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Insights on Habitat Selection and Behavioural Patterns of Peale's Dolphins (*Lagenorhynchus australis*) in the Strait of Magellan, Southern Chile

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Abstract

During the austral summer/autumn of 2001, habitat selection of Peale's dolphins (*Lagenorhynchus australis*) was assessed through a five-month land-based survey in two sectors on the central west coast of the Strait of Magellan, Punta Arenas, Chile. The main objective of this study was to evaluate habitat selection of Peale's dolphins in relation to kelp beds and the behavioural patterns determining dolphins habitat use. In 191 h of observation effort, habitat use of Peale's dolphins displayed a significant concentration in only a small part of the study area, which was strongly associated with kelp beds. Feeding was the most frequent behaviour observed, followed by traveling. The former behavioural state was observed principally inside and on the border of kelp beds, while traveling was observed mainly outside the beds. Peale's dolphins' preference for kelp beds, which seemed to be their primary feeding ground, was evident throughout this study. Kelp forests appear to be a fundamental habitat for Peale's dolphins in coastal ecosystems, and their protection might be crucial for the conservation of Peale's dolphin populations.

Key Words: Peale's dolphin, *Lagenorhynchus australis*, habitat selection, behavioural patterns, kelp beds, *Macrocystis pyrifera*, southern Chile

Introduction

A highly heterogeneous ecosystem often results in clumped resources (food and refuge), rather than randomly or systematically distributed (Samuel et al., 1985; Stevick et al., 2002). Animals need to select, within a mosaic of rich and poor areas, those microhabitats that provide better possibilities for higher biological fitness (Rosenzweig, 1981). An adequate identification at different spatio-temporal scales of key habitats and core areas within a population's home range, where biologically and socially important behaviours concentrate, is an important element in understanding a species' ecology and is crucial for the conservation and management of any population and its habitat (Ben-Shahar & Skinner, 1988; Karczmarski et al., 2000).

Peale's dolphin, *Lagenorhynchus australis*, is a little known cetacean restricted to the coastal waters of southern South America. It has been reported from Golfo San Matías, Argentina (38° S); around the tip of South America, including the Falkland Islands; to Valparaiso, Chile (33° S) (Aguayo-Lobo et al., 1998; Goodall et al., 1997a, 1997b). Peale's dolphin is the most coastal and, hence, most easily observed of the three species of the genus *Lagenorhynchus* inhabiting the Southern Hemisphere; it also has the most restricted distribution.

Peale's dolphins inhabit two types of coast on each side of the continent (Goodall et al., 1997a). In the south, they frequent the protected channels and fjords, which are much more extensive on the Chilean side. Farther north, and throughout most of their distribution on the east coast, Peale's dolphins inhabit the exposed coast over the continental shelf. In the southern portion of the distribution, both in Argentina and Chile, Peale's dolphins are documented to frequent extensive algae banks, the kelp beds, *Macrocystis pyrifera*, which are more abundant in the protected channels and fjords than along the exposed coastline. Peale's dolphins have been observed swimming through and around the algae, outside the line of kelp beds, or shoreward, between the kelp beds and the beach (de Haro & Iñiguez, 1997; Goodall et al., 1997a; Lescrauwaet, 1997). In spite of these opportunistic observations and although Lescrauwaet (1997) pointed out that Peale's dolphins spend a large part of the day scanning kelp beds for food, no systematic effort has been made so far to gather data to assess the importance of these banks for Peale's dolphins.

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Consequently, the main goal of this study was to evaluate the habitat selection of this dolphin species in relation to *M. pyrifera* and to observe the behavioural patterns determining Peale's dolphin habitat use in the Strait of Magellan.

Materials and Methods

Study Area

The Strait of Magellan is a unique sub-Antarctic ecosystem with complex climatic features (Endlicher & Santana, 1988). It is located at the southernmost tip of South America, between 52° S and 54° S, extending for about 500 km, and it functions as a confluence of water masses from the Pacific and Atlantic Oceans (Iriarte et al., 2001). The Strait of Magellan is influenced strongly by large amounts of freshwater runoff from rivers and precipitation, is light-limited (normally cloud-covered for 6-8 months), and is particularly affected by strong winds during the spring and summer seasons (Endlicher & Santana, 1988).

Data gathered in this study were obtained from observations in two, 5-km sectors on the central west coast of the Strait of Magellan, respectively 35 km south (Agua Fresca) and 10 km north (Río Seco) from the city of Punta Arenas (53º 15' S, 70º 55' W) (Figure 1). Each of these sectors was divided into 21 sections of 250 m each (linear coastline).

Water temperature in the study area varied between 6° and 9° C. Especially during the spring and summer months, wind strength often reaches 70-80 km/h, with gusts of 120-140 km/h (Lescrauwaet, 1997). These dominant northwest or westerly winds can persist for days and strongly influence both observation efforts and ecological conditions (i.e., water clarity, primary productivity). Along the coast, abundant and extensive kelp beds (up to 150 m wide) can be found at short distances from the shoreline.

Data Collection

Data were collected between January and May 2001 through land-based observations performed from two fixed vantage points chosen in each sector. Generally, two observers, with 10 x 50 binoculars, scanned the study area to locate Peale's dolphin groups. When spotted, the group was tracked throughout the entire observation period until it was lost (group follow protocol, after Mann, 1999). A group of dolphins (a sighting) was defined as any aggregation of one or more dolphins (including all age classes) observed close to each other within 20 m (Mann, 1999).

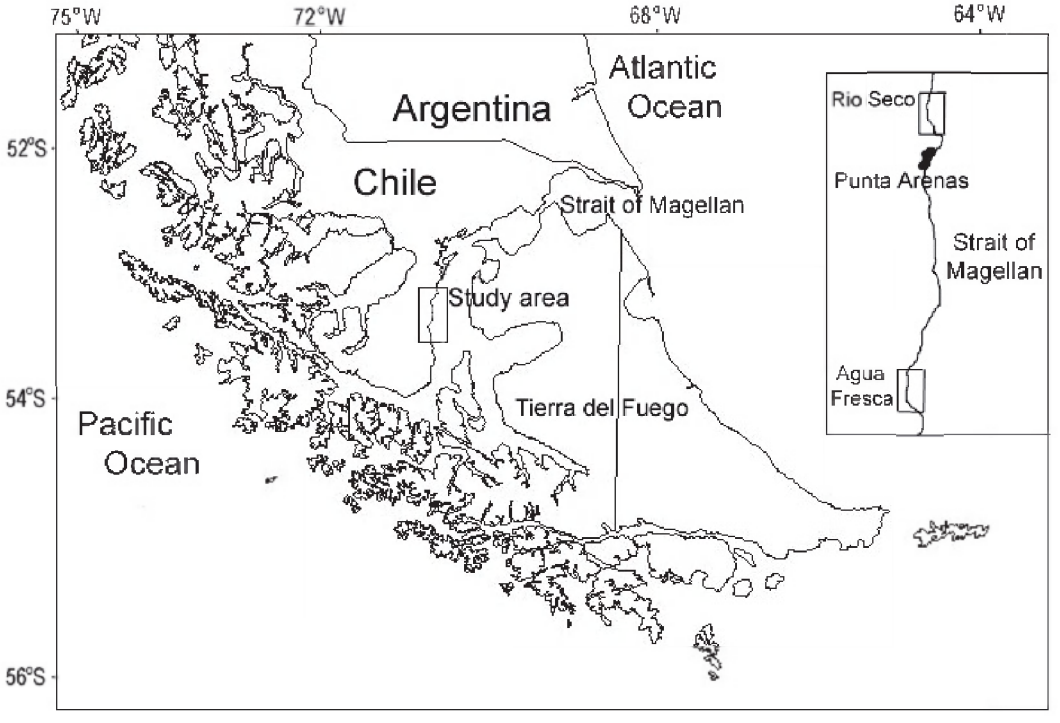


Figure 1. Map of the Strait of Magellan with an inset of the study area

Every sighting included information on time of sighting, group size, behavioural state, and location in relation to a section number (from 1 to 21). These data were recorded thereafter every 5 min. If a group was out of sight for 5 min, a search for a new group started. Observation efforts varied and were limited to favourable environmental conditions. When possible, observations started at 0800 h through 1900 h, and were restricted to no rain and sea states ≤ 3 Beaufort.

The behavioural states were defined as follows:

- *Feeding:* Repeated unsynchronised dives in different directions in a specific location. Peale's dolphins could be observed chasing fish; making circles; and having a parallel swimming formation with fast, directional, and synchronised movements. A frequently observed diving pattern displayed two to three short dives of 10-15 s followed by a longer one of 80-120 s.
- *Resting:* Very slow movements or stationary at the surface.
- *Socialising:* Individual interactions within a group; frequent physical contact, often with vigorous movements and aerial behaviours such as leaping and breaching. Sexual and aggressive behaviours are included in this category.
- *Traveling:* Directional and persistent movement at constant speed.
- *Foraging/Traveling:* Net directional movement, often with repeated unsynchronised dives in different directions, which probably represents them opportunistically scanning and searching for food.

A kelp bed was defined as the area covered with *M. pyrifera* along the coast, which presents an interior shoreward boundary at an average distance of 10 m from the low tide line, and an exterior seaward boundary, which ranged at a distance of 50 to 200 m from the low tide line. For the purpose of this study, the definition of "kelp bed extent" includes all channels and spaces not wider than 50 m.

For every group that was followed, the Peale's dolphins' position relative to the kelp bed was recorded as to whether they were "inside" (between the seaward and shoreward boundaries), "outside" (further than 10 m from the seaward boundary), or "on the border" (within 10 m from the seaward boundary) of kelp beds.

Aerial photographs taken at an altitude of 300 m, which were obtained from the Fotogrametric Service of the Chilean Air Force (SAF), were digitised for kelp beds' mapping representation relative to the coast line, using *Surfer, Version 7.0*®, software. These maps (Figures 2 & 3) were created under the Universal Transverse Mercator (UTM) coordinate format.

Data Analysis

Time spent by Peale's dolphins in each section was calculated as the Habitat Selection (HS) Index as a proportion of the total observation effort in the sector. Time spent by Peale's dolphins engaged in a particular behavioural state in a section was calculated as the Behavioural Coefficient (BC) as a proportion of the total time spent in the specific behavioural state in the whole sector.

To determine whether Peale's dolphins used the area evenly or not, a one-sided Kolmogorov-Smirnov goodness-of-fit test was applied (Zar, 1999). This test would also identify the sections receiving significantly greater than uniform use (Samuel et al., 1985). A chi-squared test was performed to assess whether the behavioural state occurrence was homogeneous or not. To evaluate the existence of any significant association between dolphin behavioural state and dolphin position in relation to kelp beds, a chi-square test contingency table analysis of five columns (behavioural states) and three rows (location relative to kelp beds) was performed. Analysis of Variance (ANOVA) was carried out to find any significant association between dolphin group size and behavioural states. The statistical software packages *Statistica 5.0*® and *SPSS*, *Version 8.0*, were used for analysis ($\alpha = 0.05$).

Results

Base Data

From 191-h of effort accomplished during a five-month study period, Peale's dolphins were effectively observed on 98.8 h (51.83% effective observation). From this, 34.6 h effective were achieved at Agua Fresca (36.02% effectiveness), and 64.2 h effective were achieved at Río Seco (67.47% effectiveness). In total, 142 groups of Peale's dolphins were sighted, of which 97 groups were sighted and followed at Río Seco. Group size average in this sector was 5.58 (SD = ± 3.27), varying between one and 15 animals. At Agua Fresca, 45 groups were sighted and followed, with a group size average of 4.28 (SD = ± 3.20), varying between one and 15 animals.

Habitat Selection Patterns

Dolphins occurred at all 21 sections in Río Seco. Nevertheless, the distribution of observations was not uniform (Figure 2) since the HS Index varied significantly among sections ($D+ = 0.272$, $p < 0.05$). Five sections had greater than uniform use, cumulative representing 23.8% of the entire area: Sections 21 (HS = 0.183), 5 (HS = 0.122), 7 (HS = 0.078), 16 (HS = 0.069), and 17 (HS = 0.053).

Peale's dolphins also were observed in all 21 sections at Agua Fresca; however, the frequency of

distribution (Figure 3) was not even. The HS Index varied significantly among sections ($D+ = 0.635$, $p < 0.05$). Four sections were identified to have greater than uniform use, representing 19% of the entire area: Sections 21 (HS = 0.603), 2 (HS = 0.101), 20 (HS = 0.061), and 1 (HS = 0.060).

Behavioural Patterns

In both sectors, feeding was the most frequently observed behavioural state (BC = 0.64), followed by traveling (BC = 0.122), socialising (BC = 0.114), foraging/traveling (BC = 0.107), and resting (BC = 0.017).

Each behavioural state (Figure 4) was not observed uniformly at Río Seco nor at Agua Fresca ($X^2 = 55.85$, $df = 4$, $p < 0.05$ and $X^2 = 61.33$, $df = 4$, $p < 0.05$, respectively). In both Río Seco and Agua Fresca, feeding was the behavioural state that explained the non-uniformity in frequency of

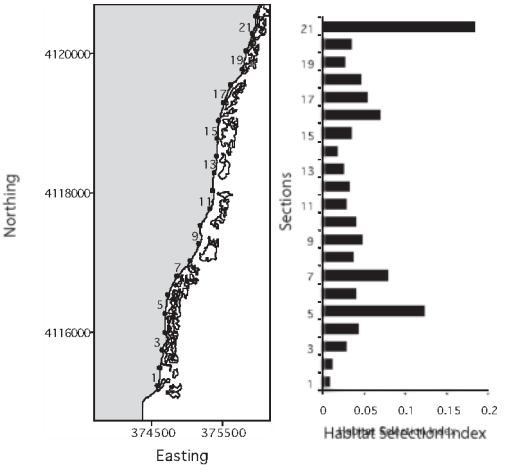


Figure 2. Spatial distribution of Peale's dolphins, *L. australis*, represented by the Habitat Selection (HS) Index along the 21 sections in Río Seco; kelp bed distribution is shown in map on the left.

occurrence (BC = 0.594 and 0.725, respectively) since all other behavioural states occurred with no significant difference ($X^2 = 6.72$, $df = 3$, $p > 0.05$ for Río Seco and $X^2 = 5.11$, $df = 3$, $p > 0.05$ for Agua Fresca).

Average group size differed significantly (Figure 5) in relation to behavioural states at both Río Seco and Agua Fresca (resting was not considered since the BC was very low in both sectors) (ANOVA, $F = 32.85$, $df = 3$, $p = 0.001$ and $F = 10.198$, $df = 3$, $p = 0.001$, respectively). At Río Seco, traveling had the lowest average group size (3.86 animals per group, SD = ± 1.68), while foraging/traveling had an average group size of 4.14 (SD = ± 1.83); feeding, 5.22 (SD = ± 2.75);

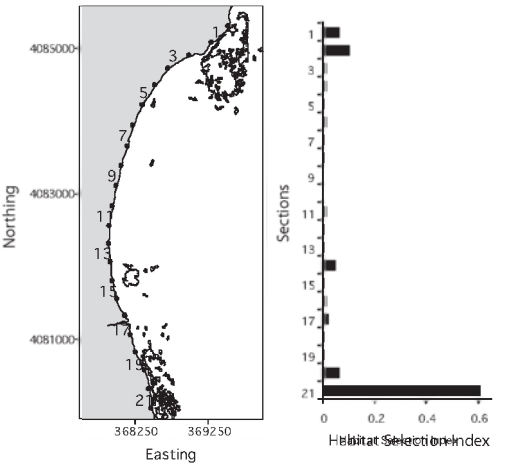


Figure 3. Spatial distribution of Peale's dolphins, *L. australis*, represented by the HS Index along the 21 sections in Agua Fresca; kelp bed distribution is shown in map on the left.

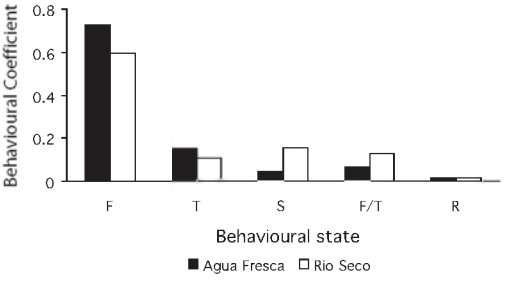


Figure 4. Behavioural Coefficient (BC) of Peale's dolphins, *L. australis*, in Río Seco and Agua Fresca, by behavioural states: feeding (F), traveling (T), foraging/traveling (F/T), socialising (S), and resting (R)

and socialising, the highest average group size, 6.92 (SD = ± 2.29). At Agua Fresca, traveling had the lowest average group size (2.53 animals per group, SD = ± 1.40), while foraging/traveling had an average group size of 4.29 (SD = ± 3.85); feeding, 4.95 (SD = ± 3.36); and socialising, 4.88 (SD = ± 2.76).

In both sectors, the behaviours of the Peale's dolphins varied significantly (Figure 6) in relation to whether the animals were inside, on the border, or outside the kelp beds (contingency table $X^2 = 132.22$, $df = 8$, $p < 0.001$ for Río Seco and $X^2 = 132.22$, $df = 8$, $p < 0.001$ for Agua Fresca). At Río Seco, feeding was observed principally inside and on the border of kelp beds (BC = 0.53 and BC = 0.38, respectively). Traveling was registered with greater frequency on the border and outside the kelp beds (BC = 0.45 and BC = 0.43, respectively). Socialising was often observed inside (BC

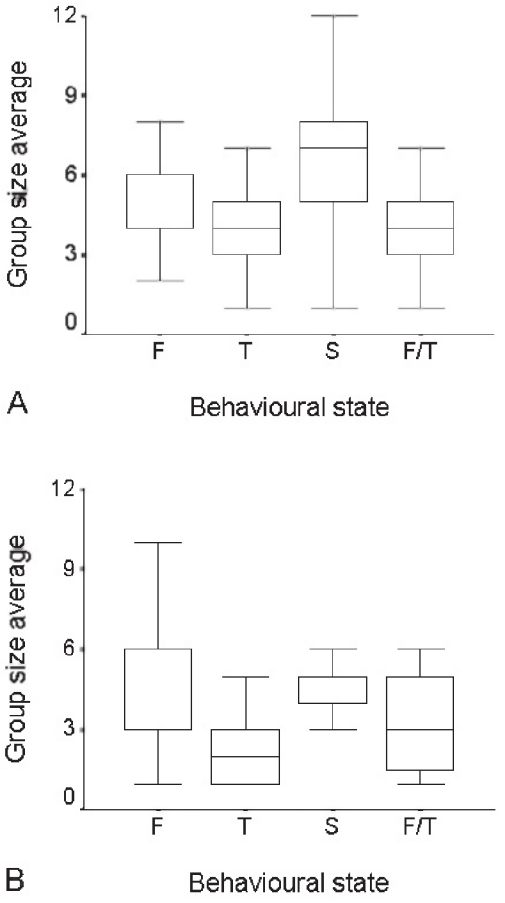


Figure 5. Box whisker plot of group size of Peale's dolphins, *L. australis* (mean ± SE), in Río Seco (A) and Agua Fresca (B) relative to behavioural states: feeding (F), traveling (T), socialising (S), and foraging/traveling (F/T)

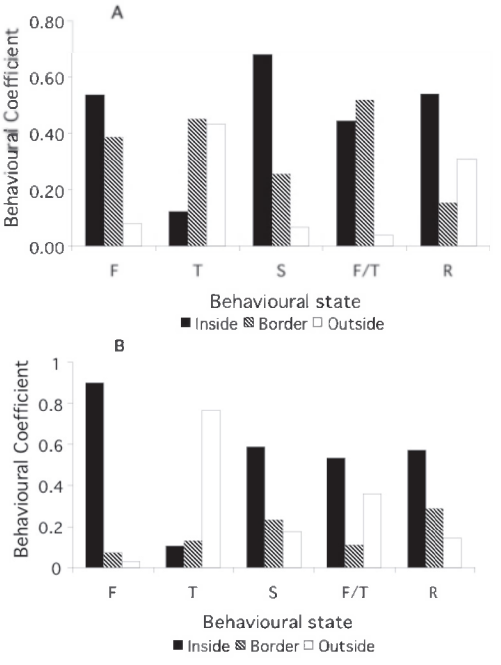


Figure 6. Behavioural Coefficient of Peale's dolphins, *L. australis*, relative to their position in the kelp bed in Río Seco (A) and Agua Fresca (B) by behavioural states: feeding (F), traveling (T), socialising (S), foraging/traveling (F/T), and resting (R)

= 0.68), whereas foraging/traveling was mainly recorded on the border and inside the kelp beds (BC = 0.51 and BC = 0.43, respectively). At Agua Fresca, feeding was seen mainly inside the kelp beds (BC = 0.90), as well as socialising (BC = 0.59). Traveling was registered principally outside the beds (BC = 0.77), whereas foraging/traveling was mostly observed inside (BC = 0.54).

Discussion

Peale's dolphins showed a habitat selection pattern for a small portion of the entire study area in both coastal sectors. Their behavioural states were not evenly distributed over the coastal zone, and their preference for kelp beds, which seemed to be their primary feeding ground, was evident throughout this study.

At Río Seco, five sections were identified as having greater than uniform use, which represented 50.5% of the total time Peale's dolphins were observed in that sector. On the other hand, at Agua Fresca, only four sections were identified as having greater than uniform use, which represented 82.5% of the total time dolphins were observed in that sector.

Most studies on coastal dolphins propose that habitat selection and use patterns occur principally as a function of distribution, movement, and abundance of their prey species (Ballance, 1992; Karczmarski et al., 2000; Stevick et al., 2002) and secondly, as a way to find refuge from predators (Evans, 1993); however, prey species also respond to specific environmental variables, which are at the same time the variables selected by predating dolphins, such as depth (for *Cephalorhynchus hectori*, Bejder & Dawson, 2000; Bräger et al., 2003; for *Sousa chinensis*, Karczmarski et al., 2000; for *Cephalorhynchus commersonii*, Lescrauwaet et al., 2000), water clarity, sea surface temperature (for *C. hectori*, Bräger et al., 2003), coastal reefs (for *S. chinensis*, Karczmarski et al., 2000), proximity to rivers and estuaries (for *Tursiops truncatus*, Ballance, 1992; for *Cephalorhynchus*

eutropia, Ribeiro, 2003), and seagrass (for *T. truncatus*, Barros & Wells, 1998).

Peale's dolphins were strongly associated with kelp beds. At Agua Fresca, they were on the border or inside kelp beds during 82.5% of the effective observation time, and for 88.5% of their effective observation time at Río Seco. These results are consistent with those published by de Haro & Iñiguez (1997), Goodall et al. (1997a), and Lescrauwaet (1997).

Feeding was the most frequent activity observed in both sectors, followed by traveling. The association between traveling and feeding, in which animals move rapidly over areas that are poor in resources and stay longer in feeding grounds, has been widely reported in cetaceans (Ballance, 1992; Karczmarski et al., 2000; Stevick et al., 2002). The greater the level of food predictability, the more evident this movement pattern (Stevick et al., 2002). Peale's dolphins were observed feeding and foraging/traveling mainly inside and on the border of the kelp beds, while traveling occurred principally outside the kelp beds. These results suggest that kelp beds may be a major source of prey in near-shore habitats for Peale's dolphins and that this pattern might be an indicator of some degree of predictability in the distribution of resources. Würsig (1986) suggested that Peale's dolphins tend to frequent and return to areas where they have previously found food, providing evidence that, under many circumstances, random search is augmented by memory of previous success.

At Agua Fresca, Peale's dolphins selected mainly those areas with kelp bed coverage, which contrast with the middle sections composed of sandy bottom and no kelp beds (*Patagonotothen tesselata*). Although the kelp bed was distributed more homogeneously at Río Seco than at Agua Fresca, significantly, dolphins still selected only five sections. This suggests that dolphins select areas with *M. pyrifera* in relation to key variables other than just kelp bed presence, which might be in response to special features at a very small spatial scale (tens of meters), such as kelp bed distribution, structure, disposition, and coverage (amount of inner channels and space). In those sections with very dense kelp bed coverage, Peale's dolphins seemed to spend more time in the border, while in those sections with more inner passages and channels, they ventured more often inside the beds. Moreno & Jara (1984) mentioned two fish species that frequented these space areas within the kelp beds, which was observed forming schools, and *Champsocephalus essox*, which have more solitary behaviours. Predation on these species may be one of the reasons why Peale's dolphins frequent spaces or channels inside the kelp beds more often. Furthermore, prey capture efficiency may be diminished due to high density of kelp plants, and venturing inside dense areas with no open areas might even be dangerous when surfacing to breathe.

Moreno & Jara (1984) identified 18 fish species in kelp beds in the fjords of Tierra del Fuego, and most of these species are demersal or benthic. These observations correlate well with data on the feeding ecology of Peale's dolphins off northeastern Tierra del Fuego, where they were associated with demersal and bottom prey species captured in or near kelp beds (Schiavini et al., 1997). In addition, according to these authors and from personal communications from divers (for sea urchins) in our study area, Peale's dolphins also predate on octopus and squid among the kelp bed holdfast.

Kelp beds might serve as food source, rather than refuge from predators. No big sharks that could act as potential predators are found in the Strait of Magellan. Killer whales (*Orcinus orca*) are observed with some frequency in the study area, however, and could be a potential predatory threat. Nevertheless, there are neither observations nor data available on killer whales preying on Peale's dolphins. We suspect that kelp beds may not act as a good refuge since in the Strait of Magellan there is evidence of killer whales going through the kelp beds and stranding on the beach to take southern sea lions (*Otaria flavescens*) (Ricardo Matus, pers. comm.).

Peale's dolphin group size differed significantly, depending on their behavioural state. Traveling had the lowest group size average for both sectors, while socialising reached the highest. Feeding was performed mainly by small groups of four to five animals in comparison to cooperative feeding far from shore, in which more than 15 animals can be observed capturing prey. Feeding strategies of dolphins in nearshore habitats, such as kelp beds in the Strait of Magellan, may differ from those living in more open coastal habitats. Peale's dolphins foraged in small groups or even individually on prey that may not form schools, whereas open coastal dolphins may benefit by coalescing into larger groups to feed on schooling fish and squid prey. As pointed out by Würsig (1986), in addition to decreasing risks of predation, schooling in dolphins enhances foraging efficiency. Our results are consistent with those of bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, where resident dolphins tend to prey on fish that generally do not congregate into large schools and often were associated with seagrass areas (Barros & Wells, 1998). The size of prey schools or individual prey may restrict the size of cooperative groups (Connor, 2002). Furthermore, an ideal group size

optimises energy intake, as shown for "transient" killer whales in British Columbia, in which most animals commonly hunt for harbour seals (*Phoca vitulina*) in groups of three that yield a higher per individual energy intake than larger or smaller killer whale groups (Baird & Dill, 1996).

Vegetated ecosystems, such as seagrass, have been proposed to be important areas for food in coastal dolphins (Barros & Wells, 1998). Kelp forests provide a rich environment of favourable conditions such as food, spatial refuges, nesting sites, and nurseries for a wealth of invertebrates, fish, and algae (Moreno & Jara, 1984; Ojeda & Santelices, 1984; Santelices & Ojeda, 1984). Peale's dolphin dependence on kelp bed ecosystems seems to be strong enough to elicit concern that they might be vulnerable to habitat loss. A large alteration of kelp forest could affect dolphin coastal feeding grounds and/or reduce nursery areas of dolphin prey species. The high productivity of kelp bed areas implies their energetic importance to Peale's dolphin populations. The need to protect these ecosystems seems clear to provide conservation for Peale's dolphins.

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