Agreement on the Conservation of Albatrosses and Petrels

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Occurrence of Black-browed Albatross (*Thalassarche melanophris*) in southern Peru provides clues on their northern limit

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SUMMARY

The Black-browed Albatross (*Thalassarche melanophris*) has a circumpolar, well-documented, breeding distribution in the southern hemisphere. However, information on post-breeders and juveniles dispersal is scarce, particularly off western South America. Records off Chile occur commonly as north as ~24°S. Although the presence of the species in Peru is documented, the limited number of records is insufficient to describe the species status on Peruvian waters. To fulfill this gap, we conducted two at-sea surveys during fall and spring 2019 to determine their seasonal distribution, abundance, and habitat preference on Peruvian waters. We recorded sightings along 36 transects from the coast up to 100 nm offshore. We surveyed 7678 km2 over 483.7 h of observation, recording 46 individuals in autumn and 4 in spring, occurring only from Callao (12°S) to the southern limit (18°20′ S), with the greatest concentration found between 16 and 17°S. Black-browed Albatrosses occurred mainly over the continental slope (5.91 birds/100 km2). The majority of sightings corresponded to adults (63%), whereas sub-adults (37%) were mainly second-year juveniles (67%). The significant drop in density during spring and the large presence of adults during autumn suggests that post-breeders reach southern Peru during their wintering migration, returning to their breeding colonies in southern Chile, next spring. Given the absence of Black-browed Albatrosses north of Callao, we suggest that the northern limit for the species is related to the coastal branch of the Humboldt Current System and competition with the Waved (*Phoebastria irrorata*) and Salvin's (*Thalassarche salvini*) Albatrosses, which are abundant in the warmer waters off central-north Peru.

1. INTRODUCTION

The Black-browed Albatross (*Thalassarche melanophris*) is the most abundant albatross in the Southern Hemisphere (Tickell 2000). The species breeds on sub-Antarctic islands around South America, with nearly ~70% of the world breeding population (535,600 breeding pairs) occurring in the Falklands/Malvinas Islands (ACAP 2010; Wolfaardt 2013; BirdLife International 2020). Several islands located in southern Chile hold another ~21% of its world population (Arata and Xavier 2003; Moreno and Robertson 2008; ACAP 2010), mainly at the Diego Ramirez Archipelago (56°31′S; 68°43′W) with ~55,000 breeding pairs, Ildefonso Archipelago (55°44′S; 69°28′W) with ~54,284 breeding pairs (Robertson et al. 2017), and Diego de Almagro Island (51°32′S; 75°20′W) with ~15,600 breeding pairs (Lawton et al. 2003).

The Black-browed Albatross has a broad pelagic distribution, ranging from subtropical to polar waters, mainly shallow (<1000 m) waters, although they can frequent deeper waters associated with oceanic frontal systems (Wakefield et al. 2011). Different populations have spatially segregated foraging areas throughout the year, dispersing mainly on a northsouth axis (BirdLife International 2004). Although foraging areas of breeding birds are reasonably well-known, information on the distribution of non-breeders and juveniles is sparse (ACAP 2010; Pardo et al. 2017). Breeding birds at Diego Ramirez, Ildefonso, and Diego de Almagro Islands forage mainly on the continental shelf and slope of central and southern Chile, reaching as north as 33°S (Wakefield et al. 2011). During the nonbreeding season, adult Black-browed Albatrosses from Diego Ramirez distribute mainly northward along the Humboldt Current (BirdLife International 2004), where they are known to interact with the pelagic Swordfish (Xiphias gladius) fishery off northern Chile, between 24 and 32°S (Gonzalez et al. 2012).

There are very few reports of its occurrence further north along the western South American coast. One individual was recorded close to Guayaquil (~02°S) off continental Ecuador in the 1960s (Harris 1968). Records for Peru from the GBIF database (www.gbif.org) are also scarce, with 2.55 records per year, mostly during autumn and winter (72% of records) (GBIF 2021); sightings occurred mainly off Callao and Pisco (12–14°S, see Fig. 1 for localities mentioned in the text), likely associated with tourism activity. In addition, photographs in eBird database provide evidence of three more birds, all of them during wintertime: one in August 2008 at 75 nm offshore Callao (12°08′S; 77°50′W), one in August 2009 at 13 nm offshore Callao (12°06′S; 77°16′W), and one in July 2019 at 120 nm offshore Ilo (18°05′S; 77°24′ W). In both databases, no records were northern than 12°S. Although these scattered records confirm the presence of Black-browed Albatrosses on Peruvian waters, they fail to inform on the seasonality and intensity of use of habitats. Here we provide a first systematic sampling of the distribution and abundance of Black-browed Albatrosses off Peru.

2. METHODOLOGY

The Peruvian Marine Research Institute (IMARPE) ran two pelagic research cruises during 2019, one in late autumn (May to June) and another in spring (October to November), completing 32 and 36 parallel transects, spaced every 15 nm, in autumn and spring, respectively. The geographic sampling coverage was between northern Peru (04–06°S) and the Chilean (18°20′S) boundary, and from the coastline to 80 nm offshore (Fig. 1). Seabird observations were carried out by two observers working simultaneously, from dawn to dusk, from each side of the bridge of the RV Humboldt (16 m above sea level) while the ship was underway. Sightings stopped during oceanographic stations or trawling, when

complementary information was gathered. Transects were partitioned every 6 min, or one nautical mile (1 nm), since the vessel's cruise speed was 10 knots. All bird species within a 90° quadrant at each side, up to 500 m each side, were recorded following the methodology described by Johansen et al. (2015). Using the vessel speed and distance, we calculate the surface area surveyed, in km2.

We recorded the behavior of birds (flying, resting on the water, feeding, or scavenging), age class (adults, and subadults: first, second and third-year old), and associated species for each sighting (following Shirihai 2008; Howell and Schmitt 2018; Howell and Zufelt 2019). Abiotic variables recorded included ship position and course, depth (m), sea surface temperature (°C), salinity, and wind speed (m/s). This intense sampling design allowed us to determine the use by Black-browed Albatrosses of different habitats in a short period, i.e., like a snapshot of their distribution in both seasons. We characterized habitat used by albatrosses according to their depth: continental shelf (0 to 200 m isobath), continental slope (201 to 4500 m), Peru-Chile Trench (>4500 m), and the Abyssal plain (offshore, beyond the Peru-Chile Trench). The habitat classification was an adaptation of Wakefield et al. (2011) for the specific bathymetric zones off the Peruvian coast.

To explore the associations between biotic and abiotic variables, the principal component analysis (PCA) ordering method was applied. The objective was to reduce the number of variables to a smaller number, losing as little information as possible. The resultant principal components or factors will be a linear combination of the original variables and independent of each other (Hotelling 1933). PCA was performed to explain the associations between the abundance of the Black-browed Albatross and the following quantitative variables, sea surface temperature (SST), sea surface salinity (SSS), latitude (°S), depth (m), distance to the coast (nm), and wind velocity (m/s), with previous normal distribution standardization of these variables. These variables were chosen to characterize the water masses used by albatrosses, which off Peru are also related to the width of the continental shelf.

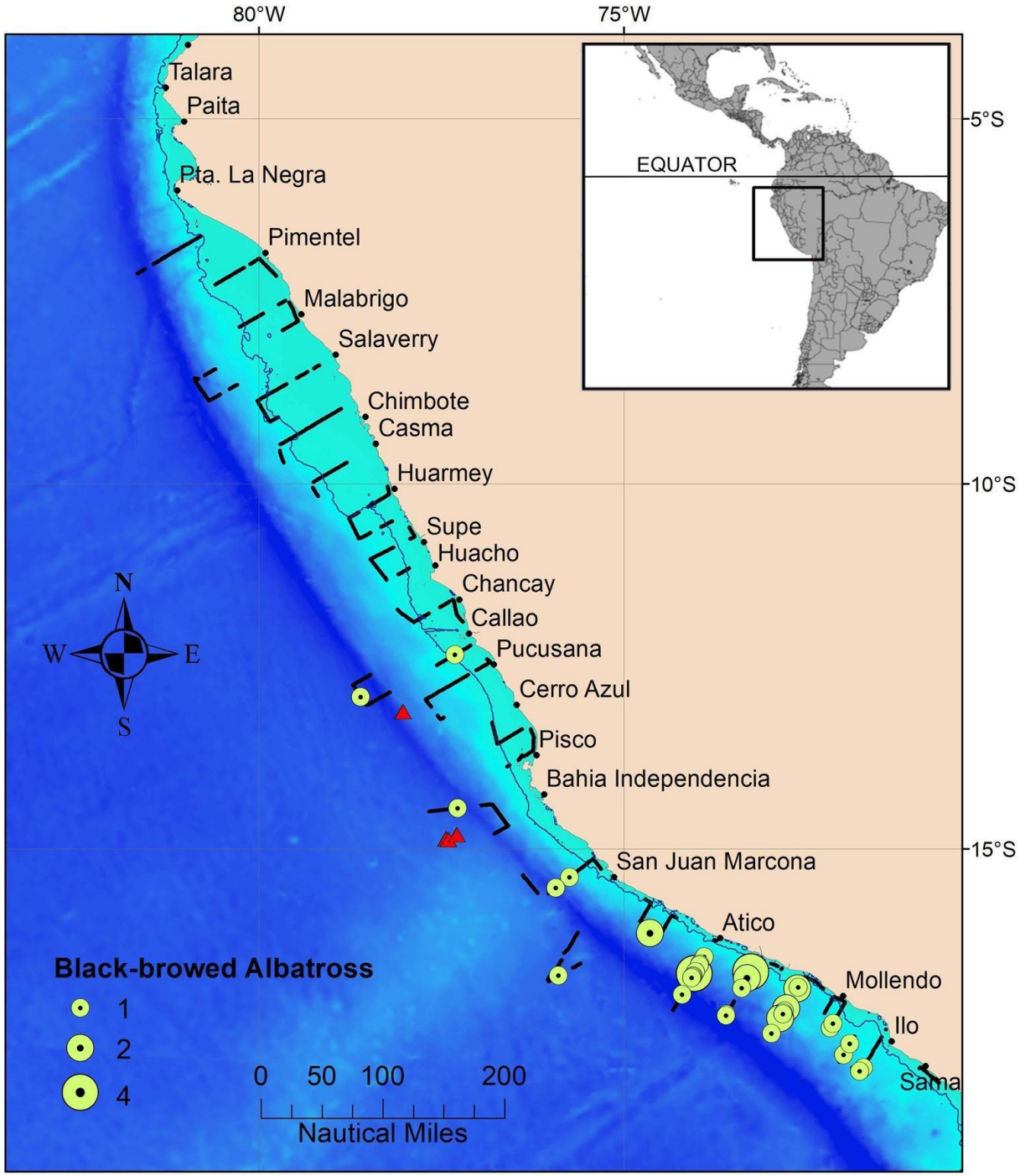

Figure 1. Spatial distribution and relative abundances of Black-browed Albatrosses (*Thalassarche melanophris*) during autumn 2019 (green circles). Solid black lines indicate the surveyed tracks during autumn. Red triangles represent the few individuals sighted during spring 2019. The continuous blue line represents the 200 m isobaths where the continental shelf breaks

3. RESULTS

We sampled during 483.7 h in both autumn and spring cruises from Punta Sal (04°S) to Morro Sama (18°S) in autumn, from Lobos de Tierra (06°S) to Morro Sama in spring, and from the coast up to 100 nautical miles, covering an area of 2760.5 km2 during autumn (Fig. 1) and 4917.8 km2 during spring 2019. A total of 46 Black-browed Albatrosses were recorded during autumn between Callao (~12°S) and Morro Sama (~18°S), with a mean density (mean ± 1 SD) of 2.37 ± 4.3 birds 100 km2 (range: 0–14.4) (Fig. 1). No birds were sighted north of Callao, so those transects density was zero. By contrast, only four Black-browed Albatrosses were recorded in spring, with a mean density of 0.21 ± 0.82 birds/100 km2 (range: 0–4). These albatrosses were observed over the continental slope at 13°06′S; 78°01′W (~150 km offshore Pucusana), and three more between 140 and 160 km offshore Bahia Independencia (~14°50′S) (Fig. 1).

The vast majority of birds (73%) were flying, followed by resting on the water (22%) and feeding (5%). Black-browed Albatrosses were associated with small bird groups, mainly represented by Buller's Albatross (*Thalassarche bulleri*), Chatham Albatross (*Thalassarche eremita*), White-chinned Petrels (*Procellaria aequinoctialis*), and Hornby's Storm Petrels (*Oceanodroma hornbyi*).

The great majority of Black-browed Albatrosses registered during autumn occurred over the continental slope (82.6% of sights; n = 38 birds), with a mean density of 5.91 birds/100 km2, followed by the Peru-Chile Trench (13%, n = 6), with a mean density of 1.94 birds/100 km2 (Table 1). Isolated birds composed the great majority (>60%) of sightings. A total of seven flocks (i.e., 2 or more individuals) were recorded, each with mean of 2.7 individuals (range: 2–4 birds), with the largest concentration of flocks occurring between Atico and Mollendo (16–17°S) (Fig. 1). This area was characterized by a mix of coastal superficial waters (CSW) and subtropical superficial waters (SSW), with mean SST of 16.7°C and mean SSS of 34.94. The age class composition was dominated by adults (63%, n = 29).Within sub-adults (37%of sights, n = 17 birds) were of second-year birds (67%), followed by third year (18%) and first-year (15%). According to our PCA axys-1, Black-browed Albatross abundance was mainly associated with salinity (corr = 0.99), distance to the coast (corr = 0.98), SST (corr = 0.84), and wind (corr = −0.78). The PCA axys-2 suggested that bathymetry (corr = −0.94) and latitude (corr = −0.82) were also significant (Fig. 2).

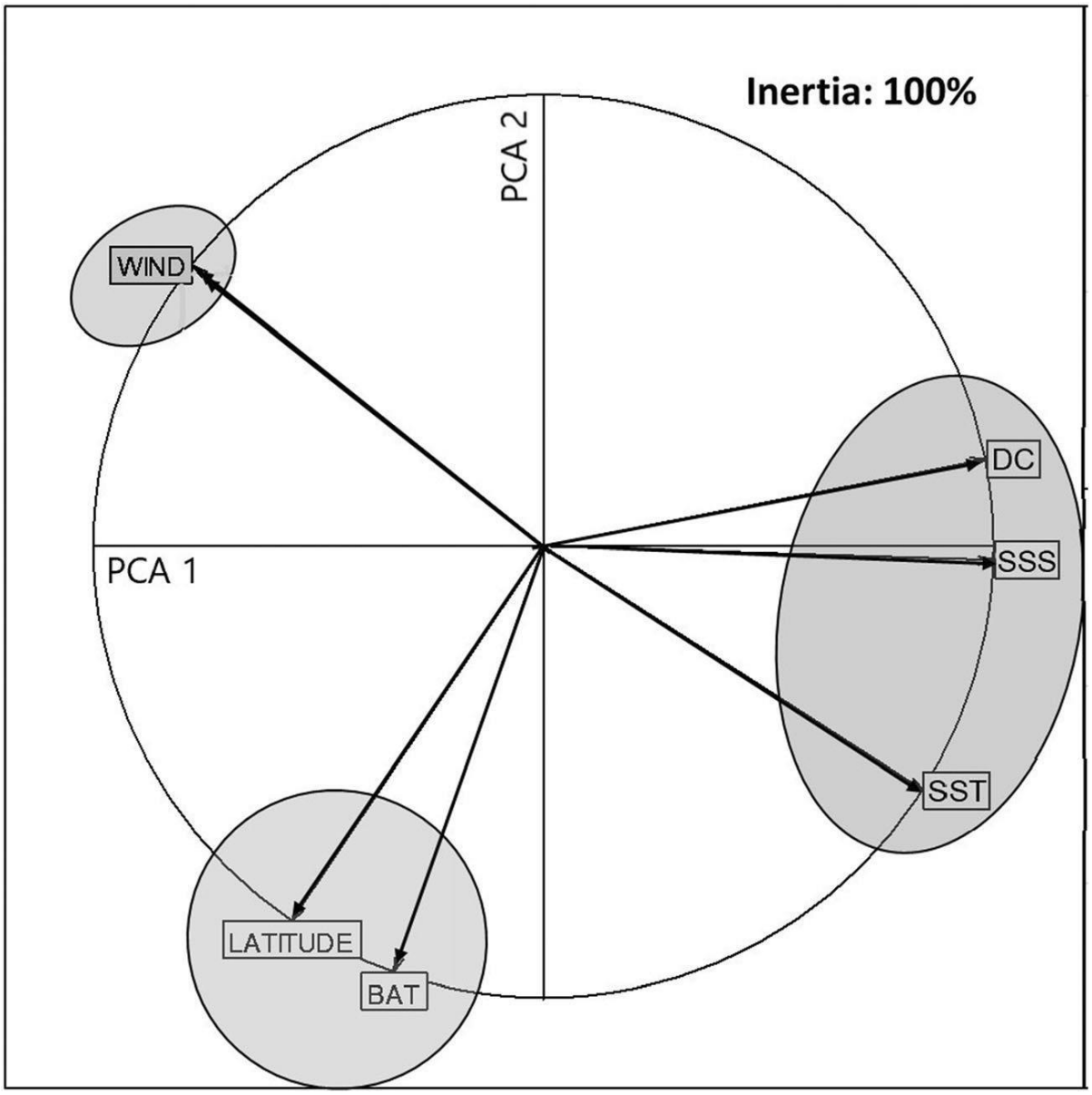

Figure 2. Principal component analysis (PCA) of Black-browed Albatross, using the quantitative variables albatross abundance (quantity), sea surface temperature (SST), sea surface salinity (SSS), latitude (in degrees south), depth or bathymetry (BAT) distance to thecoast in nautical miles (DC) ,and wind velocity (m/s) (WIND)

4. DISCUSSION

Aggregations of Black-browed Albatrosses during autumn were located in an area characterized by a complex interaction between the northward, cold, and fresher Humboldt Current System (HCS) and the poleward, subtropical Peru-Chile Undercurrent (PCUC), which interaction forms eddy-like structures offshore the Peruvian shelf and shelf-slope, between 15 and 17°S (Chaigneau et al. 2013). The Peru Coastal Current, PCC (the coastal branch of the HCS), intensifies during fall and winter, reaching as north as 13°S, where a cyclonic eddy forms, pushing coastal waters offshore. This region is characterized by an intense upwelling cell located between Pisco (14°S) and San Juan de Marcona (16°S), driven by intensified alongshore winds in this region, bringing cold waters (17°C in winter) to

the surface (Bakun and Mendelssohn 1989; Strub et al. 1998). During spring and summer, the PCC weakens and the PCUC intensifies, bringing warmer and saltier waters along the Peruvian coast. This pattern is affected by El Niño (La Niña) events, which intensified the PCUC (PCC) (Chaigneau et al. 2013). Interestingly, we have no records of Black-browed Albatrosses north of Callao (12°S), coincident with the westward flow of the PCC offshore. Likewise, records in the GBIF database are mainly south of Callao (GBIF 2021), with the northernmost record (4°S) in October 2017, coinciding with a weak La Niña event (NOAA Climate Prediction Center 2017).

This study confirms the extensive use by adult and juvenile Black-browed Albatrosses in southern Peru, related to the northern limit of the coastal branch of the Humboldt Current System. The significant proportion of adults recorded (63%) and scarce records of Black-browed Albatrosses during spring, an order of magnitude lower than in autumn, suggests that these albatrosses may be returning south to start breeding activities. Thus, albatrosses recorded in autumn would correspond to post-breeding adults (and post-fledgling juveniles) migrating to their northernmost wintering area.

Similarly, the abundance and proportion of adult Salvin (*Thalassarche salvini*) and Chatham (*Thalassarche eremita*) Albatrosses of Chile and Peru also shows a substantial drop during spring compared to autumn (Spear et al. 2003), as adult birds return to their colonies. Similar patterns had been described for albatrosses from Kerguelen, South Georgia, and the Falkland Islands (Phillips et al. 2005; de Grissac et al. 2016), where post-breeding and new-fledged juveniles alike migrate between 2500–5000 km to their wintering grounds just after the end of the breeding season. This study extends the regular non-breeding range of Black-browed Albatrosses along the Humboldt Current as far north as Callao (12°S), over 5000 km north of their closest colony in southern Chile. Adult albatrosses from Diego Ramirez Islands migrate during their nonbreeding season (April–August) northward along the Humboldt Current, reaching areas as north as the Tropic of Capricorn, 23°27′S (~ 4000 km; Javier Arata, unpubl. data). This study extends the known wintering range for adult Black-browed Albatrosses ~1600 km north.

The northern distribution of the Black-browed Albatross may be limited by a mix of environmental conditions and competition with other albatross species. The northern limit of the Peru Coastal Current, characterized by a mix of Subantarctic Water and Equatorial Subsurface Water masses (15–17°C, ~34.9; Silva et al. 2009), is marked by the intrusion of subtropical waters of the Peru-Chile Undercurrent, which carries subtropical water (>18°C,>35; Silva et al. 2009) from the equator south. On the other hand, the presence of other albatross species, including Chatham, Salvin's, and Waved (*Phoebastria irrorata*) Albatrosses(Jahncke et al. 2001; Spear et al. 2003; BirdLife International 2004; Quiñones et al. 2021), in warmer waters of central-north Peru may outcompete Black-browed Albatrosses further north.

Our results highlight the importance of the highly productive Northern Humboldt Current System, used by adult and subadult Black-browed Albatrosses during wintering period, with densities up to 5.9 birds/100 km2. This distribution put them in contact with a range of fisheries operating in northern Chile and southern Peru, with additional threats including incidental and intentional killing. During cruises, we registered frequent small artisanal boats targeting Giant Squid (*Dosidicus gigas*) using squid-jigs, and Blue Sharks (*Prionace glauca*) and Shortfin Mako Sharks (*Isurus oxyrinchus*) using longines. Both artisanal fisheries are common in oceanic waters in southern Peru (Adams et al. 2016; Csirke et al. 2018), and interactions with Black-browed Albatrosses, which gradually approach the boats when offal discards of giant

squids and sharks occurred, are common (Andrey Moreno and Christian Jimenez, pers.comm.). Although very few records of by-caught Black-browed Albatross exist in the region, two in the Ilo (~17°S) longline, and one in the Salaverry (~08°S) drift-gillnet artisanal fisheries (Pro Delphinus 2008), our results suggest that Black-browed Albatrosses interact frequently with fisheries in southern Peru during autumn and winter. The information provided could be useful for mitigation measures to artisanal and industrial fisheries and thus protect this specieswhenever they occur.

Table 1. Habitat use of the Black Browed Albatross (*Thalassarche melanophris*) off Peru duringautumn 2019. Habitat was characterized according to depth: Continental Shelf (0 to 200 m isobath); Continental Slope (201 to 4500 m); Peru Trench (> 4500 m) and Abyssal plain (offshore the Peru - Trench). Percentage of recorded birds per habitat (N° birds (%); the number of flocks observed (N° of flocks); mean number of birds per flock (Mean N° / flock). Note: we consider a flock when at least two birds were registered in the same geographical position.

Habitat	**Depth mean (range)**	**No. birds (%)**	**Density** **Birds / 100 km2** **(mean** ± 1 SD)	**No. flocks**	**Mean N°** **Birds per flock**
Continental Shelf	179 m	1 (2.2)	0.2	-	-
Continental Slope	2344 m (432 - 4479	38 (82.6)	5.9 ± 5.7	6	2 . 7
Peru Trench	5716 m (4821 - 7232)	6 (13)	1.9 ± 1.5	1	2
Abyssal plain	4082 m	1 (2.2)	0.79	-	-

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