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Movements and Distribution of Short-finned Pilot Whales Off Ecuador as Revealed by Sighting and Satellite Tagging Data

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Research Article

Keywords: pilot whales, Ecuador, Eastern tropical Pacific, satellite tracking, population structure, habitat use

Posted Date: April 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9285564/v1

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Abstract

Short-finned pilot whales were recorded and satellite-tagged during pelagic monitoring along the central coast of Ecuador (1º15' S – 2º30' S) to improve understanding of the ecology and demography of this pelagic cetacean. Survey effort comprised 18 trips (seven in 2024 and 11 in 2025), totaling 2,587.2 km and 90.1 hours, with greater coverage during the warmer season (February-April). Thirteen groups were documented, totaling an estimated 218–250 individuals in water ranging from 240 to 1,771 m in depth. Relative abundance along the continental slope was 9.04 whales per 100 km of survey effort. Mean group size was 18.1 individuals (SD = 9.86; range = 2–35). A total of 139 distinct individuals were photo-identified, including eight intra-annual resightings. Satellite tags were deployed on twelve individuals. Based on spatial distribution, tagged individuals were classified into two clusters: coastal and oceanic. The 95% utilization distribution (UD) of the coastal cluster encompassed 28,353 km² and was primarily associated with the continental slope. In contrast, the oceanic cluster exhibited a substantially larger 95% UD (457,000 km²), extending across deep-slope and offshore waters. This bathymetrically structured spatial segregation suggests the presence of two ecotypes with distinct habitat-use strategies. Offshore movements further suggest that the Carnegie Ridge may function as a migratory pathway between mainland Ecuador and the Galapagos Islands. We recommend expanding surveys to the colder and dry season to better resolve population structure and assess relationships between pilot whale distribution and environmental variability.

INTRODUCTION

The short-finned pilot whale (*Globicephala macrorhynchus*) inhabits tropical and temperate waters worldwide, mainly along the edge of the continental shelf and in areas with high topographic relief, between 50° N and 40° S (Bernard and Reilly 1994; Jefferson et al. 2008; Olson 2018). Its body size, coloration, bulbous forehead with a short beak, forward-positioned dorsal fin, and pronounced sexual dimorphism make it relatively easy to identify at sea compared to other mid-sized cetaceans. However, distinguishing it from its cold-water counterpart, the long-finned pilot whale (*G. melas*), can be challenging in regions where their distributions overlap (Bernard and Reilly 1994; Jefferson et al. 2008; Minton et al. 2018; Olson 2018). Beyond differences in distribution, the two species can be differentiated by cranial morphology (Van Bree 1971; Bernard and Reilly 1994) and genetic traits (Oremus et al. 2009). Given their preference for different water temperatures and the strong regional genetic structuring observed in both species (Oremus et al. 2009; Van Cise et al. 2016), it is unlikely that their habitat ranges overlap in tropical waters.

Both pilot whale species exhibit similar social structures, forming stable pods of a few dozen individuals in matrilineal associations, with little or no male dispersal from their natal groups and low maternally inherited mtDNA diversity (Alves et al. 2013; Amos et al. 1993; de Stephanis et al. 2008; Oremus et al. 2009; Mahaffy et al. 2015; Van Cise et al. 2016; Servidio et al. 2019). This social organization with nested hierarchical levels is also observed in other matrifocal species such as killer whales (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*) where social groups can remain stable over time because

kinship and social learning rather than environmental factors, shape their social structure and even geographic patterns (Hoelzel et al. 2002; Whitehead et al. 2002; Cantor et al. 2015).

While significant advances have been made in understanding the social structure of pilot whales through photo-identification and genetic studies, important aspects of their local and regional movements remain poorly understood. This information is essential for understanding patterns of habitat use and vulnerability to human activities, which must be managed to reduce their impact (Evans et al. 2008). Because pilot whales inhabit oceanic waters, monitoring individuals at sea presents substantial logistical challenges. Consequently, most socio-ecological data have been gathered from remote islands or archipelagos, where access to deep water is easier than in continental regions. Available data reveal different patterns of site fidelity and residency (e.g. Alves et al. 2013; Boran and Heimlich 2019; Esteban et al. 2022; Hill et al. 2018; Mahaffy et al. 2015; Servidio et al. 2019; Van Cise et al. 2016). The frequency with which pods or clans visit sampling sites may relate to the location and size of their home ranges. The degree of overlap in clan distribution areas is crucial for identifying nested social groups or separate population units that may partially share home ranges (Mahaffy et al. 2015; Van Cise et al. 2017). Satellite tagging has been helpful in revealing the large-scale movements and habitat use of various whale species (Johnson et al. 2022), and it is increasingly being used to track pilot whales in different parts of the world. In the eastern Atlantic, western Mediterranean, and western Pacific, pilot whales have been fitted with satellite tags to determine preferred regions, home ranges, and movement pathways, thereby aiding conservation efforts (Hill et al. 2018; Abecassis et al. 2015; Weyn et al. 2025; Verborgh 2015; Verborgh et al. 2016; Thorne et al. 2017). In Florida, tagging has been used to examine survival, diving patterns, and post-release movements of stranded pilot whales (Wells et al. 2013; Tyson Moore et al. 2020). Digital Acoustic Recording Tags (DTAGs) have also been deployed on pilot whales to study short-term diving behavior and foraging strategies (e.g. Baird et al. 2002; Shearer et al. 2022).

In the eastern Pacific, short-finned pilot whales are widely distributed but tend to concentrate in equatorial waters, a pattern likely linked to the oceanographic conditions that characterize this zone (Au and Perryman 1985; Ballance et al. 2006). Their abundance was estimated at around 589,315 individuals in 2000 (CV% = 25.5) (Gerrodette and Forcada 2002), although this estimate does not include the entire eastern Pacific (Minton et al. 2018). While no forms or subspecies of the short-finned pilot whale have been reported in the eastern Pacific (Van Cise et al. 2016), morphotypes with geographical and social segregation have been reported in the western Pacific in waters around Japan (Kasuya et al. 1988). Recent genetic studies indicate that up to three distinct evolutionary units occur in the western Pacific and may constitute different subspecies, although further research is required for their proper characterization (Oremus et al. 2009; Van Cise et al. 2016).

On the west coast of South America, the short-finned pilot whale is continuously distributed from Colombia (7°N) to northern Chile (25°S) (O'Hern et al. 2017; Palacios et al. 2012; Santillán 2021; Guerra et al. 1987). In continental Ecuador, the species is primary known from strandings (Castro and Van Waerebeek 2022; Chiluiza et al. 1998; Félix et al. 2011). Similarly, in the Galápagos Islands, records of this species are largely based on strandings and remains, although it is considered relatively common in

the archipelago (Palacios et al. 2004; Denkinger et al. 2013; Palacios and Salazar 2002), especially in the northern part and off Isabella Island where large pods with several juveniles are commonly seen (Hector M. Guzman, unpublished data). Despite these records, systematic documentation of cetacean distribution in Ecuadorian waters remains limited, although recent work has expanded knowledge of offshore species in the region. Nonetheless, the short-finned pilot whale is known to be widespread in oceanic waters between mainland Ecuador and the Galápagos Islands, as shown by oceanographic cruises conducted in the region (e.g. Clarke et al. 2002; O'Hern et al. 2017). Based on data from the Eastern Tropical Pacific (ETP) Cetacean and Ecosystem Assessment Cruises conducted by the USA Southwest Fisheries Science Center (SWFSC) between 1986 and 2003 (Hamilton et al. 2009), Gerrodette and Palacios (1996) estimated the abundance of pilot whales within Ecuador's continental jurisdictional waters at 3,013 individuals (95% CI: 991–9,160). Given the wide confidence interval, this estimate should be interpreted with caution.

Here we present data on the movements of short-finned pilot whales tagged off the central coast of Ecuador, as part of a long-term study on the ecology and demography of pelagic cetaceans. This information provides a baseline for future research on abundance, population structure, habitat use, threat identification, and ultimately guides management and conservation strategies for this little-known species in the region.

MATERIAL AND METHODS

The study area

The study area is located on the central coast of Ecuador (Fig. 1). Ecuador's continental coast is characterized by a narrow shelf, 15–40 km wide. Beyond the shelf, the seabed drops steeply to depths of up to 4,000 m, where the subduction zone forms as the Nazca Plate descends beneath the South American Plate (Pedoja et al. 2006). A tropical climate with two well-defined seasons characterizes the coast of Ecuador: a warmer rainy season from December to May and a cooler drier season from June to November. During the warmer months, sea surface temperature (SST) can reach up to 29.5°C, while in the cooler months, it can drop to 20°C (Chinacalle-Martínez et al. 2021).

The area is highly dynamic oceanographically, influenced by the Equatorial Front, which results from the confluence of the Humboldt or Peruvian Current from the south, characterized by cold, saline, highly productive waters, and tropical waters from the north, which are warmer, less saline, and less productive (Wyrtki 1966). A complex system of trans-Pacific zonal flows in the region includes the westward South Equatorial Current, with its northern and southern branches straddling the equator, and the eastward-flowing Equatorial Undercurrent (Fiedler and Talley 2006; Kessler 2006). The Galápagos Islands, located ~ 1,000 km west of mainland Ecuador (90°30' W, 0°30' S), are also embedded in this system. Between mainland Ecuador and the Galápagos lies the Carnegie Ridge, a prominent geological feature that acts as a natural seaway for marine species and was recognized by the IUCN as a 460,183 km² Important Marine Mammal Area (IMMA) (IUCN-MMPATF, 2023). The area is also affected by the El Niño–Southern

Oscillation (ENSO). During the warm phase (“El Niño”), SST can rise by up to 4°C above average, while during the cold phase (“La Niña”), SST can fall by up to 2°C below average (Fiedler 2002). These phases are associated with changes in wind speed, rainfall, thermocline depth, circulation patterns, and biological productivity, with notable impacts on the distribution of marine species, including seabirds, small pelagic fish, and marine mammals (Barber and Chávez 1983; Ramírez and Urquizo 1985; Fiedler 2002).

Surveys

Between February 2024 and April 2025, we conducted surveys along 140 km of the continental slope in waters at depths of 500-1,200 m, from Isla de la Plata to Salinas city, central Ecuador (1º15' S – 2º30' S) (Fig. 1). The effort was concentrated during the warmer season (February-April), when oceanographic conditions are more stable, usually two or lower on the Beaufort wind scale. A 12 m fiberglass boat with an upper deck 2 m above the waterline and powered by twin 150-HP outboard engines was used as a research platform. Surveys were conducted at a speed 20–25 km/h. Puerto López in the north and Salinas in the south (100 km apart) were used as the launching sites. From Puerto López, the surveys moved 40 km northwest to La Plata Island to reach the desired depth, then headed south. From Salinas, some surveys extended southwest into the Gulf of Guayaquil and returned to Salinas, and others headed north to La Plata Island and then Puerto López (Fig. 1).

The crew, consisting of three to five researchers and three sailors, scanned the horizon on both sides of the boat *ad libitum*, searching for pilot whales and other cetaceans. Upon detecting the animals, the boat carefully approached the area to collect data on group size, age/sex composition, and behavior. Pilot whales were considered adults, subadults, or calves based on the size estimated by eye, once agreed upon by researchers in the field. Calves were assigned when an obviously small animal was seen alongside a large one, presumably its mother. Immature animals were identified by their intermediate size between adults and calves, and adult males because of their larger size and wider dorsal fin. The sex of the tagged animals was determined in eight cases based on size (males) and whether calves accompanied the animals (females). Photographs of dorsal fins for individual identification were taken with digital cameras equipped with 100–400 zoom lenses. Good photographs were used to create a catalogue. Individuals recorded off mainland Ecuador were also compared with a group of 20 pilot whales photographed in the Galapagos in March 2023.

The positions of sightings and the survey track were recorded with a Garmin 60 handheld GPS. The track log was used to calculate effort after the sighting periods (off-effort) were removed. The encounter rate (number of whales/km of survey) was used as an indicator of relative whale abundance in the study area.

Satellite tagging

Transmitters on pilot whales were deployed from the boat's bow at short distances (1–3 m) using a standard Dan-Inject CO_2 veterinary compressed air launcher (www.dan-inject.com). The transmitter was attached to an arrow fitted with a specialized tip designed to carry it; the arrow was also buoyant and could be recovered. The air pressure ranged from 5 to 15 bar (15.3 kg cm-1), adjusted based on the distance to the animal. We used the LIMPET SPOT-365 percutaneous model (Wildlife Computers, Seattle, U.S.A), capable of transmitting for up to 343 days depending on its programming. The maximum number of daily transmissions was set at 250. For transmissions reaching the satellite when the animal surfaced, the manufacturer set the fast and slow repetition rates (seconds) to 41.5–47.5 and 86.5–92.5, respectively. We determined the positions from the Argos satellite classes with locations 3, 2, 1, 0, A, and B, with errors in varying accuracy estimated between 150 m and 5 km, to track the general movements of the whales (see Zerbini et al. 2006; Guzman et al. 2013; Guzman and Felix 2017).

To reduce infections, the tips, anchors, and transmitters were treated with oxytetracycline-polylyxin topical ointment (Terramycin™) and chemically sterilized before deployment. The Institutional Animal Care and Use Committee (IACUC) at the Smithsonian Tropical Research Institute approved all procedures described above.

Spatial data processing

Raw location data were imported and processed in R (R Core Team 2024), and all records were inspected for structural consistency, completeness, and potential duplication. To reduce spatial bias associated with Argos telemetry, especially repeated position estimates with identical coordinates, exact duplicate locations (same individual ID, latitude, longitude, and timestamp) were removed as part of standard quality control procedures for Argos telemetry data (Douglas et al. 2012).

All locations were converted into spatial features using the sf package in R. Data were initially stored in a geographic coordinate reference system (WGS84) and subsequently reprojected to UTM Zone 17S, an appropriate projected coordinate system for distance- and area-based analyses in the study region.

Space-use analysis and bathymetric association

Population-level utilization distributions were estimated using fixed kernel density estimation implemented in the *kernelUD* function of the *adehabitatHR* package (Calenge 2006). All filtered locations were combined into a single population identifier to estimate overall space-use patterns. The reference bandwidth selector (href) was used to smooth the utilization distribution; a method widely applied in marine mammal studies when spatial coverage is extensive but uneven (Worton 1989). Utilization distributions were calculated on a grid with a spatial resolution of 500 m, balancing spatial precision, computational stability, and ecological relevance.

From the resulting utilization distributions, the 95% and 50% volume contours were extracted using *getverticeshr*. The 95% contour was interpreted as the population home range, encompassing most of

the space used, while the 50% contour represented the core-use area corresponding to regions of highest use intensity (Esteban et al. 2022).

Bathymetric data were obtained from a polygon-based layer covering the study area from the IHO-UNESCO Global Bathymetric Chart of the Oceans GEBCO (https://download.gebco.net/) with a grid 15 arc-second resolution. Prior to analysis, the dataset was cleaned to remove non-relevant classes and reclassified into five ecologically meaningful depth categories (0–50 m, 50–200 m, 200-1,000 m, 1,000–3,000 m, and > 3,000 m). Depth classes were treated as ordered categorical variables reflecting increasing depth, and the bathymetric layer was reprojected to the same UTM coordinate system as the kernel polygons to ensure spatial congruence and accurate area calculations.

To quantify the relationship between pilot whale space use and bathymetry, the 95% home range and 50% core-use polygons were spatially intersected with the bathymetric layer. For each depth class, the area of overlap (km²) was calculated and expressed as a proportion of the total area of the corresponding kernel contour (Gredzens et al. 2014). This polygon-based approach provides a spatially explicit assessment of habitat representation within utilization distributions and avoids biases associated with point-based depth extraction, which can be sensitive to sampling density and spatial autocorrelation (Aarts et al. 2008). Finally, spatial patterns of pilot whale space use were visualized by overlaying kernel contours, location points, bathymetry, and geopolitical boundaries using R packages *ggplot2* and *ggspatial*.

RESULTS

Effort

During the study period, a total of 18 trips were conducted, seven in 2024 and 11 in 2025, covering 2,587.2 km and 90.1 hours of survey (Table 1). Ten trips followed the route between Puerto López and Salinas and vice versa. Four trips started and ended in Puerto López, and surveys focused on the northern sector of the study area. The remaining four trips started and ended in Salinas, covering the western and southwestern areas of the outer Gulf of Guayaquil (Fig. 1). Trip distances ranged from 100 to 197 km, with durations of 3.0 to 7.6 hours (Table 1). Other small and large cetacean species were also recorded during surveys; however, these data are not included in this work.

Table 1
Research effort and other information associated with surveys including ports of arrival and departure, distance, number of groups and animals recorded. Periods: February 26 - March 17, 2024, and February 15 - April 24, 2025.

Date	Departing Port	Arriving Port	Distance (km)	Time (h)	Groups	Whales	Whales/km
26/2/2024	P. López	Salinas	160.8	4.71	1	12	0.07
27/2/2024	Salinas	Salinas	107.5	6.35			
28/2/2024	Salinas	P. López	116	4.50			
14/3/2024	P. López	Salinas	164.8	5.48	1	20	0.12
15/3/2024	Salinas	Salinas	137.5	4.36			
16/3/2024	Salinas	P. López	176.3	5.93	1	2	0.01
17/3/2024	P. López	P. López	197.4	7.64			
15/2/2025	P. López	Salinas	160	4.83	2	22–30	0.04
16/2/2025	Salinas	Salinas	126.4	5.43	2	40–50	0.04
17/2/2025	Salinas	P. López	157.9	4.03			
22/3/2025	P. López	P. López	124.7	5.03			
23/3/2025	P. López	Salinas	156.2	5.14	1	30	0.19
24/3/2025	Salinas	Salinas	109	3.89	1	15–20	0.06
25/3/2025	Salinas	P. López	128.1	4.18	1	12	0.09
21/4/2025	P. López	Salinas	172.1	5.50			
22/4/2025	Salinas	P. López	134.1	4.08	2	32–37	0.06
23/4/2025	P. López	P. López	157.5	6.10			
24/4/2025	P. López	P. López	100.9	2.93	1	33–37	0.03
			2,587.2	90.09	13	218–250	0.09

Sighting data

Distribution

Pilot whales were recorded throughout the western part of the study area beyond the continental shelf (> 200 m). Off Salinas, groups were closer to shore than off Puerto López because the continental shelf

in this region is narrower (Fig. 1). The average depth at which pilot whale groups were initially recorded was 904 m (SD = 435.2, range 240-1,771 m) (Fig. 1).

Group size and relative abundance

Thirteen groups were recorded during the study, totaling 218–250 animals. The average group size was 18.1 (SD = 9.86, range 2–35) (Table 1). The relative abundance of pilot whales was estimated at 9.04 per 100 km of survey distance, though this value includes the entire surveyed distance (deep waters, harbor entrances, and exits). Therefore, the relative abundance in waters beyond the shelf is even higher.

On eight occasions (61.5% of the groups), pilot whales were accompanied by offshore bottlenose dolphins (*Tursiops truncatus*), although the purpose of such associations was unclear as no direct interaction between individuals of both species was evident.

Photo-identification

Across the 13 recorded groups, 139 distinct individuals were identified with only eight resightings. The resighted individuals were recorded during the last survey (24 April 2025), when one of the largest groups was observed. All resighted individuals had previously been recorded on 15 February 2025, when two groups were encountered in proximity (Table 1). Of the resighted animals, seven belonged to the first group of approximately 25 individuals, and one to the second group, which comprised only two animals, suggesting that all resighted individuals were part of the same social unit. The interval between sightings was 68 days, indicating some degree of fidelity to the site. No matches were found between mainland pilot whales and the 20 pilot whales from Galapagos. Given the low resighting rate across the 13 groups recorded, it is estimated that around 10 distinct social units appear to frequent the study area, but further research is needed to improve our understanding of population structure.

Tagging data

Twelve satellite tags were deployed during the study: two in 2024 and ten in 2025 (Table 2). Five were deployed on females, two on large males, and in the remaining cases, sex could not be determined. Four tags transmitted only a few times on the day of deployment due to equipment failure; therefore, only the remaining eight were included in the analysis. These eight tags transmitted for 26–62 days (mean = 39.3 days, SD = 11.9). The maximum distance traveled by a tagged whale was 2,862.3 km. The average travel speed of whales was 60.2 km d-1 (SD = 15.2, range = 43.9–89.8 km d-1).

Based on the spatial distribution of locations and their relationship to the continental shelf and slope, individuals were visually classified into two spatial clusters associated with contrasting bathymetric domains: four individuals were assigned to a coastal cluster and four to an oceanic cluster. For the remaining individuals, transmission duration was too short to allow cluster assignment (Table 2). There was no significant difference in transmission duration between the coastal and oceanic clusters (37.3 d, SD = 5.4 vs. 41.5 d, SD = 17, respectively; Mann–Whitney U test, U = 8, N1 = 4, N2 = 4, $P > 0.05$). The average speed of oceanic whales (66.6 km d-1, SD = 8.4, range = 58.8–75.3) was 11% higher than that of coastal whales (59.4 km d-1, SD = 20.8, range = 43.3–89.8), although the difference was not statistically

significant (Mann-Whitney U test, U = 4, N1 = 4, N2 = 4, P > 0.05). The lower variability in average speed observed among oceanic individuals compared to coastal individuals is largely attributable to one coastal whale (ID 228105), which traveled at nearly twice the speed of the other three coastal whales and exhibited a markedly different movement pattern. Excluding this individual, the mean speed of oceanic whales was 25% higher than that of coastal whales. However, the small number of tagged individuals precludes more robust statistical comparisons.

Regarding sex, two females and two males were classified as coastal, and one female as oceanic (Table 2). The three identified females exhibited relatively similar average speeds, with the oceanic individual showing the highest value (range = 49.7–58.8 km d-1). In contrast, the two coastal males displayed markedly different speeds (43.3 vs. 89.3 km d-1), which may reflect different reproductive strategies.

Table 2
Information on the tagged pilot whales off Ecuador between 2024 and 2025. Identification codes (PTT, Platform Transmitter Terminal) enable the association of each individual with a specific spatial cluster.

PTT ID	Spatial cluster	Sex	Start date	Final date	Longevity (d)	Travel distance (km)	Speed (km d-1)
228106	Coastal	F	14/3/2024	11/4/2024	29	1,439.9	49.7
227478	Coastal	F	14/3/2024	1/5/2024	49	2,681.9	54.7
228099	Oceanic		23/3/2025	21/4/2025	30	2,168.5	72.3
228100	Oceanic		23/3/2025	29/4/2025	38	2,862.3	75.3
228103	Oceanic	F	23/3/2025	4/5/2025	43	2,527.8	58.8
227474	Coastal	M	24/3/2025	24/5/2025	62	2,681.9	43.3
227475		F	24/3/2025	24/3/2025			
227477			25/3/2025	25/3/2025			
228101		F	22/4/2025	22/4/2025			
227479	Oceanic		25/3/2025	1/5/2025	38	2,251.7	59.3
228105	Coastal	M	22/4/2025	17/5/2025	26	2,334.70	89.8
228109			24/4/2025	24/4/2025			

Home range

Kernel utilization distributions revealed pronounced differences in the bathymetric composition of home ranges between the two clusters. For individuals in the coastal cluster, the 95% utilization distribution (UD) was primarily associated with the continental slope, covering 28,353 km^2 (Fig. 2; Table 3). The 1,000–3,000 m depth class represented 50.3% of the total home-range area, while shallower slope

waters (50–200 m and 200–1,000 m) together accounted for 34.0% (Table 3; Fig. 3). Abyssal depths deeper than 3,000 m constituted a comparatively small fraction of the home range (15.7%). Core-use areas (50% UD) of coastal whales were even more concentrated in slope habitats. The 1,000–3,000 m band comprised 46.5% of core-use space, followed by the 200-1,000 m zone (27.7%) and the 50–200 m band (25.0%). Use of abyssal depths was negligible in core-use areas (< 1%), indicating that the most intensively used habitats of coastal individuals were restricted to the shelf-edge and slope. Coastal individuals made back-and-forth movements concentrated over 200 km along the continental slope. No transmissions occurred outside Ecuadorian jurisdictional waters, indicating short latitudinal movements despite some whales transmitted for more than 40 days (see Table 3).

Oceanic individuals exhibited a markedly different pattern, with their 95% UD concentrated in offshore waters and extending over a broader area than that of coastal individuals, covering 457,000 km^2, which is 16-fold the UD of coastal individuals (Fig. 2; Table 3). The 1,000–3,000 m depth class represented 64.4% of the home-range area, and abyssal waters deeper than 3,000 m contributed an additional 30.3% (Table 3; Fig. 3). Shallow slope habitats < 1,000 m collectively accounted for less than 6% of the home range. This pattern was even more pronounced in core-use areas, where the 1,000–3,000 m band comprised 68.6% of core-use space and abyssal depths contributed 24.6%. Shallow and upper-slope waters together accounted for only 6.8% of the core-use area, indicating that oceanic individuals concentrated their most intensive spatial use in deep-slope and offshore environments. Oceanic individuals' movements extended approximately 600 km northwestward and 800 km westward, reaching the boundary of the Galápagos Marine Reserve (40 nautical miles around the archipelago). Some individuals also moved south of Colombia before turning westward. These longitudinal movements indicate a level of connection between mainland Ecuador, southern Colombia, and the Galápagos Islands.

Table 3
Bathymetric composition of the 95% (home range) and 50% (core-use) kernel utilization distributions for coastal and oceanic clusters of short-finned pilot whales. Values represent the area (km²) and the percentage of each utilization distribution that overlaps predefined depth classes.

Cluster	Depth class	Area (km²) HR95	% HR95	Area (km²) HR50	% HR50
Coastal	50–200	5,126	18.1	1,281	25
Coastal	200–1000	4,501	15.9	1,415	27.7
Coastal	1000–3000	14,262	50.3	2,377	46.5
Coastal	< 3000	4,464	15.7	40.4	0.8
Oceanic	50–200	13,386	2.93	4,911	3.68
Oceanic	200–1000	10,842	2.37	4,194	3.14
Oceanic	1000–3000	294,306	64.4	91,488	68.6
Oceanic	< 3000	138,483	30.3	32,810	24.6

Movements of individuals tagged together

Female individuals ID 228106 and 227478, tagged within the same group on 14 March 2024, exhibited similar coastal movement patterns and speed, suggesting they remained associated for at least 28 days, the transmission duration of the first individual (Fig. 2). Similarly, individuals ID 228103 and 228099 from the oceanic cluster, tagged on 23 March 2025, remained associated for at least 37 days, matching the transmission duration of the second individual and showed high average speed (72.3–75.3 km d-1) (Fig. 2). In contrast, individual ID 228100, which was tagged alongside the latter two, separated after only a few days and continued transmitting for an additional month. Although it was also classified within the oceanic group, it exhibited extended movements, initially northward to southern Colombia and subsequently southwestward, which did not match the trajectories of the other two individuals, despite similar transmission durations (see Table 2).

DISCUSSION

The presence of short-finned pilot whales in Ecuadorian waters has mainly been documented during oceanographic research cruises between the mainland and the Galápagos archipelago (e.g. Clarke 1962; Clarke et al. 2002; Hamilton et al. 2009; O'Hern et al. 2017). However, information on the species' demography, population structure, and movement patterns in the region remains limited. This study is the first to specifically examine the distribution and movements of short-finned pilot whales in Ecuadorian waters using targeted pelagic surveys and satellite tagging. Our findings confirm the consistent presence of the species along the continental slope and farther west toward the Galápagos Islands, where, although frequently reported (Denkinger et al. 2013; Palacios and Salazar 2002), dedicated research efforts remain limited.

Relative abundance

The relative abundance along the continental slope (9.04 whales per 100 km of survey) was higher than figures reported in previous studies in Ecuador and neighboring countries. Clarke (1962) conducted whale surveys between Ecuador and the Galápagos Islands in 1959. He reported a relative abundance of 0.75 pilot whales per 100 km (converted from whales per 100 nautical miles of survey), which is 12 times lower than the estimate obtained in this study. However, in a similar expedition 30 years later, the number of pilot whales recorded was 10 times higher, 7.7/100 km of survey (Clarke et al. 2002). Both expeditions were conducted under similar conditions and along the same route during the austral spring (September–October). Before his first expedition in Ecuador, Clarke surveyed the central coast of Chile in 1958, reporting 7.13 pilot whales per 100 km of survey, suggesting that, in the southern part of South America, pilot whales in continental waters may have been nearly as abundant as in Ecuador. Nonetheless, in this case, the species was likely the long-finned pilot whale (*Globicephala melas*), since the short-finned pilot whale's distribution only extends south to northern Chile (Guerra et al. 1987; Aguayo et al. 1998). O'Hern et al. (2017) conducted surveys between mainland Ecuador and the Galápagos Islands aboard oceanographic research vessels from 2001 to 2011, mainly during the austral spring, and indicated that pilot whales were among the most abundant cetacean species, although no relative abundance values were provided. In southern Colombia, Herrera et al. (2011) reported a sighting rate of 0.66 pilot whale groups per 100 hours of survey along the route between Malpelo Island and the Colombian mainland. Still, no sightings were recorded around the island. Considering the reported vessel speed (8–11 knots) and mean group size (9 individuals), the sighting rate per 100 km would be equivalent to 1.04 whales, which is 8.6 times lower than that found in this study.

Unlike our study, which focused on continental waters, the other studies also included oceanic waters between Ecuador and the Galápagos Islands (~ 1,000 km westward) and between the Colombian coast and Malpelo Island (~ 500 km). These comparisons suggest that pilot whales are more abundant along the continental slope than in open-ocean waters in this part of the eastern Pacific. Similarly, sightings during SWFSC cruises show a concentration of pilot whales near mainland Ecuador and Peru and around the Galápagos Islands, but fewer records in between (see Fig. 17 in Hamilton et al. 2009). In Clarke's second expedition off Ecuador, the relative abundance of pilot whales increased after the observation of a group of 80–100 animals around San Cristóbal Island, Galápagos (Clarke et al. 2002). Pilot whales are known to prefer waters around 1,000 m deep along the continental shelf edge and around oceanic archipelagos (Boran and Heimlich, 2019). This pattern is also observed between the Ecuadorian mainland and the Galápagos Islands. Higher productivity at shelf breaks and associated submarine canyons provides important foraging habitats for pilot whales and other deep-water cetaceans and can serve as a predictor variable (Abecassis et al. 2015; Thorne et al. 2017; Shearer et al. 2022).

Movement patterns

Short-finned pilot whales tagged in Ecuadorian waters exhibited two distinct movement patterns: short-range coastal latitudinal movements and long-range oceanic longitudinal movements, revealing strong

bathymetric segregation in space use. Individuals performing coastal movements mainly used upper- and mid-slope habitats, showed minimal use of abyssal environments, and occupied relatively small home ranges. In contrast, whales undertaking long-range movements displayed a clear preference for deep-slope and offshore waters, with limited use of the shelf-edge zone and substantially larger home ranges. These last individuals are probably less likely to visit the study area than coastal whales because of their wider, more oceanic movement. Differences between movement types were even more pronounced in core-use areas, suggesting that habitat specialization occurs not only at the scale of overall home ranges but also within the most intensively used areas. Although our small sample of tagged individuals limits the data, these results suggest bathymetrically structured spatial segregation within the Ecuadorian population, supporting the existence of two ecotypes with different habitat-use patterns. Comparable population structuring, with short-range movements associated with shelf breaks and long-range movements extending into pelagic habitats, has been documented via photo-identification and genetic analyses in pilot whales in oceanic archipelagos and along continental margins (Alves et al. 2013; Abecassis et al. 2015; Mahaffy et al. 2015; Hill et al. 2018; Thorne et al. 2017).

Most of the tagged individuals within the same group in Ecuador remained together during the tracking period in both coastal and oceanic clusters (e.g. ID 228106 with 227478, 228100 with 228103) irrespective of sex (see Fig. 2). This, together with the resighting of eight individuals in the same group after 2.5 months, strongly indicates the existence of stable social groups coexisting in the same area, as reported in studies of short-finned pilot whales in oceanic archipelagos (e.g. Alves et al. 2013; Servidio et al. 2019; Mahaffy et al. 2015; Esteban et al. 2022) and of long-finned pilot whales in coastal waters (de Stephanis et al. 2008; Ottensmeyer and Whitehead 2003). Such social groups are typically characterized by animals exhibiting strong long-term bonds and preferential associations. The long-distance movements we recorded also appeared to involve social groups rather than single individuals, as indicated by animals ID 228100 and 228103 (see Fig. 2) that remained together during the transmission period (six weeks). However, a third oceanic individual (ID 228100) of unknown sex separated from the other two after a few days, suggesting that this individual belongs to another family of oceanic pilot whales that joined for a few days or exploratory movements. We acknowledge that it is not yet possible to infer the long-term stability of pilot whale social groups in Ecuador, given the limited information on individual association patterns.

The longitudinal movements of several individuals toward the Galapagos Islands suggest a migratory corridor linking areas of high social group density on the mainland to those in the Galapagos. For instance, individual ID 227479 traveled more than 800 km westward in 38 days, following a relatively direct trajectory. Individual ID 228100 also exhibited extensive westward movements, reaching more than halfway between the mainland and the Galapagos. Although in this last case the path was less direct than in the former, their trajectories converged at certain points. These movements spatially coincide with the Carnegie Ridge, an underwater mountain range formed by past volcanic activity associated with the Galapagos hotspot and extending eastward to the continental trench, where it subducts beneath Ecuador (Gutscher et al. 1999). The Carnegie Ridge has been identified as an

important migratory corridor for marine mammals, including blue whales (*Balaenoptera musculus*) and sperm whales (*Physeter macrocephalus*) (IUCN-MMPATF 2023; Guzman and Estevez, 2025). Our results suggest that this ridge may also function as a migratory pathway for pilot whales. Long-distance movements connecting distant regions have also been documented in pilot whales between Madeira and the Canary Islands in the eastern Atlantic (Weyn et al. 2025). Seamounts and other oceanographic features have been recognized as important offshore habitats for migratory cetaceans, including humpback whales (*Megaptera novaeangliae*), and may serve as navigational cues (Garrigue et al. 2015).

It is intriguing that none of the tagged whales made significant southward movements below 4°S. One possible explanation is that the Equatorial Front, formed in this area by the convergence of the cold Humboldt Current from the south and tropical waters from the north (Wyrtki 1966), serves as an ecological barrier that influences the distribution of short-finned pilot whales in tropical and subtropical waters. This parallels the case of the two varieties of short-finned pilot whales identified off Japan, whose ranges are associated with water temperature and latitude (Kasuya et al. 1988) as well as with another tropical dolphin species off Ecuador, the rough-toothed dolphin *Steno bredanensis*, whose distribution is strongly influenced by the Equatorial front (Félix et al. 2026). More broadly, changes in water masses and frontal systems are known to affect cetacean distribution in the tropical eastern Pacific (Au & Perryman, 1985). Monitoring studies when the Equatorial Front shifts further north will help clarify the movements of different social groups (or populations) and their possible links to environmental variables

Mixed-species associations with bottlenose dolphins

The frequent co-occurrence of pilot whales with offshore bottlenose dolphins (*Tursiops truncatus*) observed in this study suggests that these associations may serve functional roles beyond simple spatial overlap. Mixed-species groups have been documented in several odontocete species and are associated with reduced predation risk, improved foraging efficiency, and social benefits (Baird 2016; Syme et al. 2021). However, the association between pilot whales and bottlenose dolphins off Ecuador remains poorly understood, and additional behavioral observations are needed to better characterize its nature.

Future work

Our study represents an important advance in understanding the distribution and movements of pilot whales in this part of the eastern tropical Pacific. However, significant gaps remain in understanding ecological aspects, social structure, abundance, and other demographic parameters that require further research through long-term monitoring. The presence of two ecotypes off Ecuador suggests exposure to different environmental and human-related pressures that deserves further evaluation, especially since coastal groups may be more vulnerable to entanglement in nearshore fisheries than oceanic groups (see Félix and Samaniego 1994). Since our research only covered the first half of the year, extending monitoring to the full annual cycle will be necessary to better understand seasonal movements, as reported in other populations (e.g. de Stephanis et al. 2008; Servidio et al. 2018).

Another aspect to consider in future research is the potential impact of extreme climatic events, such as El Niño and long-term climate change, on abundance and distribution, given that the species appears to be sensitive to pronounced environmental variability. For instance, a redistribution of pilot whales occurred in California after the 1982–1983 El Niño event, with effects lasting for several years (Shane 1994; Olson 2018). Our monitoring took place during years with positive temperature anomalies of up to 2°C, associated with the 2023–2024 El Niño event, which extended until May 2024. A similar situation occurred in 2025, when positive temperature anomalies up to 2°C were recorded in the eastern Pacific between 8°N and 6°S during the first half of the year (ERFEN 2025), while conditions in the central Pacific were negative (La Niña condition) according to the Oceanic Niño Index (ONI) (Climatic Prediction Center, 2026). Since El Niño affects the entire trophic structure by reducing primary productivity in surface waters through deepening of the thermocline (Fiedler 2002), it can be expected that during normal or colder years, pilot whales may be more frequently present in the monitored area, particularly those originating from colder waters to the south. Additionally, during 2024 surveys, extensive red tides of unknown origin affected the southern and central coast of Ecuador, reducing the abundance of vertebrate species within 40 kilometers offshore. Further studies integrating environmental variables would help to better understand the drivers of pilot whale distribution in the region.

Declarations

Financial support.

This study was financed by the Pacific Whale Foundation-Ecuador, the Smithsonian Institute for Tropical Research, the Fundación Oceánica and the Museo de Ballenas.

Conflict of interest.

The authors declare no conflict of interest.

Author contributions.

Conceptualization (Fernando Félix and Hector M. Guzman). Fieldwork (Fernando Félix, Cristina Castro, May Platt and Hector M. Guzman) Writing original draft and investigation (Fernando Félix). Statistical analysis, writing – review and editing (Rocío Estévez). Investigation writing – review and editing (Cristina Castro, May Platt and Hector M. Guzman).

ACKNOWLEDGEMENTS

We thank Palo Santo Travel and the boat crew for their support during the expeditions. Fernando Rivera provided photos from Galapagos pilot whales for comparison. This research was funded with grants of

Pacific Whale Foundation and Smithsonian Tropical Research Institute. Surveys were conducted under the research authorizations MAATE-ARSFC-2023-3201 and MAATE-ARSFC-2024-0391 issued by the Ministry of Environment, Water and Ecological Transition of Ecuador.

Data availability.

Data is available directly from the authors upon a reasonable request.

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Figures

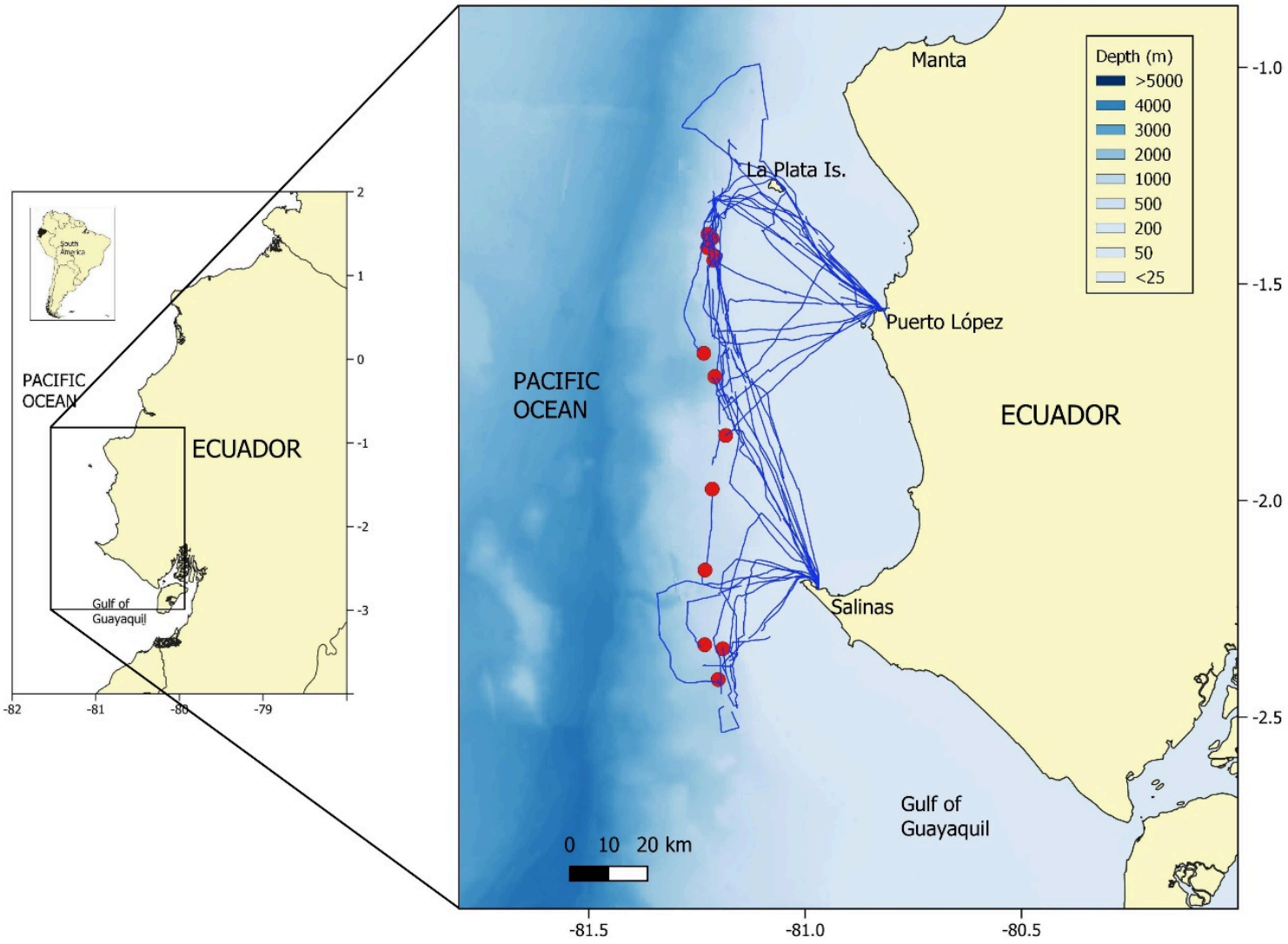


Figure 1

The study area on the central coast of Ecuador. Surveys were conducted along the continental slope between 2024 and 2025. Red dots indicate recorded pilot whale groups. The survey track lines are in blue.

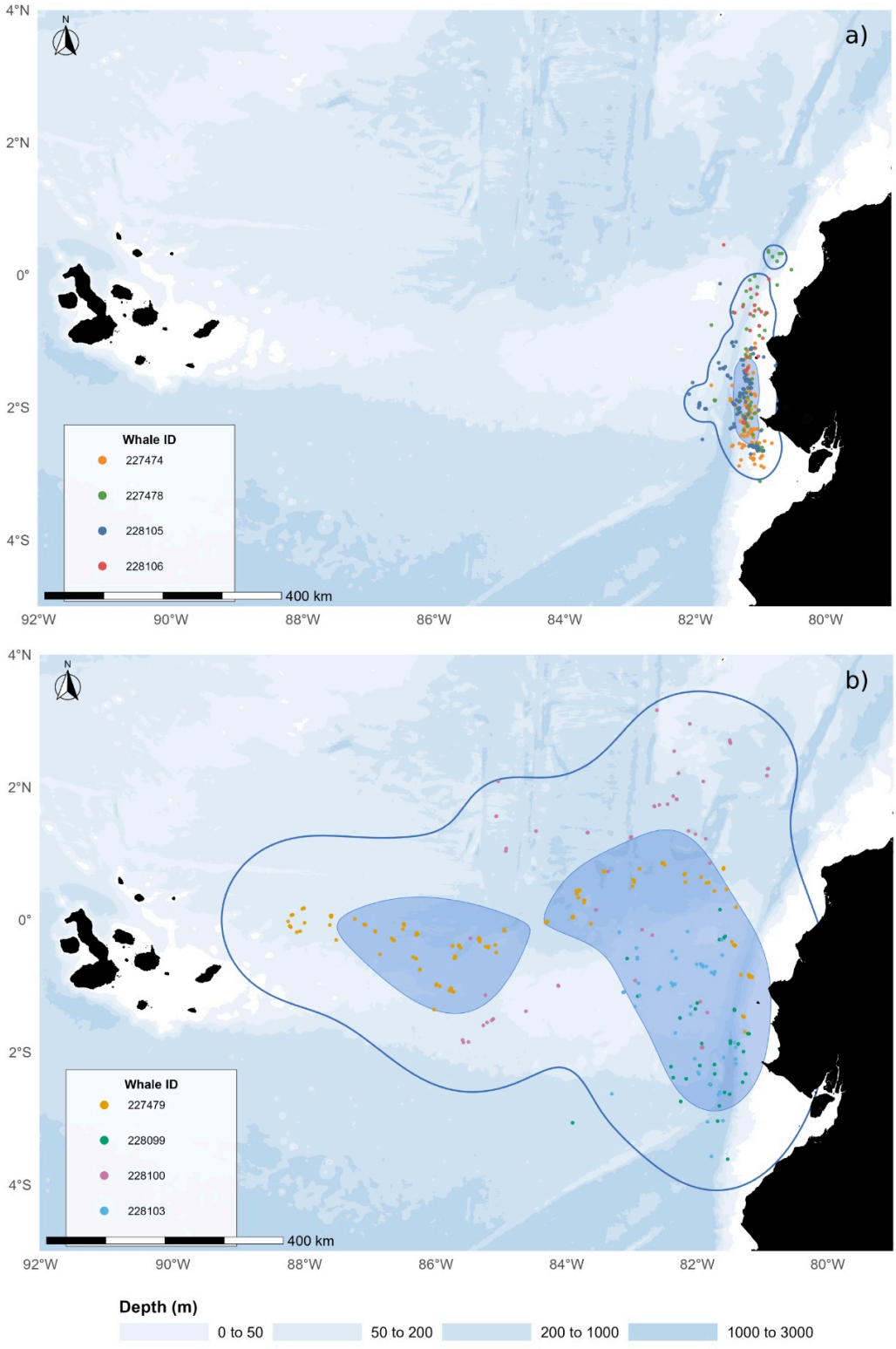


Figure 2

Spatial distribution of satellite telemetry locations and kernel utilization distributions of short-finned pilot whales in the eastern tropical Pacific. Top panel (a): coastal cluster. Bottom panel (b): oceanic cluster. Points represent filtered Argos telemetry locations and vessel-based sighting records. Blue contours indicate the 95% (home range) and 50% (core-use) utilization distributions. Background shading represents bathymetric depth classes (m). Each individual is identified with an ID number and color.

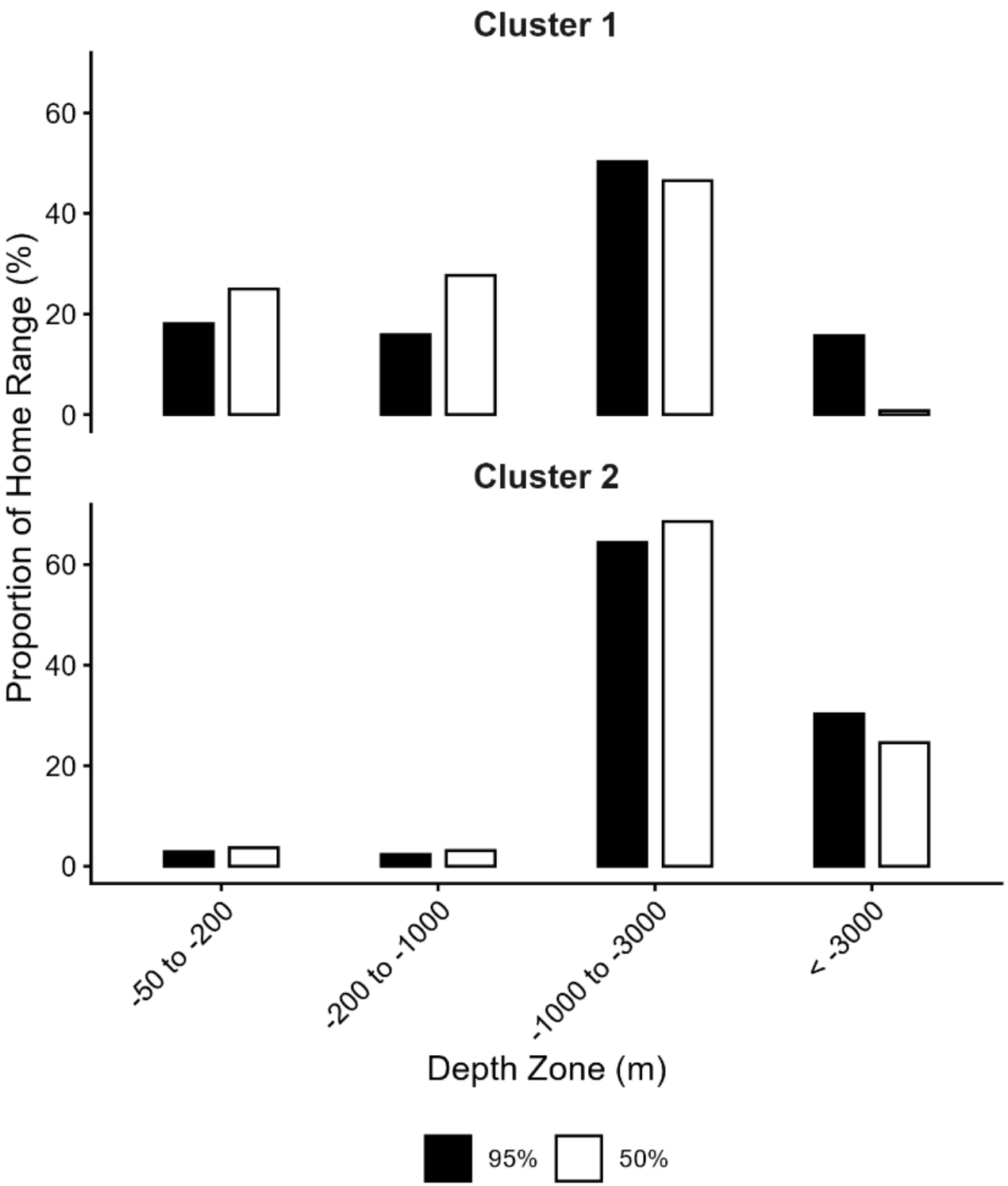


Figure 3

Bathymetric composition of home ranges (95% UD; white bars) and core-use areas (50% UD; black bars) for coastal (Cluster 1) and oceanic (Cluster 2) short-finned pilot whales. Values represent the proportion of each utilization distribution within each depth class