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SHORT NOTE

Vessel survey observations confirm wintering dispersion of northern giant-petrel (*Macronectes halli*) juveniles in southern-central Perú; what is their origin?

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The northern giant petrel (NGP) (*Macronectes halli*) is a circumpolar seabird breeding in three main groups of subantarctic islands (ACAP 2016a; Howell & Zufelt 2019). South Georgia (54°00'S, 38°36'W) in the South Atlantic is the largest colony with 15,398 breeding pairs (bp), encompassing more than 70% of the world population (Ponce *et al.* 2020). In the southwest Pacific, main breeding areas are located in the Forty Fours islets (44°00'S, 176°67'E) in the Chatham Islands Archipelago, New Zealand (~1,977 bp, Bell *et al.* 2017), and Macquaire Island, Australia (~1,793 bp, ACAP 2016a). Other representative main breeding areas in the southern Indian Ocean are Iles Kerguelen (49°09'S, 69°16'E) and Crozet (46°26'S, 51°47'E), with 1,400 and 1,263 bp, respectively (ACAP 2016a). Minor breeding areas in New Zealand are located in the Auckland islands with 340 bp (Parket *et al*. 2020); Antipodes island with 233 bp (Wiltshire and Hamilton, 2003); Campbell islands with 234 bp (Wiltshire & Scofield, 2000), and The Sisters (Chatham Islands) with 156 bp (Bell *et al*. 2018). Finally, in the south-west Indian Ocean in the Prince Edward Islands, 464 bp were counted (Ryan *et al*. 2003; ACAP 2016). Immature and juveniles NGP tend to disperse great distances from their breeding colonies, often showing an eastward movement from the south western Pacific in Macquaire island towards South America due to the prevailing westerly winds (Woehler & Johnstone, 1988; Trebilco *et al*. 2008).

There are records of the presence of juvenile NGP in the western coasts of South America (Ayala 2007; Zavalaga *et al.* 2009; Fibla *et al.* 2010, Van Den Hoff, 2011). In the austral winter 2004, juveniles loafing on Perúvian inshore waters were sighted at San Juan de Marcona (15°20'S, 75°10'W), Ilo (17°42'S, 71°22'W) and La Vieja island (14°16'S, 76°11'W) off Bahia Independencia (Ayala 2007). Between the winter-spring 2002 and 2007, 11 juvenile NGP were recorded >60 km off Callao (~12°S), the northernmost location of its post-breeding distribution known to date (Zavalaga *et al.*

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2009). There is more recent evidence from the eBird web site (https://ebird.org/home) of the presence of juveniles NGP in offshore waters of central-southern Perú during the winter and spring.

Four banded fledglings of NGP from the Kerguelen and Crozet archipelagos in the southern Indian Ocean that were recovered as juveniles in Chile revealed that these birds can travel great distances (Voisin 1990). Two band recoveries of dead juvenile NGP in northern Chile, one captured in a longline in June 2002 at 21°50′S, 72°28′W, approximately 150 km offshore Tocopilla (Zavalaga *et al.* 2009), and another found dead in March 2007 at Papudo beach (32°26′S, 71°25′W), 75 km north of Valparaiso (Fiblia *et al.* 2010), showed that these birds travelled from Macquarie Is. These findings were confirmed by Van Den Hoff (2011) who reported 34 banded fledglings and seven banded second-year *Macronectes* spp. from Macquarie Is. sighted from Arica (18°S) to Puerto Aysen (45°S) in the coast of Chile between 1955 and 2006. Although it was not possible to separate northern from southern giant petrels (*M. giganteus*) in this study because the majority of the band deployments occurred before the two species were separated by Bourne & Warham (1966), it is likely that a proportion of these birds corresponded to NGP (Van Den Hoff 2011; ACAP 2016 a,b). Thus, these and earlier findings confirmed that birds from Macquarie Is. travelled outbound distances between 12,000–13,000 km to visit the western coasts of South America (Woehler & Johnstone, 1988; Trebilco *et al.* 2008, Zavalaga *et al.* 2009; Fiblia *et al.* 2010). The recurrent visits of NGP to Chile is also reported by the Fisheries Development Institute (IFOP) in Chile. Between 2014 and 2017, 66 and seven unbanded NGP were incidentally captured in central and southern Chile (39°S–57°S) by the trawl and longline fisheries, respectively (Richard & Adasme 2019). Because NGP are not banded in New Zealand, it is also possible that a proportion of unbanded NGP reported as by-catch in Chile may come from Auckland, Antipodes, Campbell, Forty Fours, and The Sisters colonies.

Although valuable, all sightings and records of NGP in the eastern South Pacific have been opportunistic (Ayala 2007; Zavalaga *et al.* 2009; Fibla *et al.* 2010), and therefore there are limitations to explain the recurrent presence of NGP in Perú and Chile and if these birds are present farther north from Callao. Unlike previous reports, in this study we undertook systematic vessel-based survey observations of NGP occurrence along the Perúvian coast. We were particularly interested in the distribution of birds at sea, records of age classes other than juveniles, the seasonality of their presence in Perúvian waters and the association of NGP sightings to some oceanographic features.

Thirty five at-sea surveys were conducted between 1998 and 2020 (12 in austral summer, seven in autumn, six in winter and 10 in spring) onboard the BIC *Humboldt* and *Jose Olaya*, both research vessels of the Perúvian Marine Research Institute (IMARPE). The surveys were part of the biannual Pelagic Anchovy Surveys and covered a long latitudinal range for almost the entire Perúvian coast from 03°30′S to 18°20′S, except in the autumn 2019 (from 06°57`S to 18°20′S). Offshore distance ranged from 3.5 km to 180 km (100 nm) offshore (Fig. 1), completing 45 parallel transects, each separated by 15 nautical miles (nm). Birds were sighted with the aid of 10 x 50 binoculars within a 300 m strip-transect by two observers on both sides of the bridge. Observations were continuous from civil dawn to dusk (approximate 0530 h – 1830 h local time, GMT – 0500 h) while the ship was underway. Transects were partitioned every 6 minutes or 1 nm, since the vessels cruise speed was 10 knots. During these surveys, we counted NGP in Perúvian waters and categorized the habitat where birds were encountered: coastal waters (0–15 m); continental shelf (15–200 m); continental slope (201–4,500 m); Perú-Chile Trench (>4,500 m) and pelagic abyssal plain (offshore, beyond the Perú-Chile Trench). Sea surface temperature were obtained from a submerged probe recording continuously during the surveys. Likewise, for each sighting we observed birds behaviour as follows: flying, resting on the water, feeding or scavenging, and associated species. Age classes were determined using Shirihai (2008), Howell & Schmitt (2018), and Howell & Zufelt (2019) (Fig. 2). In addition, 20 seabird sightings were also carried out by IMARPE in the artisanal commercial fleet targeting jumbo squid (*Dosidicus gigas*), between Lomas (15°34′S) and Mollendo (17°) up to 210 km offshore.

A total of 11,500 observation hours and a distance of 175,000 km surveyed were completed in the 35 research cruises. A total of 34 NGP were sighted from 09°S to 18°S and between 20 to 199 km offshore (Fig. 1). Most of the NGP sightings (84%) occurred in winter-spring, and the remaining in late autumn. No birds were observed in the austral summer (February – March) despite the majority of cruises were undertaken during this season (n=12). In autumn, birds occurred between 14°20′S and 17°59′S, 35–116 km offshore. In winter, birds were sighted between 10°36′S and 14°27′S, 20–199 km offshore. In spring, birds were recorded between 09°S to 18°05′S, 28 to 183 km offshore (Fig. 1). Most of the sightings (94.2%) in all cruises were located in pelagic waters in the 12°S–18°S range, and the remaining (5.8%) in waters over the continental shelf (Fig 1). The range of Sea Surface Temperatures (SST) at the locations of this study´s sightings ranged between 15°C and 20°C, with 64% of the measurements between 18°C and 20°C.

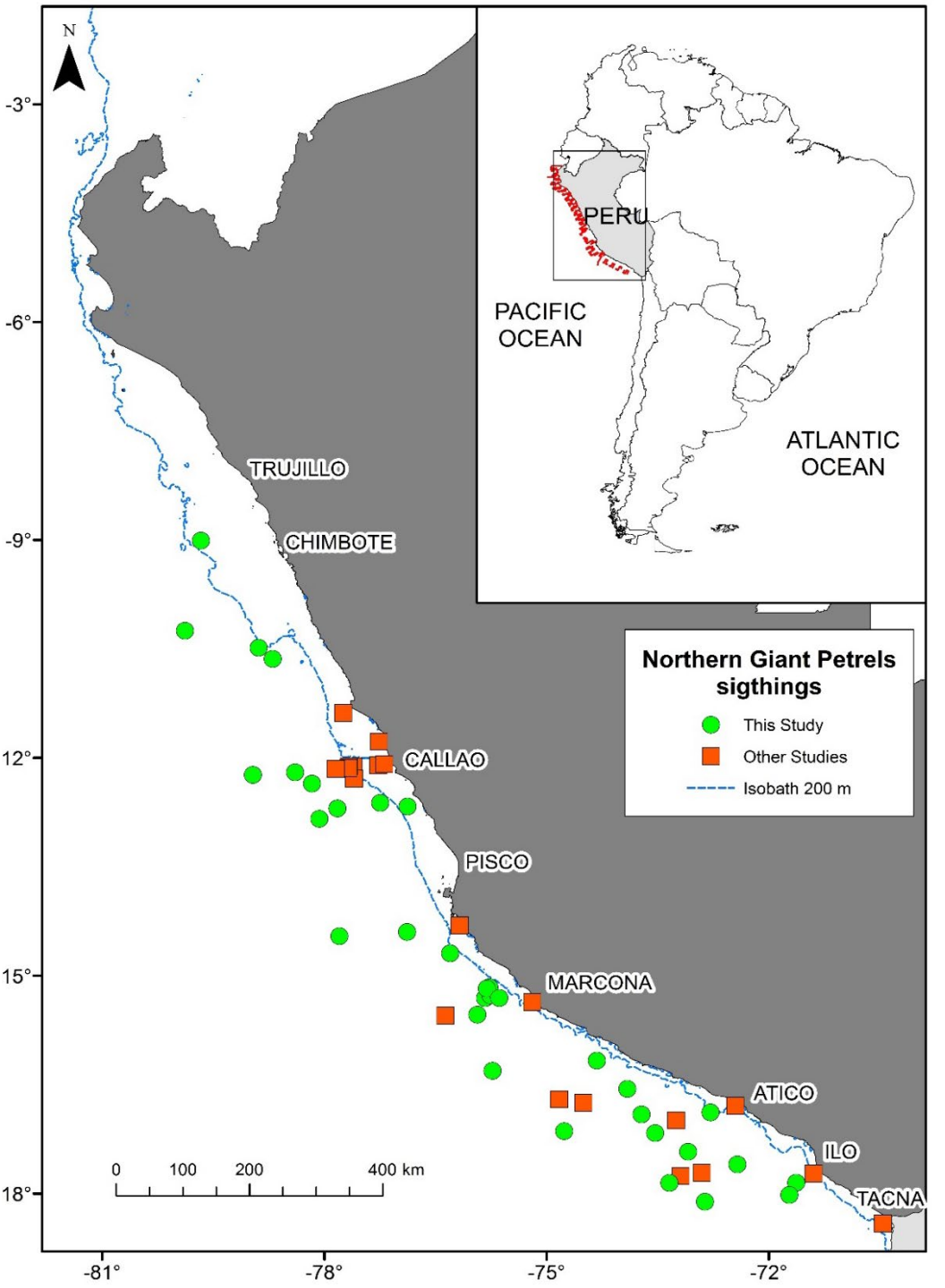

Figure 1. Sighting of juvenile northern giant petrels (*Macronectes halli*) in Perúvian waters recorded in this study from research vessel cruises between 1998 and 2020 are depicted in green circles. Additional historical records from other studies, i.e. Ayala (2007); Zavalaga *et al.* (2009); eBird (2009–2019,) are shown in orange squares. The inset shows the extent of the transects undertaken during vessel.

When historical NGP records and the sightings in the jumbo squid fleet were added to our observations, a total of 63 bird sightings allowed some insight into any preferences of marine habitats. Birds were observed over the continental slope (55.6%, n=35), followed by the continental shelf (15.9%, n=10), Perú trench (11.1%, n=7), coastal areas (9.5%, n=6), and finally the abyssal plain (7.9%, n=5). Regarding the age class composition, 96.8% of the birds (n=61) were juveniles with uniform dark plumage. Only two sub-adult (3.2%) were observed, based on the presence of some white feathers in the head and chest area, both of them were in the vicinity of the guano islands (Fig. 2). Fifty-eight percent (n=36) of the birds were observed flying, 32% (n=17) were on the water surface, 8% (n=5) were feeding and one individual was registered hooked in a longline (2%). Two juvenile NGP were observed foraging in offshore pelagic water off the Chala – Mollendo area (16°S–17°S), one of them was not photographed. However, we recorded another NGP associated with three white chinned petrels (*Procellaria aequinoctialis*) feeding in pelagic areas over the continental slope at 30 km offshore Chala (~16°S) (Fig. 2).

In the more systematic vessel surveys (n=35) in a 21-year time series (1998–2020) along the entire Perúvian coast up to 180 km in offshore and during the four seasons confirmed several patterns of the presence of NGP in Perúvian waters. First, almost all individuals sighted were juveniles (only two sub-adults). Second, NGP were absent north of 09°S.

Figure 2. Juvenile northern giant petrels (*Macronectes halli*) flying (A) and feeding (B) in pelagic oceanic waters off Atico (~16°S) in Southern Perú. Some white chinned petrels (*Procellaria aequinoctialis*) (C) also present. And finally, a sub-adult NGP in isla Mazorca (11°23'S; 77°44'W) (D). Photographs A-C by Javier Quiñones (IMARPE); photograph D by Melchor Llica (AGRORURAL).

Table 1. Sighting of northern giant petrels (*Macronectes halli*) along the southern and central coast of Perú.

Date of sighting	Latitude	Longitude	Number of birds	Distance to the coast (km)	Bathymetry at sighting (m)	Habitat	Source
Autumn season							
07 April 2017	-16.7012	-74.8293	1	117.3	5,994	Abyssal plain	Andrey Moreno
13 June 2019	-17.8476	-71.6274	1	35.6	877	Slope	This study
13 June 2019	-18.0143	-71.7217	1	52.8	1,123	Slope	This study
16 June 2019	-17.1634	-73.5337	1	86.9	4,810	Perú trench	This study
19 June 2019	-16.3059	-75.7276	1	116.7	4,264	Abyssal plain	This study
20 June 2019	-15.3031	-75.6372	1	34.6	1,293	Slope	This study
20 June 2019	-15.5326	-75.933	1	74.8	5,056	Perú trench	This study
21 June 2019	-14.3942	-76.882	1	70.7	3,635	Slope	This study
Winter season							
06 July 2004	-15.3587	-75.1923	3	0.4	15	Coastal	Ayala (2007)
12 July 2004	-17.7214	-71.3943	3	2	135	Cont. Shelf	Ayala (2007)
04 August 2004	-17.7583	-73.19	1	75	1,650	Perú trench	Zavalaga *et al.* (2009)
07 August 2004	-14.3084	-76.1716	1	8	12	Coastal	Ayala (2007)
27 August 2005	-12.1133	-77.6083	2	50	186	Shelf	Zavalaga *et al.* (2009)
02 August 2007	-12.2833	-77.6	3	55	397	Slope	Zavalaga *et al.* (2009)
16 September 2007	-12.0825	-77.1916	1	5.8	37	Cont. Shelf	Zavalaga *et al.* (2009)
25 August 2008	-14.4512	-77.7964	1	170.8	4,316	Abyssal plain	This study
28 August 2008	-12.6654	-76.8764	1	20.4	130	Cont. Shelf	This study
28 August 2008	-12.6159	-77.2448	1	56	370	Slope	This study
29 August 2008	-12.8353	-78.0682	1	134.2	3,509	Slope	This study
29 August 2008	-12.6915	-77.8232	1	103.7	2,051	Slope	This study
26 November 2008	-9.00533	-79.6675	1	111.4	120	Cont. Shelf	This study
29 November 2008	-10.4817	-78.8875	2	90.2	562	Slope	This study
08 August 2009	-12.1019	-77.2723	1	13	38	Cont. Shelf	D. Lane (eBird)
25 July 2010	-12.1494	-77.8436	1	75	1,650	Slope	N.D. Perrins (eBird)
13 September 2013	-10.6343	-78.6972	1	80.4	720	Slope	This study
17 September 2013	-12.3501	-78.1672	1	123.3	2,556	Slope	This study
18 September 2013	-12.1948	-78.3946	1	146.3	3,066	Slope	This study
18 September 2013	-12.2297	-78.9658	1	198.7	5,556	Perú trench	This study
18 July 2015	-11.7742	-77.2644	1	9	10	Coastal	C. Calvo (eBird)

Table 1. *continued*

Date of sighting	Latitude	Longitude	Number of birds	Distance to the coast (km)	Bathymetry at sighting (m)	Habitat	Source
Spring Season							
29 September 2002	-12.1133	-77.6683	2	50	475	Slope	Zavalaga *et al.* (2009)
05 October 2002	-16.9069	-73.7192	1	76.7	4,050	Slope	This study
05 October 2002	-16.5538	-73.9102	1	43.3	2,689	Slope	This study
12 October 2002	-15.3051	-75.8299	1	53.9	2,686	Slope	This study
12 October 2002	-15.2676	-75.7548	1	45.6	1,750	Slope	This study
25 October 2002	-10.2459	-79.8828	1	182.5	4,306	Slope	This study
December 2004	-17.7116	-72.9033	1	115	4,640	Perú trench	Zavalaga *et al.* (2009)
17 November 2007	-12.1366	-77.6766	1	58	742	Slope	Zavalaga *et al.* (2009)
25 October 2015	-16.791	-72.4503	1	7.4	543	Shelf	Andrey Moreno
17 November 2015	-16.9904	-73.2501	2	59.9	3,150	Shelf	Andrey Moreno
02 November 2016	-16.749	-74.5041	1	98.6	6,537	Abyssal plain	Andrey Moreno
27 September 2017	-11.3812	-77.7456	1	13.7	0	On Island	Melchor Llica
27 October 2017	-15.5493	-76.3649	1	130	3,710	Perú trench	R. Tizard (eBird)
28 October 2017	-14.6864	-76.3	1	41.7	1,364	Slope	This study
29 October 2017	-15.1531	-75.7714	1	37.2	1,109	Slope	This study
29 October 2017	-15.1729	-75.806	1	41.2	1,428	Slope	This study
05 November 2019	-16.1638	-74.3216	1	33	1,746	Slope	This study
05 November 2019	-17.1358	-74.7635	1	148.9	4,717	Abyssal plain	This study
08 November 2019	-17.8485	-73.3415	1	27.6	603	Slope	This study
08 November 2019	-17.421	-73.0896	1	95.4	4,086	Slope	This study
08 November 2019	-16.8767	-72.7868	1	137	5,535	Perú trench	This study
08 November 2019	-18.4105	-70.4565	1	10	92	Cont. Shelf	G. Riley (eBird)
09 November 2019	-18.1085	-72.8602	1	72.8	1,999	Slope	This study
09 November 2019	-17.5951	-72.4234	1	149.8	6,260	Perú trench	This study

Third, NGP were not recorded in Perúvian waters during the austral summer. Fourth, birds fed both at inshore and offshore waters. And fifth, they are found at different realms of marine habitats from coastal highly productive cold waters to warm, deep oceanic waters. In addition, during the systematic surveys we did not identify NGP associated with fishing vessels; however, during the sightings in the artisanal fishery targeting giant squid, we did identify four juvenile NGP approaching to the vessel when offal was discarded.

The occurrence of juvenile NGP in central and southern Perú constitutes one of the farthest recorded movements from their main nesting areas, ~7,000 km from South Georgia; ~11,000 km from the Forty Fours in the Chatham Islands, ~13,000 km from Macquaire island, finally ~19,500 and 21,000 km from Kerguelen and Crozet islands respectively. It is known that NGP disperse mainly between 30°S–64°S (Voisin 1988). Juveniles and sub-adults tend to disperse great distances from their breeding colonies, often with an eastward movement likely due to prevailing westerly winds (Weimerskirch *et al.* 1985; Woehler & Johnstone 1988; Voisin 1990). However, according to tracking data from their breeding colonies, they disperse to different geographical areas during their non-breeding period. For instance, breeding birds tracked from South Georgia disperse towards the Argentinian shelf-break areas up to 30°S–35°S (BirdLife International 2004; Gonzales-Solis *et al.* 2007). Satellite tracked NGP fledglings (n=5) from Macquaire disperse eastward reaching the east coast of South America up to 45°S (Trebilco *et al.* 2008). Another five NGP fledglings were tracked in Crozet and Kerguelen in the Southern Indian Ocean, dispersed eastward from their colonies, and performed at least one, and for some individuals several circumpolar trips during the first year after fledging (Thiers *et al.* 2014). There is no information of fledging dispersals from New Zealand off shore islands such as The Forty Fours, Auckland, Campell, Antipodes, and The Sisters islands. However, other tracked species in The Forty Fours, like the northern royal albatross (*Diomedea epomophora sanfordi*) and the northern Buller's albatross (*Thalassarche bulleri platei*), reached the South American Pacific coasts (Deppe 2012).

The northern limit of the NGP juvenile distribution may be the result of inter-specific competition with more numerous waved albatross (*Phoebastria irrorata*) and Salvin´s mollymawks (*Thalassarche salvini*), both species regularly use Perúvian waters as wintering grounds. Adult and immatures *P. irrorata* and *T. salvini* frequent the northern offshore waters off Perú, just close to the northernmost limit distribution of the NGP (Anderson *et al.* 2003; Awkerman *et al.* 2006; Quiñones *et al. in prep.*). *Thalassarche salvini* are even more robust and larger (mean 4.1 kg; Brooke 2004) than NGP juveniles (3.6 kg; Carlos & Voisin 2008) and may outcompete them during feeding opportunities. The lack of experience of juvenile NGP in agonistic encounters with more abundant and larger, adult albatrosses may exclude them from northern waters. The wide extent of NGP distribution in southern Perúvian waters (from coastal too offshore), with a contrasting bathymetry (from 15 to 6,260 m deep) and SST ranging from 15–20ºC during the study period, would not limit their presence in the north.

The influence of winds on albatrosses and petrel movements is well documented (Weimerskirch *et al.* 2000; Suryan *et al.* 2008), and the start of the long westerly migration was likely caused by the seasonally predictable prevailing westerly winds that dominate the Southern Ocean between 30°S and 60°S. (Weimerskirch *et al.* 2000). The great majority of our sightings (84%) were in the winter-spring seasons, and the remaining 16% in late autumn (13–20 June); this coincides with the formation of the Subtropical Jet Stream (SJT) during winter and spring in the South Pacific (Nakamura & Shimpo 2004). On the other hand, in summer-autumn the SJT is absent, coincidentally during summer cruises (February – April) no NGP were reported. Consequently, we hypothesize that most of the NGP in central and southern Perú come from the New Zealand offshore islands and Macquaire island in the far west South Pacific, and Crozet and Kerguelen in the Southern Indian Ocean. Nineteen (19) NGP fledglings band recoveries from Macquaire (1967–1986) registered in Chile by Woehler & Johnstone (1988) and subsequently by Van Den Hoff (2011) supports our hypothesis. However, we do not rule out that some birds could travel from South Georgia, since there are some band recoveries (n=6) from this UK island registered in the 1960s and 1970s on the Pacific coast of South America (Hunter 1984). We could conclude that the presence of juvenile NGP in Perú come from both areas; however, due to the strong seasonal presence of the SJT the possibilities of an origin from the west (New Zealand offshore islands, Macquaire and South Indian Ocean islands) are greater than those from the South Atlantic (South Georgia), despite that breeding pairs of NGP in the latter are almost one order of magnitude greater.

The presence of NGP in a wide bathymetric range reflects that the foraging behaviour of juveniles is versatile and adaptive during their wintering dispersion. Giant petrels often showed a flexible foraging strategy, switching from coastal to pelagic habits, probably governed by spatial-temporal changes in carrion availability (Gonzales-Solis *et al.* 2007), related mainly to penguin and seal

carcasses availability during the austral winter in their colonies (Johnstone 1979; Bruyn & Cooper 2005). The majority of the observations were made at distance, and therefore, it was difficult to discriminate males from females and determine any sex-specific migration pattern, particularly because there is clear spatial separation between sexes in their forage zones (Hunter & Brooke, 1992; Gonzales-Solis 2004).

In southern Perú, we noted several small artisanal boats targeting giant squid using hand-line, and blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*) using artisanal long-lines. Both artisanal fisheries are very common in oceanic waters in southern Perú (Adams *et al.* 2016; Csirke *et al.* 2018). In both artisanal fisheries there was interaction with NGP, which gradually approach the boat when offal discards of giant squid and sharks occur (Andrey Moreno & Christian Jimenez, *pers. comm*.). Moreover, NGP was also registered close to inshore guano islands and headlands, probably looking for fledglings of seabird species or carrion close to the colonies. Humboldt penguin (*Spheniscus humboldti*) in Perú fledges from July to December (Zavalaga & Paredes 1997) and Perúvian diving-petrels (*Pelecanoides garnotii*) chicks leave their nests colonies almost year-round (Jahncke & Goya 1998) and are present <30 km offshore (Figueroa *et al.* 2011). We could infer that NGP in the coastal areas were males, since switching from coastal to pelagic habits, probably governed by spatio-temporal changes in carrion availability, in contrast females remains in pelagic waters (Gonzalez-Solis *et al*. 2007). The provided information demonstrates the importance of the Northern Humboldt Current for juveniles NGP during their wintering season, and give new insights to take measures for the proper management of this highly migratory species.

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