which might also have an effect on the abundance and diversity of dolphins' original prey species. All of these impacts, derived from aquaculture activities, might be reducing resource availability and habitat quality for dolphin species.

This is very important, since it has been seen that for marine mammals to forage efficiently, they need areas with enough food resources available (Woodley and Gaskin, 1996; Martin and Smith, 1999; McConnell *et al.*, 1999). A decrease in prey availability would cause an increase in food searching by predators, and if the limit is surpassed, predators might respond by leaving those areas in search for areas rich in food, otherwise, reproductive or growth rates might be affected (Harwood, 2001).

The salmon industry and mussel farming present common impacts, such as the organic enrichment due to faeces and pellets, but also the high increased of boat traffic, which are used for transportation and maintenance. From a general point of view, boat presence and traffic might cause significant behavioural alterations in cetaceans (Kruse, 1991; Bedjer *et al.*, 1999; Williams *et al.*, 2002), including fatal collisions (Wells and Scott, 1997). In Yaldad it was possible to observe that boat traffic caused dolphin negative reactions. They altered significantly their behavioural patterns. Foraging was interrupted every time a boat approached and after the encounter, dolphins took long time before returning to normal behaviour. It is probable that noise and boat presence not only alter dolphins' behaviour, but also their preys (Janik and Thompson, 1996; Aleen and Read, 2000). It is also possible that the impact from vessel traffic is not only restricted to the time they approach to a group of dolphins, but also their behaviour might be affected by the noise pollution and the constant "alert-state" that dolphins maintain (Richardson *et al.*, 1995; Bedjer *et al.*, 1999). Impacts caused by boat traffic might restrict or exclude animals from important areas, producing long-term effects (Richardson *et al.*, 1995; Harwood, 2001)

The loss and destruction of habitat is one of the main threats to global biodiversity (Meffe and Carrol, 1997) and one of the greatest current concerns on cetacean conservation (Whitehead *et al.*, 1999). The increment of human impacts in coastal areas, as a result of urban and industrial development, has reduced natural resources and represents a growing and potential threat to marine environments (McIntyre, 1995; Roberts and Hawkins, 1999). Coastal cetacean populations have been severely affected, especially in areas where human development is higher (Whitehead et al., 1999). Dolphin species with coastal restricted distribution generally tend to select and depend on specific habitat features (Karczmarski, 2000; Viddi, 2002; Hastie *et al.*, 2003) and hence, the loss of these areas can affect the population survivorship (Harwood, 2001). However, an earlier identification of important areas for the animals could help minimizing or even preventing the impacts from anthropogenic activities.

Protecting important areas for dolphins might be crucial to ensure not only the conservation of the dolphin population, but also for the whole complex system they inhabit. Since dolphins are top predators, they act as environmental indicators and biodiversity regulators (Bowen, 1997; Moore and Demaster, 1998; Whitehead *et al.*, 1999). Marine mammals might play important roles such as *key species* in some marine community and the decline of their population might cause significant alteration in species composition (Harwood, 2001). By knowing the ecological role of marine mammals and complementing with the concept of *umbrella species*, it ca be used for the conservation of marine ecosystems in general and for making recommendations on the establishment of marine protected areas (MPA) (Dawson and Slooten, 1993; Hooker *et al.*, 1999; Hyrenbach *et al.*, 2000).

Most people and children we worked with in our public awareness programme have knowledge about the existence of *toninas* (as people call dolphins), nevertheless, they did not know they were actually dolphins. The image they have of dolphins was that of bottlenose dolphins (*Tursiops truncatus*), which is given by the TV series "Flipper". They get very surprised when they realized that there are "dolphins" where they fish, have fun or travel. Due to the great isolation of these villages (there are no roads), the main and only transportation they have is their boats, so they have plenty of contact with marine flora and fauna, not only fishermen, but all their families. The school workshops talks and seminars proved a great success. Responses of the children were overwhelming and their interest and quick understanding exceeded all our expectations. Our close interaction with children did not only spark an interest in the local marine environment among them, but we also noticed a positive attitude of the childrens' parents towards our team (and our presence in their small villages), work, research and activities.

RECOMMENDATIONS AND FUTURE WORK

From our results it is strongly recommended that important or core areas for dolphins must be protected. It is also necessary to take into account the movement and habitat selection patterns (at different scales) of small cetaceans when assessing suitable areas for aquaculture. In addition, it will be important to be able to measure, qualitative and quantitatively, the dolphin energetic requirements by studying the animals' tropic ecology.
Before establishing or setting up aquaculture farms, it will be extremely essential to measure the environment capacity to support such as activities.
To minimise the impacts from boat traffic, it is recommended to establish a political regulation in the use of outboard engines. In the future, the use of four stroke engines (cleaner, noiseless and fuel efficient) must be a requirement. In areas where dolphins are frequently seen, speed limits and special routes should be established.
Fine-scale studies (such as the ones with theodolites) are of great importance to obtain detailed information on movement patterns, habitat use and interaction with anthropogenic impacts (boat traffic and effects of other aquaculture activities), but these must be complemented with larger spatio-temporal scale studies. Fine scale studies should be developed in Reñihue and Comau.
Considering that Chilean and Peale's dolphins were intensively hunted between 1970 and 1990 (Cardenas *et al.*, 1987; Oporto, 1992; Lescrauwaet and Gibbons, 1994) and that currently these species are threatened by incidental catch in local fisheries (Oporto and Brieva, 1990), the loss of critical habitats might placing these species' population in a more vulnerable situation. It will be needed conservation work at long terms to assess population abundance estimates, home range size, site fidelity, and habitat selection and large scales, in order to compare more areas within the distribution of these species.
The educational programme must expand to new areas as well as continuing in the areas of Yaldad and Comau. Leaflets, posters, updated web page, t-shirt designs are some of the things that should be design for coming years. Seminars and talks must be given at aquaculture workers and managers on the field. Special meetings will be organized with authorities and universities.

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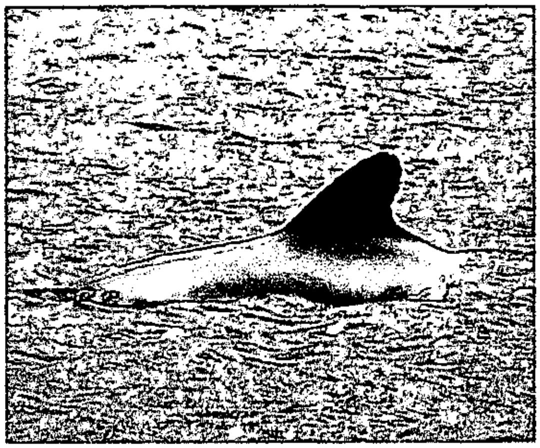
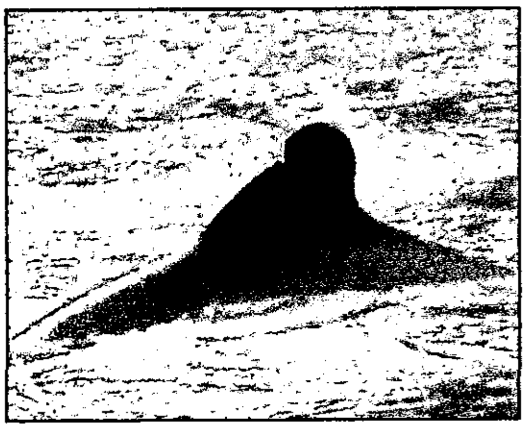
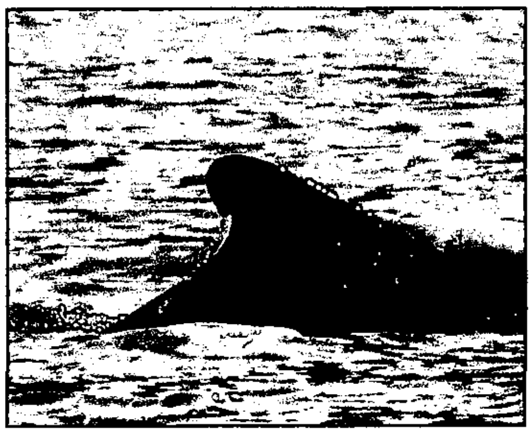
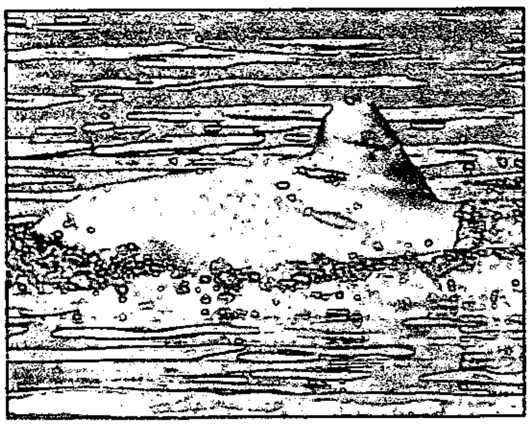
APPENDIX I

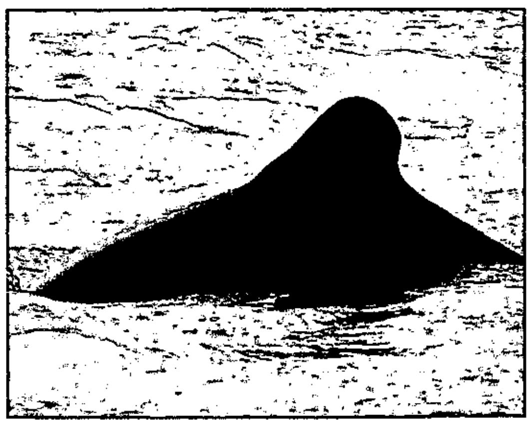
Chilean dolphin identification catalogue (Extract)



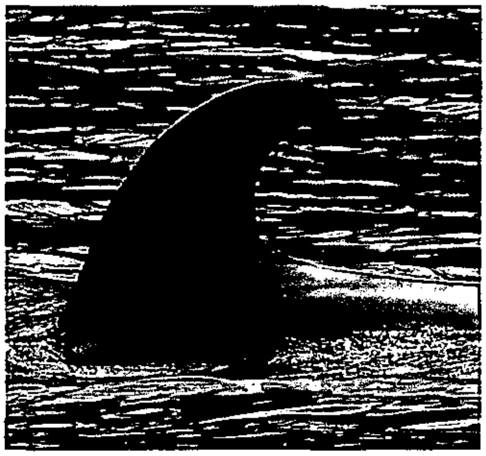


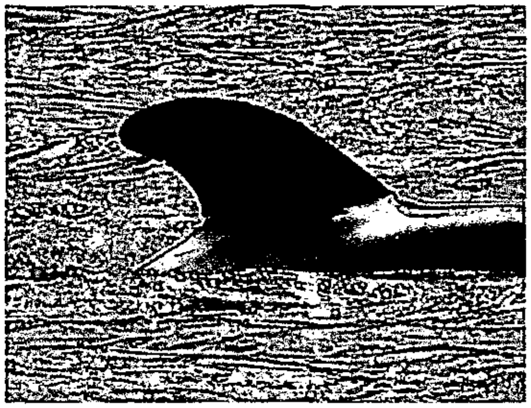


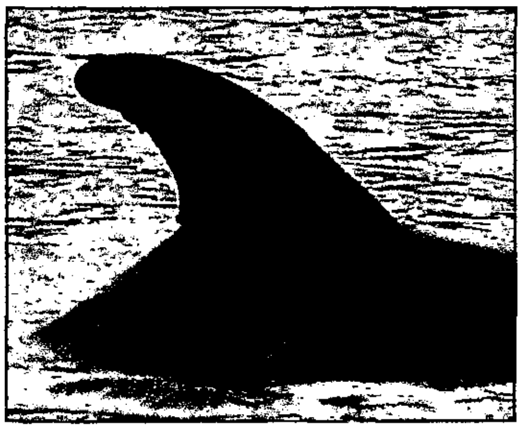


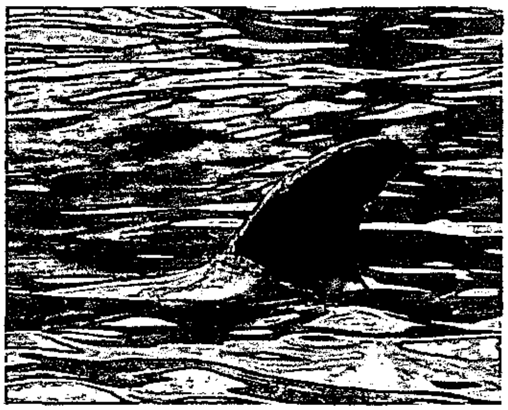


Peale's dolphin identification catalogue (Extract)









CBA/BWC
Centro Ballena Azul CHILE

Centro Ballena Azul
Santa Rosalia 111
Valdivia, Chile

Valdivia, 12 November 2003

Ms Marianne Dunn
Programme Manager
BP Conservation Programme

Dear Marianne

I am pleased to enclose the final report and material from the results obtained in the project ***Ecology and Conservation of the Chilean dolphin in southern Chile.*** All team members are sincerely thankful for the opportunity given by the BP Conservation Programme.
Enclosed you will find the final report, financial report, CD-Rom with pictures and digital version (PDF) of reports, and a pilot video of landscape and dolphin images which is been edited for educational purposes.
If you need any of the pictures with better resolution or there is any problem or detail concern the report or material, please let me know.

Respectfully yours,

Francisco A. Viddi
Marine Biologist, Project leader
fviddi@hispavista.com