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ORIGINAL PAPER

Use and exploitation of channel waters by the black-browed albatross

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Abstract Black-browed albatrosses are the most abundant albatross species of the southern hemisphere, breeding on sub-Antarctic and Antarctic oceanic islands around the globe. Their foraging habitat during the breeding season is reasonably well known along its distributional range, indicating a preferred use of waters <500 m deep. The discovery of a colony inserted within the Admiralty Sound, Tierra del Fuego, poses an interesting challenge to the known precepts on foraging behavior for the species. In this study, we present the first record on the foraging distribution of the only known inner-channel colony of albatrosses in the world, using high-resolution GPS loggers. Black-browed albatrosses breeding at the Albatross Islet used exclusively inner-channel waters, at least during the chick-guard stage. Our results indicate a significant smaller foraging range during chick-guard compared with conspecifics from Diego Ramirez and Falklands/Malvinas Islands. Implications for the conservation of this colony are discussed.

Keywords Chile · Sub-Antarctic · *Thalassarche melanophris* · Foraging habitat · Magellan Strait

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Introduction

Albatrosses and giant petrels are among the most pelagic seabird species (BirdLife International 2004). They may fly vast distances in a few days from their breeding colonies to foraging areas located in the open ocean (Shealer 2002; BirdLife International 2004; Falabella et al. 2009). During breeding season, the distance traveled, the trip duration, and the time invested foraging at sea are constrained by the need to satisfy both parents and chick's food requirements (Huin et al. 2000). Although these pelagic seabirds face threats at their breeding sites, their main problem involve interactions with fisheries in the marine environment, where thousands of birds are killed by longline fishing (Anderson et al. 2011). They are, therefore, excellent indicators of the marine ecosystem status, especially in the high seas (BirdLife International 2004).

Black-browed albatrosses (*Thalassarche melanophris*) are the most abundant albatross species of the southern hemisphere, breeding on sub-Antarctic and Antarctic oceanic islands around the globe (Gales 1998). However, as longline and trawl fisheries have caused population declines, the species were classified as endangered by the IUCN (2008). Recent population estimates have showed that about 96 % of their world population is confined to the waters around the southern tip of South America (Wakefield et al. 2011). In light of this fact, the discovery of new colonies in southern Chile in recent years should not be

surprising (Arata et al. 2003; Aguayo et al. 2003; Marin and Oehler 2007), increasing from three to six the number of breeding colonies of black-browed albatrosses for Chile and placing the country second worldwide with 20 % of their global population (Robertson et al. 2007). Considering that their main colonies are in remote oceanic islands located in productive areas with a high prevalence of strong winds (BirdLife International 2004; Wakefield et al. 2011), the existence of a small colony at the dead end of a channel in Tierra del Fuego, more than 275 km from open ocean, is remarkable (Aguayo et al. 2003).

Black-browed albatrosses are among the most mobile and wide-ranging of marine predators (Weimerskirch et al. 1997; Huin 2002; Phillips et al. 2004). This species is a very efficient glider, undertaking long foraging trips in search for food, particularly during incubation and post-brooding; by contrast, trip duration and distance during brooding are much restricted (Wakefield et al. 2011).

The understanding of factors influencing the foraging of breeding adults requires the analysis of patterns under different conditions. Precisely, the unique location of the Albatross Islet, the only nearly land-locked breeding site recorded for the species, isolated from other albatross and petrel species, suppose a unique opportunity for such comparative studies. Here, we provide the first description of the at sea distribution and activity patterns of individuals from the only known inner-channel colony of albatrosses in the world, using high-resolution GPS loggers.

Materials and methods

Black-browed albatrosses were tracked at Albatross Islet (54°27′25″S, 69°01′12″W) during January 2012 (breeding season 2011) and December 2012 (breeding season 2012). This colony holds 62 breeding pairs (Moreno and Robertson 2008). We captured breeding adults at the nest by hand and equipped them with i-gotU USB GPS Loggers Model GT-120 (Mobile Action Technology Incorporation, New Taipei City, Taiwan), designed for trekking sports. These devices measured 44.5 × 28.5 × 13 mm, weighted 20 g and had a memory storage capacity of 16 MB. The weight of the tags represented less than 1 % of the bird's body mass, well below the recommended 3 % threshold (Phillips et al. 2003). As they are not waterproof, we used silicone gel and fit each logger inside three rubber-thumbs cut off from domestic cleaning gloves. Instruments were set to record a bird position every 30 min with a battery-life expectation of about 5 days. The GPSs were attached to the mid-dorsal mantle feathers of the back, between the wings, using water-resistant tape Tesa 4651 (Tesa SE, Hamburg, Germany; Wilson et al. 1997).

Eight individuals were tagged between 7 and 11 January 2012 (thereafter, season 2011), obtaining a total of 13 complete foraging trips from seven of these birds. One instrument was not recovered during this season. A total of twelve individuals were tagged between 7 and 14 December 2012 (thereafter, season 2012); we obtained 15 complete foraging trips from nine birds this season. In both seasons, only complete foraging trips, with records from departure to arrival to the nest, were included. No nest desertions of sampled couples occurred during the field work.

Foraging areas were characterized through the use of the kernel density function (Worton 1989; Wood et al. 2000; BirdLife International 2004; Falabella et al. 2009) available in Spatial Analyst tool of ArcGis 10 (ESRI, Redlands, CA, USA). Distribution was modeled using a grid size of 500 m and a search radius of 5,000 m. Density distributions are represented on the maps by 50, 75, and 95 % utilization distribution contours, indicating areas within which tracked individuals spent 50, 75, and 95 % of their at-sea time, respectively, for both seasons (Falabella et al. 2009).

Foraging trips were characterized according to their range, total distance traveled, duration, and ground speed. Behavior of albatrosses during the foraging trips was described using ground speed from consecutive GPS locations as proxy. Data were categorized in 'day,' 'twilight,' and 'night' according to the local dawn, sunrise, sunset, and dusk times for the Albatross Islet during the study period, using the TerraTime software (Udell Enterprise, www.terratime.net). Considering the low sample size, every foraging trip was treated as independent.

Inter-seasonal comparisons of different trip metrics were performed using Mann–Whitney U test and frequency distributions were tested using χ^2 statistics.

Results

Breeding black-browed albatrosses from Albatross Islet were tracked during two consecutive seasons, 2011 and 2012, covering late and early chick-guard stage, respectively. Overall, 28 trips (13 in season 2011 and 15 in season 2012) from 16 adult individuals were obtained during this study. The frequency of locations obtained suggests a good performance of the instruments during the short foraging trips sampled (median 30.2 min; 95 % CI 27–63 min).

During both seasons, albatrosses exploited exclusively inner waters from Admiralty Sound and the Magellan Strait (Fig. 1). We identified three key areas where the tracked individuals spent most of their foraging time. The largest area was located inside the Admiralty Sound, from around the colony until the middle section of the Sound; another

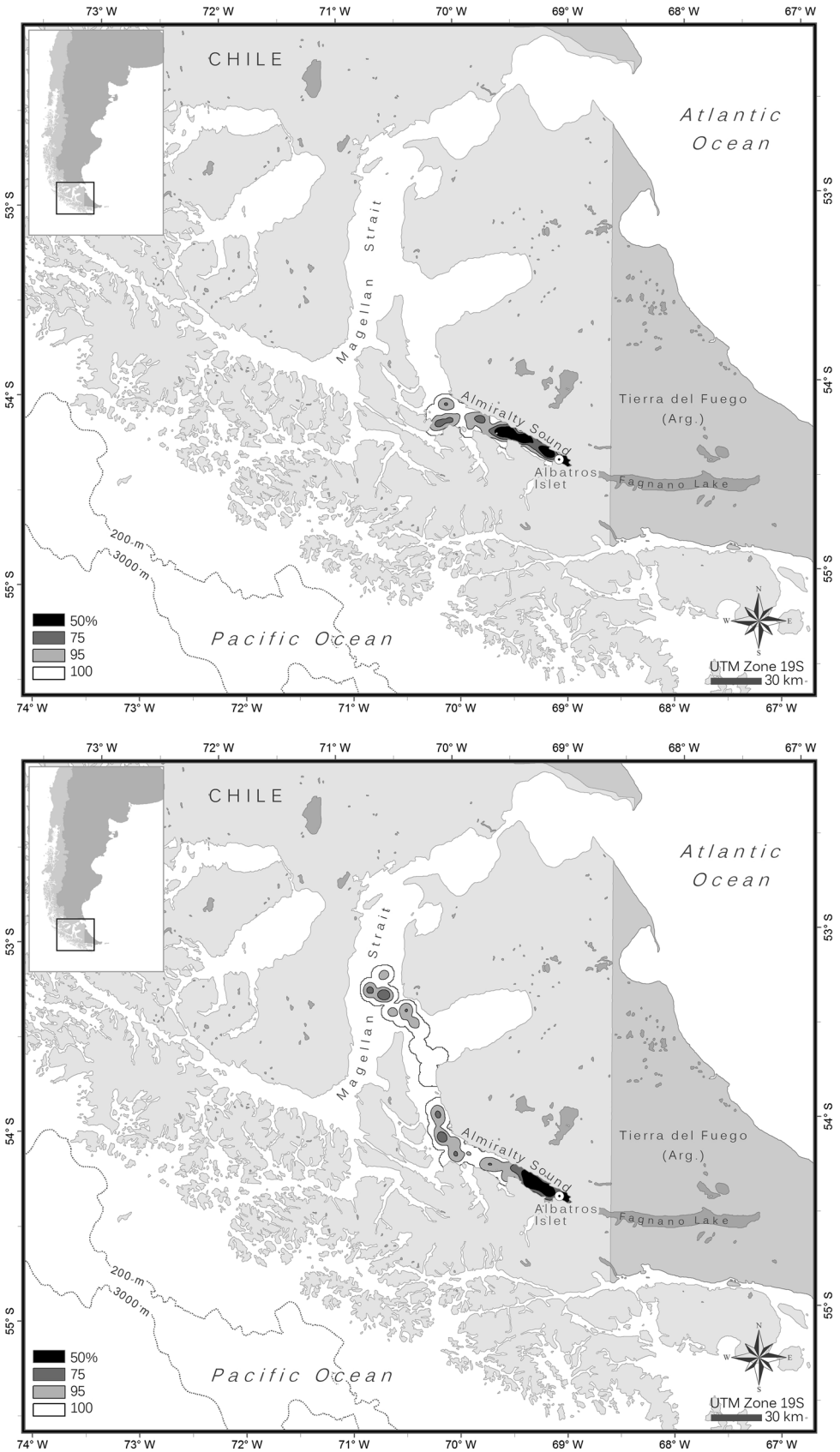

Fig. 1 Density distribution of breeding black-browed albatrosses tracked from Albatross Islet, Tierra del Fuego (South America), during early (December 2012; *top*) and late (January 2012; *bottom*) chick-guard period. All available data for each season were included, and distributions are represented by 50, 75, and 95 % utilization contours obtained by kernel analyses

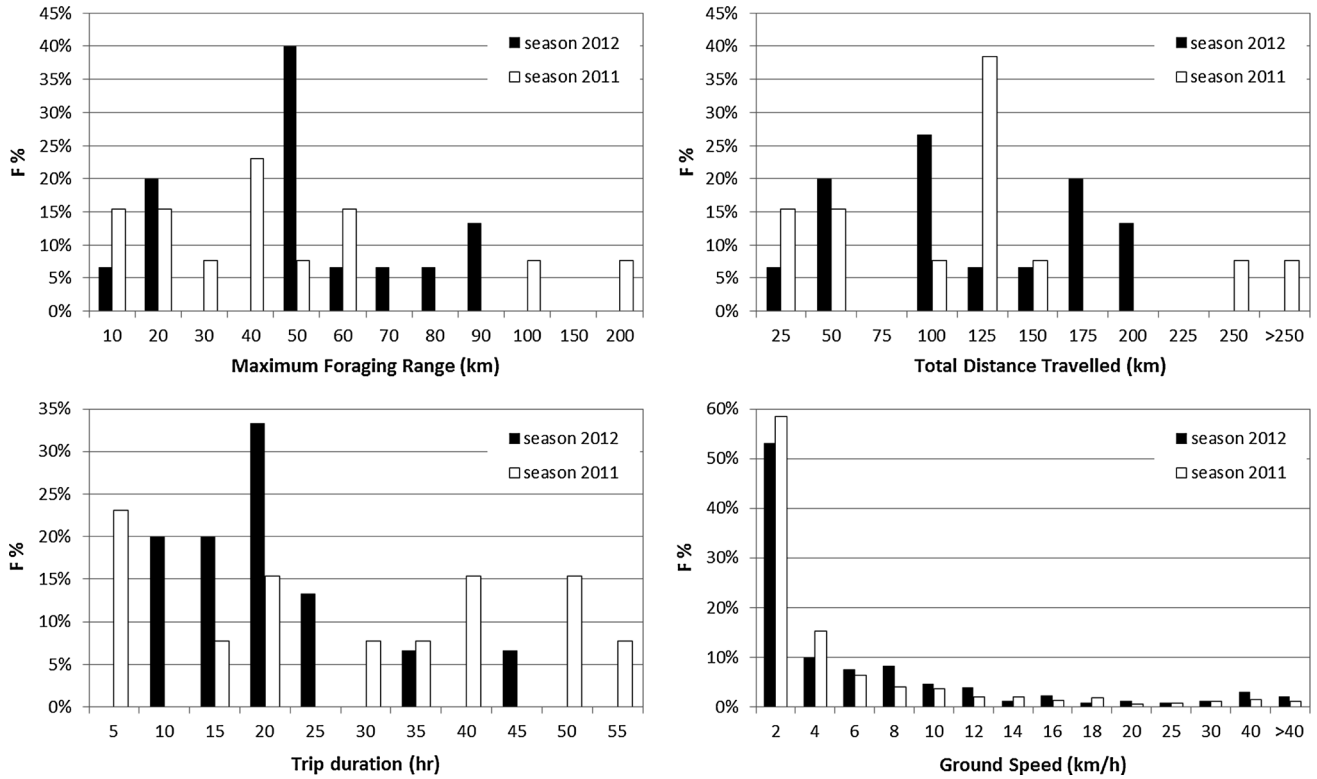

Fig. 2 Frequency distribution of maximum foraging range (*top, left*), total distance traveled per trip (*top, right*), trip duration (*bottom, left*) and ground speed estimated for two consecutive GPS locations (*bottom, right*) during 2011 and 2012 breeding seasons

area was located at the mouth of the Admiralty Sound; and a third area was located in the middle of the Magellan Strait, just 25 km southeast of Punta Arenas city.

The median maximum foraging range from the colony was 36 and 45 km during seasons 2011 and 2012, respectively, with a maximum range of 173.6 km (Fig. 2). The median total distance traveled per foraging trip was 105 and 99 km in seasons 2011 and 2012, respectively, with the longest total distance traveled being 432 km (Fig. 2). Median trip duration was 26 and 18 h during seasons 2011 and 2012, respectively, (Fig. 2). Maximum foraging range and total distance traveled per trip were similar between seasons, although there is a tendency for trips becoming longer during late guard stage (season 2011). However, neither of the above metrics were significant between seasons. Interestingly, five out of nine birds tracked multiple trips showed a long-short-long pattern.

Most trips started during daylight (2011: 8 out of 13; 2012: 11 out of 15) with only a single bird departed during nighttime (in 2011). Individuals tracked flew fast mainly when traveling from the colony to their foraging ground or when returning to the colony (Fig. 3); by contrast, movements once at the foraging ground were slow compare with the nearby colony at Diego Ramírez (mean ground speed during brooding = 21–26 km h^{-1}; J. A. Arata, unpublished data), with >75 % of its movements at speeds <6–8 km h^{-1} (Fig. 2). Ground speed was particularly slow during the night.

Likewise, the total distance traveled during a foraging trip in our study was significantly shorter than the recorded for Falklands/Malvinas Islands (Granadeiro et al. 2011) and Diego Ramirez (J. A. Arata, unpublished data) albatrosses (Fig. 4).

Discussion

Black-browed albatrosses breeding at Albatross Islet, Admiralty Sound, Tierra del Fuego, used exclusively inner-channel waters, at least during the early and late chick-guard stages. This is the first record of such behavior described for an albatross colony around the world. In terms of conservation, the intensively used areas that were identified at sea for individuals from this colony will be helpful to promote a strategy for protecting both breeding and foraging sites.

The Albatross Islet is located at the East end of the Admiralty Sound, about 275 km from the Pacific Ocean and 385 km from the Atlantic Ocean, both distances well within the foraging range of black-browed albatrosses from

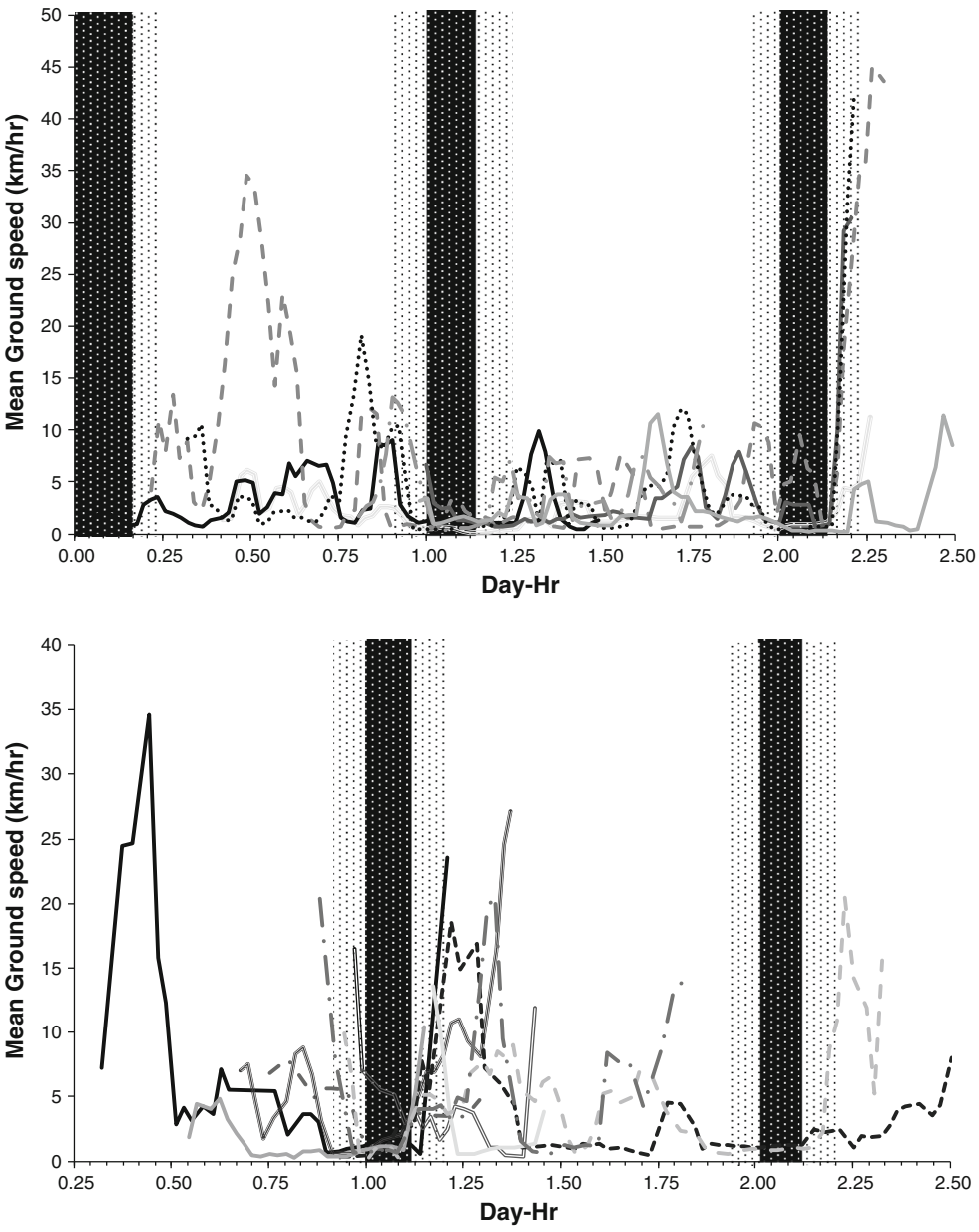

Fig. 3 Ground speed (3-moving mean) of individuals tracked during breeding season 2011 (*top*) and 2012 (*bottom*). Only one trip per bird is shown. Twilight (light hatch) and night (dark hatch) periods are also shown. Day–hour correspond to the time in a 24-h period (ex., 0.25 = 6 h; 0.75 = 18 h), from the day of departure onward

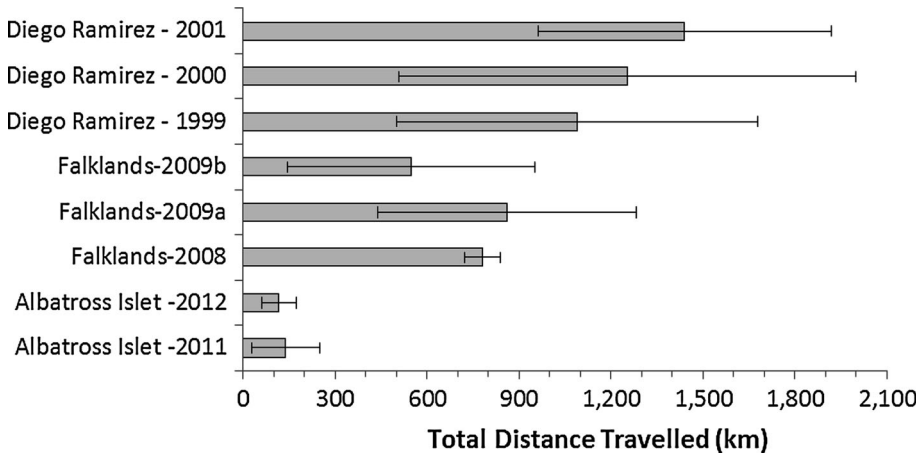

Fig. 4 Total distance traveled (km) of breeding black-browed albatrosses tracked during chick-guard stage at Albatross Islet (this study), Diego Ramírez Islands (JA Arata, unpublished data), and Falklands/Malvinas Islands [New Island: 2008 and 2009a; Steeple Jason: 2009b] (Granadeiro et al. 2011)

other colonies studied (BirdLife International 2004; Falabella et al. 2009; Wakefield et al. 2011). However, black-browed albatrosses breeding at the Albatross Islet undertook shorter foraging trips (range 52 and 47 km; duration 30 and 20 h; in breeding season 2011 and 2012, respectively) during the guard stage than conspecific individuals from Diego Ramirez and Falklands/Malvinas Islands (Fig. 4), making this the black-browed albatross colony with the smaller home range known to date. This suggests the presence of a predictable food source within the Magellan Strait and associated channels.

Potential local prey items are the lobster krill *Munida gregaria* and the fuegian sprat *Sprattus fuegensis*, which are abundant food sources in these channels (Tapella et al. 2002; Diez et al. 2012). These prey items had been found in stomach samples from black-browed albatrosses taken at Diego Ramirez (Arata and Xavier 2003), among other prey items. In the Admiralty Sound, there is no longline or trawl fisheries and, consequently, the availability of fishing discards in the area are null, making this colony dependent on natural caught preys.

Clupeid fish and lobster krill are found close to the sea surface intermittently, where they could become accessible to albatrosses (Diez et al. 2012). In fact, fuegian sprat and lobster krill had been detected at the sea-surface 13 and 22 times, respectively, out of 29 night surveys conducted at Francisco Coloane Marine Protected Area (53.7°S, 72.2°W) between November 2011 and May 2012, being preys of potential importance to several top predators in the area (D. Haro, unpublished data).

The potential availability of these prey items may be damped by the presence of Humpback whales (Acevedo et al. 2007) and large colonies of Magellan penguins (Bingham and Hermann 2008) in the Magellan Strait, which are better suit predators in these shallow waters than the albatross. The Albatross Islet is the smallest black-browed albatross colony recorded in Chile and the World. Competition with diving, shore species may be an important factor for this. Further investigations for understanding foraging niche partitioning, energy budget, and reproductive output by albatrosses from the Albatross Islet might provide useful insights into the persistence of this unusual colony.

Finally, it is interesting to notice that black-browed albatrosses tracked from other colonies in Chile are known to use inner fjord and channel waters during the breeding season. By contrast, albatrosses from Falklands/Malvinas and South Georgia, the other two closest colonies, do not venture into the Magellan Strait or Beagle Channel during the breeding period (BirdLife International 2004; Falabella et al. 2009; Wakefield et al. 2011). However, we observed an individual banded in Falklands/Malvinas in the Albatross Islet during season 2009 (P. Catry, personal communication), indicating that some individuals from Falklands/Malvinas may enter the Magellan Strait. The question on the origin of the founders could have implications for the conservation status of this colony, considering that black-browed albatrosses from Chile and the Atlantic (Falklands/Malvinas and South Georgia) have different non-breeding distributions and face very different risks from fishing fleets in Chile (Moreno et al. 2006; Moreno et al. 2008) and Argentina, Uruguay, and Brazil (Bugoni et al. 2008; Jiménez et al. 2010; Favero et al. 2013), which are reflected in different population trends in Chile with respect to the southwest Atlantic populations (Poncet et al. 2006; Huin 2001 in Robertson et al. 2007).

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