Estimating bycatch rates and abundance of small cetaceans in Pucusana, Peru to guide management and conservation initiatives

Final Report for the Consortium of Wildlife Bycatch Reduction

Project: NA20NMF0080322_6

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This document is the final report of the project entitled “Estimating bycatch rates and abundance of small cetaceans in Pucusana, Peru to guide management and conservation initiatives”. It provides a comprehensive overview of the methods used to achieve our objectives along with the key outcomes. The specific objectives of this project were:

Objective 1: Determine the at-sea distribution and abundance of small-cetaceans (with particular emphasis on Burmeister’s porpoises) in the coastal waters of one of the main ports for Peruvian coastal fisheries.

Objective 2: Determine the spatial overlap and scope of interactions with coastal fisheries using at-sea observations and fisher interviews.

Objective 3: Use interview-based surveys with fishers to characterise the interactions between net fishers and small-cetaceans and current estimate bycatch rates.

Objective 4: Trial a smartphone app with fishers to collect data on at-sea distribution and frequency of encounters with marine mammal species during fishing activities.

PROJECT BACKGROUND

Interactions of small cetaceans and fisheries have been documented in Peru since the 1960 as targeted catch, to be used as bait or aquatic wildmeat, and as incidental catch or bycatch (Van Waerebeek & Reyes, 1994; Mangel et al., 2010; Campbell et al., 2020). A systematic study conducted by Mangel et al. (2010) estimated that 2,412 small cetaceans (95% CI: 1 1,092-4,303) per year were incidentally captured by vessels from the port of Salaverry, northern Peru (8°14'S, 78°59'W) between 2002 and 2007. The study concluded that if this bycatch was representative for other ports, Peru coastal waters would continue to be one of the main areas of global concern due to the very high bycatch rates of small cetaceans.

Historically, the main species affected by fisheries interactions have been Burmeister's porpoises (*Phocoena spinipinnis)*, dusky dolphins (*Lagenorhynchus obscurus sp. posidonia*)*,* common dolphins (*Delphinus delphis*) and common bottlenose dolphins (*Tursiops truncatus*) (Van Waerebeek et al., 2022; Mangel et al., 2010; Campbell et al., 2020). Both dusky dolphins and Burmeister's porpoises in Peru are thought to be genetically distinct to populations elsewhere (Rosa et al., 2005; Mangel & Alfaro-Shigueto, 2019). These genetic differences coupled with the substantial threat posed by bycatch in the Peruvian Pacific place these species at high risk of local extinction – for Burmeister's porpoises the threat is likely higher than represented by the species-level IUCN Species Red List categorization (Felix et al., 2018). Very limited information exists about small cetaceans in Peru with most data obtained as by-products from fisheries-focused research. This lack of information has impeded our understanding of the extent and impact of fisheries-related mortality and consequently the development of effective bycatch mitigation efforts and the implementation of conservation plans to prevent species extinction or management initiatives to promote sustainable fisheries.

To address this situation, our project aimed to generate information on abundance and distribution of Burmeister's porpoises off the coast of Pucusana (12° 28' S, 76° 47' W) in central Peru, with sightings of other cetaceans also recorded for wider context. Pucusana fishing port has one of the longest documented histories of small cetacean fishery interactions. In the mid-1990s, cetacean captures occurred mostly in driftnet and demersal net fisheries (Van Waerebeek & Reyes, 1994). At that time, it was reported that over 2,000 small cetaceans were killed annually by vessels from this port alone, with annual catch estimates exceeding 1,000 dusky dolphins and more than 300 Burmeister's porpoises.

The most recent study by Campbell et al. (2020) documented ongoing bycatch and continued targeted takes of small cetaceans for use as bait in gillnet and longline fisheries in several ports, including Pucusana. However, the study was not designed to assess catch rates or species composition but confirmed that Burmeister's porpoises and the three dolphin species were regular bycatch in gillnets. Our study proposed a comprehensive assessment of the current bycatch rates and circumstances leading to bycatch (including fishing gear, practice and locations) at Pucusana using interviews with fishers.

As part of the project, we implemented dedicated boat-based surveys with Burmeister's porpoises as a focal species to provide novel information on their distribution and abundance. Combined with using interview-based surveys with fishers, we aimed to identify areas where the overlap between fisheries and porpoise distribution might lead to higher bycatch risks. In addition, fisher interviews provided insights into which fisheries and gear types contributed to small cetacean bycatch. This study offers valuable and up-to-date information about the distribution of Burmeister's porpoises and their interactions with gillnet fisheries in an area of intense fishing activity. It also establishes a baseline to guide future research and strategies to reduce bycatch interactions or resulting mortality events.

PROJECT IMPLEMENTATION AND OUTCOMES

METHODS

We used boat-based distance sampling surveys to address our Objective 1. Objectives 2 and 3 were addressed by conducting interview-based surveys with gillnet fishers in Pucusana. Objective 4 (smart phone app) built on the data collection process developed in Objective 1 and was tested with some of the fishers participating in the interviews for Objectives 2 and 3.

At-sea surveys

To assess the distribution and abundance of Burmeister's porpoises, at-sea surveys were conducted in the coastal waters of Pucusana from February 5 - 20 February 2024. Survey track lines were designed during 2023 taking into account factors such as available ports and vessels, weather conditions, and logistical constraints.

The at-sea (and passive acoustic) survey method employed here followed the standard distance sampling protocol for cetaceans (Buckland et al., 2001). Even though adaptations were implemented considering logistical constraints detailed later. This protocol was successfully trialled with Burmeister's porpoises and common dolphins off Puerto Morin (8.3984°S 78.8957°W) and Paracas, Peru (13.8395°S 76.2509°W) during February 2022 as part of a methods development project funded by the International Whaling Commission (IWC) Small Cetacean Fund. Those initial surveys used a local fishing vessel and trained a group of dedicated observers from the NGO ProDelphinus. This approach was replicated and adapted to the conditions of Pucusana using the same team of now trained and experienced cetacean observers.

1. Survey design

Only one port was available for departures and the vessel available, an adapted fishing boat, was not suitable for overnight stays. Due to these limitations, we opted for daily trips departing from the port of Pucusana. Survey routes or track lines design was based on daylight hours, maximum speed appropriate for the target species' behaviour and the maximum speed the vessel could attain. Both vessel type and porpoise behaviour limited the maximum survey speed to 5.5 knots (10 km/h).

We laid out track line patterns using as a reference the distribution pattern of Burmeister's porpoises observed in Puerto Morin and Paracas where they were recorded within 20 km from shore. Due to the scarcity of georeferenced records of Burmeister's porpoises, we relied on anecdotal sighting areas of porpoises reported by local fishers to our team members. The resulting track line design was a combination of a star-shape and zig-zag pattern like those implemented in Puerto Morin and Paracas. This design aimed to maximise the on-effort time (i.e., reduce gaps between transects) and ensure representative coverage of the study area considering habitat characteristics such as depth and proximity to the shore.

Wind direction and sun position were factored into setting the travel directions, aiming to minimize the effect of swell and sun glare which can impact cetacean detection and cause observer fatigue. A maximum of 10 hours daily effort were planned based on a 12-hour daylight period, environmental conditions, and maximum vessel speed. A 25 nm (46km) radius was drawn around the port of Pucusana to represent the maximum offshore distance the vessel could cover in one day. The drawn circle defined our study area boundaries and track lines were placed to ensure representative coverage of the study area (**Figure 1**).

Our goal was to conduct 14 daily surveys with potential routes ranging from 41 to 53 nm (76 to 98 km) to be completed as continuous tracks with no off-effort spacing. Different survey routes allowed flexibility to adapt the route based on weather conditions (e.g., wind speed and direction). The final survey design aimed for a total survey effort of 708.6 nm (1312.33 km).

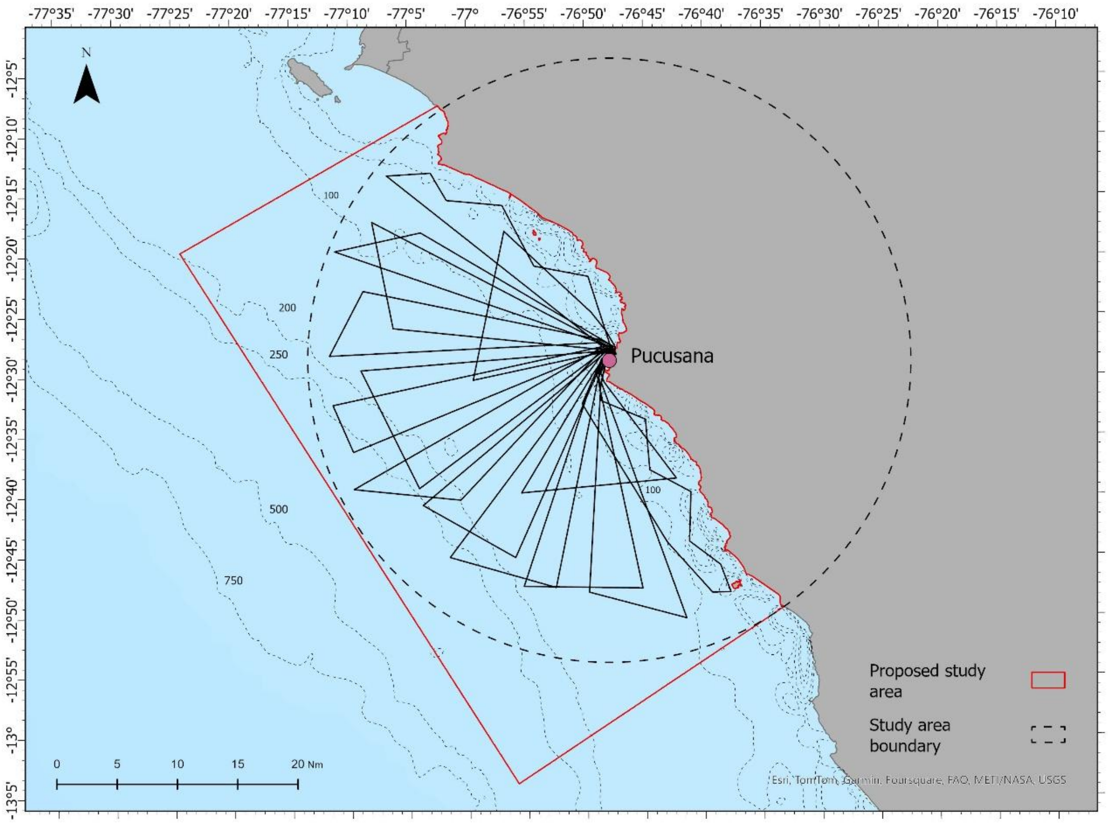


Figure 1. Survey track lines (black lines) designed for Pucusana. Red lines delimit the study area (used for density surface modelling, see below) and the dashed circle indicate the 25 nm radius from port taken to be the maximum distance the vessel could reach and return from in one day.

2. Survey implementation

On the day prior to each survey, we reviewed the weather forecast to select the most suitable route. The survey followed standard distance sampling protocols for cetaceans. Given the characteristics of the vessel, only one observation platform was available, located at the vessel's highest point. Two dedicated observers were stationed on either side of the vessel searching for porpoises with the naked eye and covering the sea surface from ahead to the side abeam. Binoculars were always available to aid observers with close-up views and species identification. As part of the distance sampling method, distance and angle to the sightings were recorded upon first sighting. Angles were measured using an angle board fixed to the observation platform, aligned to centre line of the vessel, while distance was estimated by eye or with 10x50 reticle binoculars.

The survey team consisted of two dedicated observers and two data loggers who rotated positions every 30 minutes to prevent fatigue, limiting each observer to one hour of continuous observation. The core observer team included at least three experienced observers who had participated in previous Burmeister's porpoise surveys. Survey implementation was overseen by Ph.D. student Clara Ortiz Alvarez.

Data collection was conducted using a custom-written Cybertracker app developed for the 2023 surveys, adapted to our new study area Pucusana. Paper sheets were maintained as a backup. Recorded information included: effort data (start and end time and GPS positions in 10-30 second intervals), survey conditions every 30 min (Beaufort, visibility, wind speed and direction, sun glare, swell and sightability), environmental information (depth and sea surface temperature when possible using the vessel echosounder), sighting data (angle, distance, GPS position, species ID and ID confidence, group size, behaviour, sighing cue and aspect towards the vessel) and anthropogenic activities (e.g. vessel traffic, fishing activities).

3. Acoustic monitoring

We implemented acoustic monitoring in collaboration with Dr. Magnus Wahlberg from the University of Southern Denmark and MSc Rurth Ortés. To obtain acoustic detections of porpoises (and other cetaceans) during at-sea surveys, a 1-channel hydrophone array was towed behind the vessel on a 180 m long dyneema rope. The array was contained inside a bespoke towbody built by Dr. Jay Barlow. Data was processed by M.Sc. Ruth Ortés through a bespoke click detector developed by R. Ortés in Pamguard (vers.2.02.09, Gillespie et al., 2008).

4. Modelling approach

We used the Density Surface Modelling (DSM) approach to estimate the abundance of Burmeister's porpoises in our study area. The implementation of a DSM is a two-step process (1) modelling the detection function and (2) abundance estimation (Miller et al., 2013). The first step uses radial distances and angles collected during surveys to calculate the perpendicular distances, which are later used to model the detection function. For the second step, track lines were divided into defined segments to serve as units of analysis for modelling the abundance and distribution of Burmeister's porpoises. Additionally, a prediction grid overlapping the study area was prepared to predict the abundance and distribution of porpoises using spatial modelling with covariates across the study area off Pucusana.

Detection function

In distance sampling, the detection function is a mathematical model that describes the probability of detecting an animal at a given distance from the transect line. To estimate the detection probability, it is suggested to have at least 60 to 80 sightings (Buckland et al., 2015). In Pucusana we recorded a total of 23 Burmeister's porpoise sightings, which is insufficient for estimating the detection probability for this location alone. Therefore, to obtain a reliable estimation of the detection probability we combined Pucusana data with data from Puerto Morin recorded in 2023 with 87 confirmed sightings of Burmeister's porpoises.

We used a combined total of 110 sightings — 87 from Puerto Morin and 23 from Pucusana —to model the detection function and calculate the effective strip width. The first step was to calculate the perpendicular distance using the radial distance and angle data recorded at first sighting. In Puerto Morin three perpendicular distances exceed 200 m (201, 423, 492 m), while in Pucusana, this distance did not exceed the 100 m from the track line. We tested two key functions, hazard rate and half normal, and different co-variate combinations including sea state (Beaufort), sightability and vessel type. Vessel type was included to account for differences in survey conditions, such as observation platforms and surveyed areas. Models were executed using untruncated and truncated at 200 m distance data. To model the detection function we used the software R (vers.4.3.0) and package RDistance (McDonald et al., 2015).

Density Surface modelling

The next step was to estimate the abundance of Burmeister's porpoises in Pucusana using the detection function modelled in the previous step. Track lines were split into segments of 1 km length, based on the resolution of environmental data, and a buffer of 100 m on each side (effective strip width) over which environmental covariates were integrated. The effective strip width was calculated using the average detection probability estimated by the best model and the truncation distance. All spatial analysis steps were conducted using the software QGis v. 3.30.3. Segments with poor sighting conditions such as sea state values of Beaufort >3 and a sightability index ≥ 2 were excluded from the analysis.

Three covariates were considered: X (Longitude) and Y (Latitude) in UTM coordinates and water depth as the median depth per segment. Depth data were obtained from the General Bathymetric Chart of the Ocean (GEBCO) (GEBCO Compilation Group, 2023). Spatial (X/Y) coordinates were obtained from the mid-point of each segment. Due to the spatial orientation of the Peruvian coastline, X coordinates generally reflect the distance from the coast (inshore-offshore), whereas Y coordinates capture potential alongshore (North-South) gradients.

Generalised Additive Models (GAMs) were built using group size as the response variable with median depth, X and Y coordinates as covariates. To avoid collinearity, X coordinates and median depth were not used in the same model. Tweedie and Negative binomial distributions were considered with different co-variate combinations. The best model was selected using AIC and by inspecting the model diagnostics using the gam.check() function in the DSM package (Miller et al., 2013) in the software R v. 4.3.1 (R Core Team, 2023). The best-fitting model was used to predict density across the study area using a prediction grid of 2 km x 2 km. covering an area of 3,530 km^2.

<u>Interview-based surveys</u>

To determine the overlap and scope and to characterise fisheries interaction with small-cetaceans, we conducted semi-structured interviews previously tested to assess marine megafauna fisheries interactions (Costanza et al., 2022; Ortiz-Alvarez et al., 2020). The interview questionnaire is divided into 5 sections: 1) "background information" including general information, (2) "vessel and fisheries characteristics" to describe fishing vessels (e.g., size, motor), fishing gear characteristics, effort (3) "Burmeister's porpoise and dolphins sightings" including the fisher's ability to identify species, frequency of sightings and description of sighting areas (4) "Burmeister's porpoise and dolphins bycatch" including questions about target species, fishing gear characteristics interacting with animals, and bycatch frequency, number of animals captured, fate and condition of animals and (5) "honesty/reliability assessment" to allow interviewers to score respondent reliability. Interviews included a printed map where fishers were asked to indicate fishing, sightings and bycatch areas. Trained interviewers were supplied with all materials, including species identification guides, to support the identification of small-cetacean species by fishers. Before beginning interviews, all participants were informed about the anonymous and voluntary status of the questionnaire and the main purpose and objectives of the project. Team members had long-standing experience using interviews with fishers to obtain insights into fishing practices and bycatch.

RESULTS

At-sea surveys

The survey implementation in Pucusana covered 777.5 nm (1440 km) of effort over 15 survey days. We recorded 34 Burmeister's porpoise sightings, of which 23 were confirmed sightings. Notably, 91% (n = 21) of porpoise sightings occurred within the first 15 nm (27km) from the coast. The continental shelf in Pucusana is narrow compared to the northern sections, allowing us to survey areas with depths up to 250 m; however, most porpoise sightings and acoustic detections were recorded in waters shallower than 100 m depth (**Figure 2**).

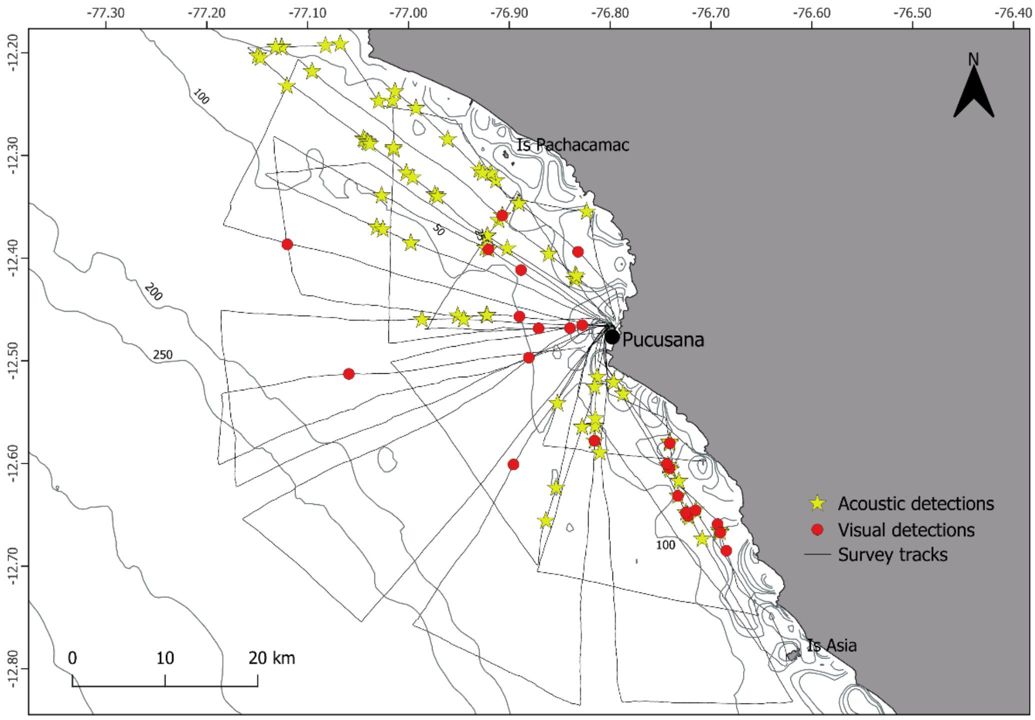


Figure 2. Sightings of Burmeister's porpoises (red circles) and acoustic detection (yellow stars) in Pucusana study area with the realised track lines in dash lines.

Modelling approach

To model the detection function and later determine the abundance and distribution of Burmeister's porpoise using a DSM approach we only used visual detections.

Detection function

The best model used the Hazard Rate key function with a truncation distance at 200 m and vessel type as covariate. Average detection probability (p) was estimated at p = 0.505 (CV = 0.06) and effective strip width (ESW) at 100 m. Detection probability was higher close to the transect line and declined after 100 m **(Figure 3**). The detection function and strip width estimated for Pucusana are close to those obtained using only Puerto Morin data (Detection function: p=0.504, cv=0.08, effective strip width=100 m). Similarities may reflect the influence of the Puerto Morin data on the overall sample size. Additionally, the sighting distances of Burmeister's porpoises recorded in Pucusana did not exceed 100 m from the transect line, aligning with the range of sightings recorded in Puerto Morin.

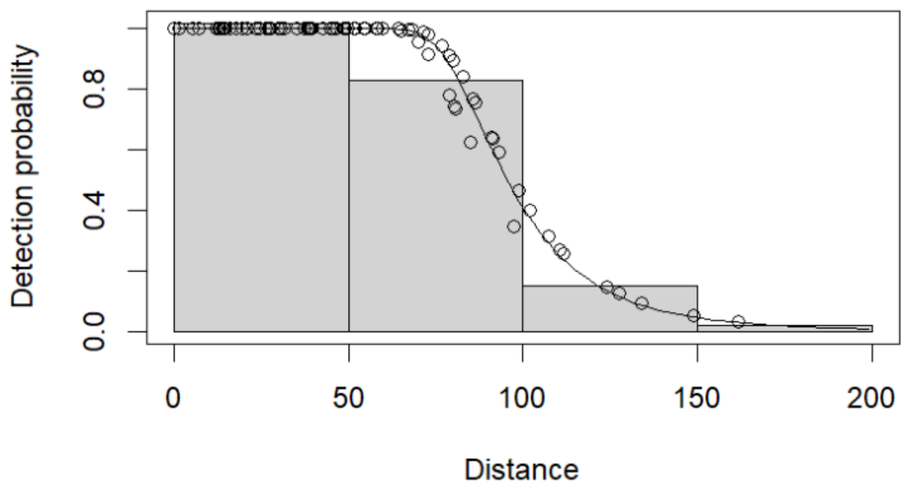


Figure 3. Frequency distribution of perpendicular distances from transect line (grey histogram) and Hazard rate model detection curve fitted to Burmeister's porpoise sightings from Puerto Morin and Pucusana. Sightings were truncated at 200 m.

Density surface modelling

Using the average detection function, the best-fitting model used a Tweedie distribution and retained X and Y spatial coordinates. The abundance of Burmeister's porpoises in the study area was estimated to be 268 individuals (CV=0.25), with a lower 95% confidence interval of 167 and upper 95% confidence interval of 431. The predicted spatial distribution aligns with both visual and acoustic detections in the southern part of the Pucusana study area (**Figures 2 & 4**). However, a discrepancy is noticeable in the northern section, where acoustic detections were recorded but no visual sightings were reported.

The absence of visual detections in the northern section and the discrepancy between acoustic detections and predicted distribution could be attributed to an observer perception bias or/and animal availability bias. Perception bias occurs when observers fail to detect animals, possibly due to challenging conditions (Boyd et al., 2019). In our case, sea state (Beaufort) or swell might have been factors affecting porpoise detections by observers. Animal availability bias occurs when animals are underwater or concealed by other animals and are therefore not visible for observers (Boyd et al., 2019). Behavioural changes documented for porpoises in the presence of vessels, include shifting to diving and an increase of their time underwater (Akkaya et al., 2017; Roberts et al., 2019; Hazebroek, 2023), could also have hindered observers from detecting porpoises. Likewise, porpoises might have been obscured by other marine mammals, particularly groups of dusky dolphins (*Lagenorhynchus obscurus*) or South American sea lions (*Otaria byronia*) further complicating their detection. The possibility of porpoises being obscured by the presence of dusky dolphins and South American sea lion is supported by the overlap between the sightings of these species with porpoise acoustic detections and an absence of visual detections in the northern section of the study area (**Figure 5 & 6**).

This apparent mismatch between acoustic detections and the predicted distribution may suggest a bias towards a lower abundance estimate due to the lack of visual detections. Even though the abundance for Pucusana might be underestimated, low abundance of porpoises around Pucusana might also reflect the intense direct catch and bycatch of small cetaceans reported for this location during the 1990s (Van Waerebeek and Reyes, 1990; 1994; Van Waerebeek et al., 2002). However, it is important to note that this is the first abundance estimation for Burmeister's porpoise in Pucusana and it represents a snapshot of a particular month and area. Despite its limitations, this study establishes a baseline to guide future research and conservation initiatives. Implementing seasonal surveys and continuous monitoring using stationary acoustic devices could contribute to identifying seasonal changes in habitat use, distribution, and abundance of Burmeister's porpoises in the area.

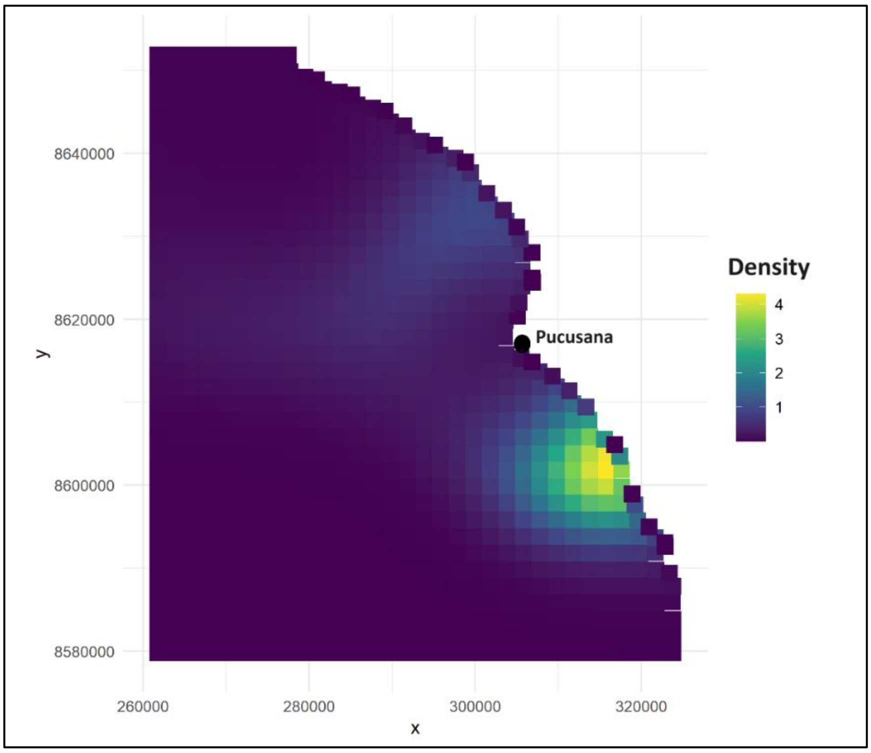


Figure 4. Map of the predicted density of Burmeister's porpoises in Pucusana, Peru. Density scale shows the number of animals within a prediction grid cell of $4km^2$.

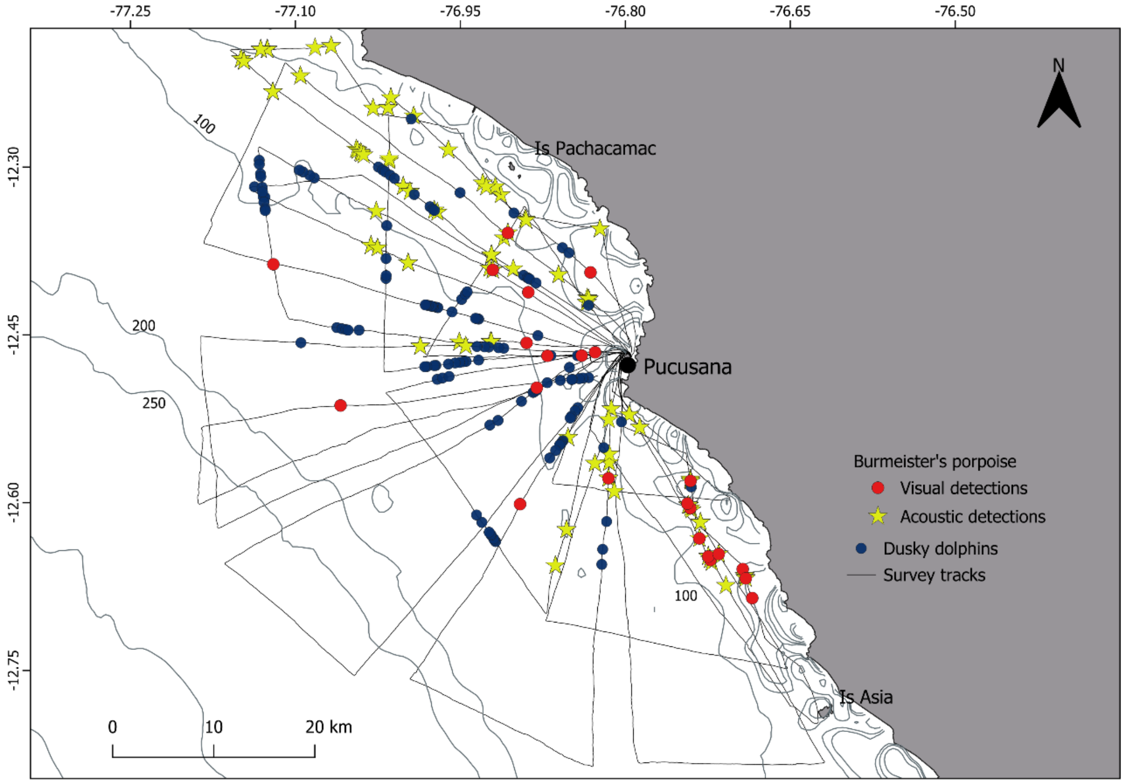


Figure 5. Sightings of Burmeister's porpoises (visual and acoustic detections) and dusky dolphins recorded in Pucusana study area with the realised track lines.

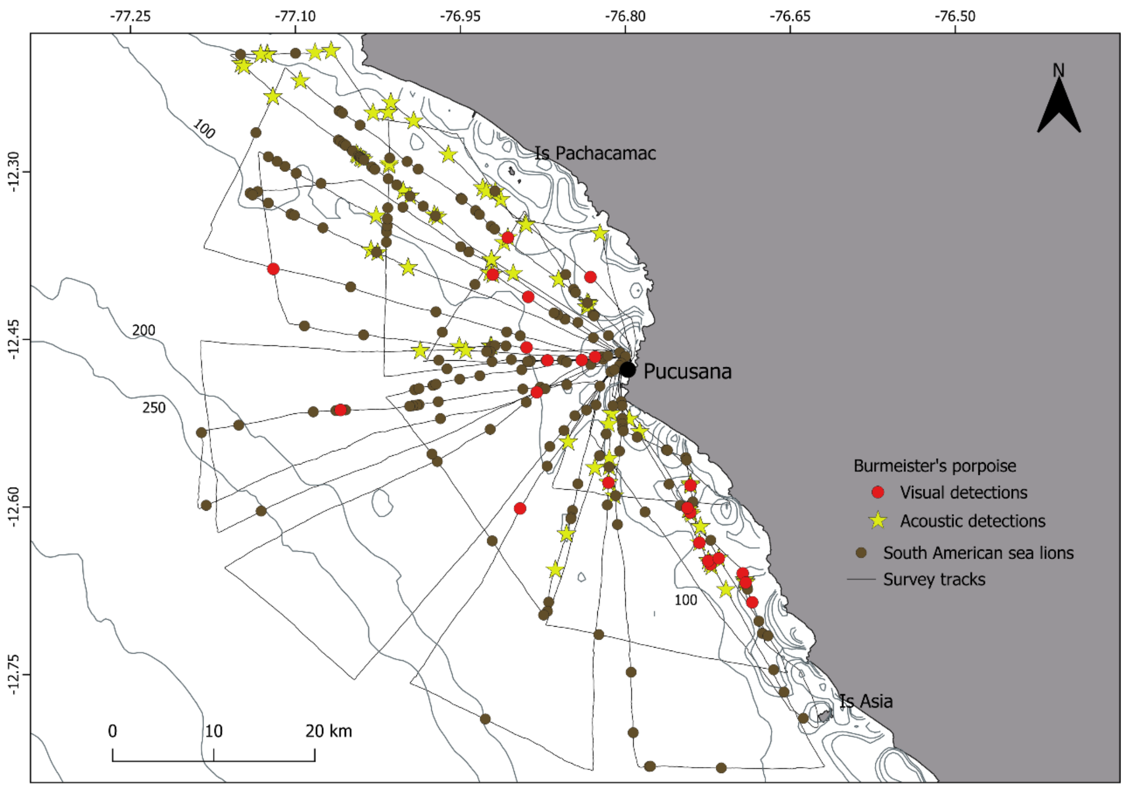


Figure 6. Sightings of Burmeister's porpoises (visual and acoustic detections) and South American sea lions recorded in Pucusana study area with the realised track lines.

Marine fauna diversity

Even though the Burmeister's porpoise was our principal species, we also sighted other marine mammals from three different taxonomic groups. Sightings were spread across the study area including offshore areas where no porpoise visual detections were registered. We recorded four delphinid species (common, dusky, bottlenose dolphins and orca), baleen whales (species unidentified) and South American sea lions (**Table 1**). Dusky dolphins (n=107) were the most frequently sighted species, particularly in the northern section of the study area inshore of the 250 m contour depth (**Figure 5**). Baleen whales (n=46) were the second most frequently sighted species group throughout the study area including inshore and offshore areas (**Figure 7**). Common dolphins were only sighted in waters deeper than 100 m whereas a few sightings of bottlenose dolphins occurred in inshore and offshore waters (**Figure 7**). We also recorded a single orca sighting at approximately 20 km from the coast.

South American sea lions (n=201) were also observed across the study area with more sightings concentrated close to coast within the first 15 nm (~30km) from shore (**Figure 6**). Colonies of this species can be found on the nearby Pachacamac and Asia islands.

Other sighted species included devil rays (n=46), from the species *Mobula mobular,* which were frequently seen leaping in waters beyond the 100 m depth contour (**Figure 8**). Likewise, other species recorded in these deeper waters include sunfishes and sharks along with three sightings of green turtles. Two additional green turtles were spotted within the first 4 km from the coast (**Figure 8**).

Table 1. Marine species sighting events recorded during surveys in Pucusana.

Group	Species	Number of sighting events
Marine mammals	Dusky dolphin (*Lagenorhynchus obscurus*)	107
	Common dolphin (*Delphinus delphis*)	15
	Bottlenose dolphin (*Tursiops truncatus*)	5
	Orca (*Orcinus orca*)	1
	South American sea lion (*Otaria byronia*)	201
	Unidentified baleen whales	46
Sea turtles	Green turtle (*Chelonia mydas*)	5
Elasmobrachs	Devil rays (*Mobula mobular*)	46
	Sharks	3
Bonny fishes	Sunfish (*Mola mola)*	4

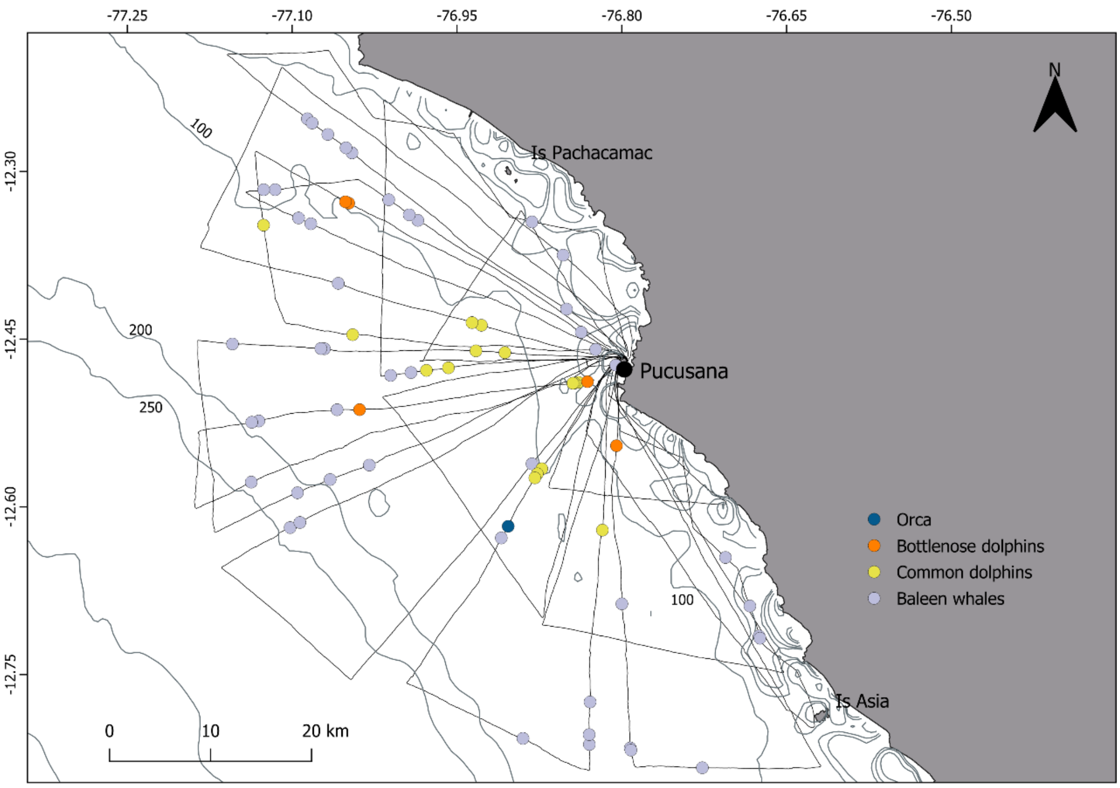


Figure 7. Sightings of other cetaceans (see inset legends for details) in Pucusana study area with the realised track lines.

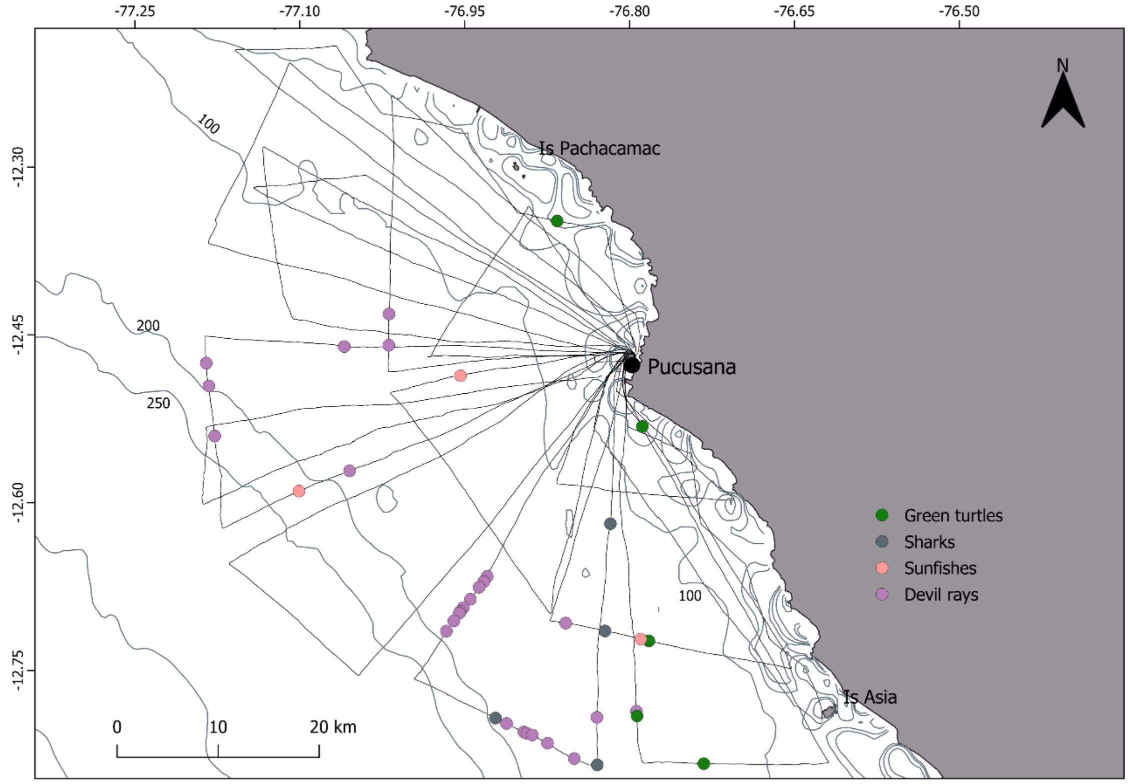


Figure 8. Sightings of other taxonomic groups (see inset legends for details) in Pucusana study area with the realised track lines.

Interview-based surveys

We conducted 61 interviews with fishers from Pucusana in January 2024 and from April to July 2024. The first few months of the year are a period of high fishing activity, limiting the time fishers could allocate to interviews. Eight interviews were discarded because of inconsistencies in the data collected or incomplete responses.

On average, the age of fishers was above 40 years of age, with approximately 30 years of fishing experience. Ninety four percent (94%) of fishers interviewed reported fishing as their primary occupation and 32% reported to own a vessel. Over 50% of fishers reported using gillnets year-round, targeting species like Eastern Pacific bonito (*Sarda chilensis chilensis*), dolphinfish (*Coryphaena hippurus*) and various elasmobranchs including rays (likely Myliobatis sp., blue sharks (*Prionace glauca*), smooth hammerheads (*Sphyrna zygaena*), shortfin makos (*Isurus oxyrinchus)*), and other bony fishes like corvina drum (*Mugil cephalus*), silverside (*Odontesthes regia*), chub mackerel (*Scomber japonicus*), jack mackerel (*Trachurus murphyi*), palm ruff (*Serioella violacea*), corvina (*Cilus gilberti*), and billfishes. The net mesh sizes used by fishers ranged from 1 to 25 inches, with the most common being 4-inch mesh, reported by 62% of fishers (n=33), followed by nets of 6 to 7-inch mesh reported by more than 30% of fishers. Only 4 fishers reported using nets with mesh sizes from 10 to 25 inches, mainly targeting shark and billfishes.

The duration of fishing trips varied depending on the target species, ranging from daily trips for fishing bonito to longer trips, between 14 and 21 days when targeting dolphinfish or elasmobranchs. The reported areas were concentrated between Pachacamac and Asia islands, extending up to 30 nm from the coast. These areas align with known reports for small scale gillnet fisheries targeting similar species in waters extending to 60 nm offshore (Salazar et al., 2020). However, based on fisher responses, this area could extend to more than 100 nm from the coast. Our results suggest a considerable overlap between the predicted distribution (visual detections) and acoustic detections of Burmeister's porpoise and fishing activities in Pucusana. This overlap is further corroborated by fisher's reports of sightings and bycatch events of Burmeister's porpoises (**Figures 8 & 9**).

From all participants, 62% (n=33) of fishers reported sightings of Burmeister's porpoises during their fishing activities. Most fishers, 67% (n=22), reported that porpoises mainly occurred in pairs or groups of three, primarily within the first 5 nm (9 km) from the coast and in less than 100 m water depth (**Figure 8**). However, two fishers reported sightings of groups with up to 30 animals, and sighting distances of up to 100 nm. Using maps, fishers identified areas near Pucusana port and around Pachacamac islands as locations where they encounter porpoises more frequently (**Figure 8**).

Based on interviews and at-sea survey results, there is a noticeable overlap between sighting areas identified by fishers and our visual and acoustic detections (**Figure 9**). This result is consistent with a previous study that found Burmeister porpoises using areas withing the first 50 km from the coast and with <200 m depth (Clay et al., 2018). Nonetheless, fishers also identified distant areas from the coast up to 100 nm (150km) and deeper waters > 500 m as sighting locations for porpoises. Although Burmeister's porpoises are generally associated with inshore areas and waters of <200 m (Clay et al., 2018), the possibility of different habitat preferences cannot be ruled out, especially as offshore areas remain unexplored. Habitat preferences and distribution could be linked to food availability, which might change seasonally (Dolar et al 2006).

Porpoise sightings were reported to occur any month throughout the year. However, more than 50% of fishers indicated to have sightings more frequently from October to February, except in November.

Table 2. Information on Burmeister's porpoises (BP) as reported by fishers interviewed in Pucusana. Percentage of fishers reporting porpoise sightings, distance from the coast and group size in (%) of fishers.

% fishers reporting Burmeister's porpoise sightings (n)	Distances from the coast where BP sightings occurred (%) *						BP group size reported by fishers (%) *			
	≤5 mn	≤10 mn	≤15 mn	≤30 mn	≤50 mn	≤100 mn	1-2	2-3	≤10	≤30
62 (33)	25	9	4	8	9	8	33	33	27	6

**Based on the number of fishers reporting BP sightings.*

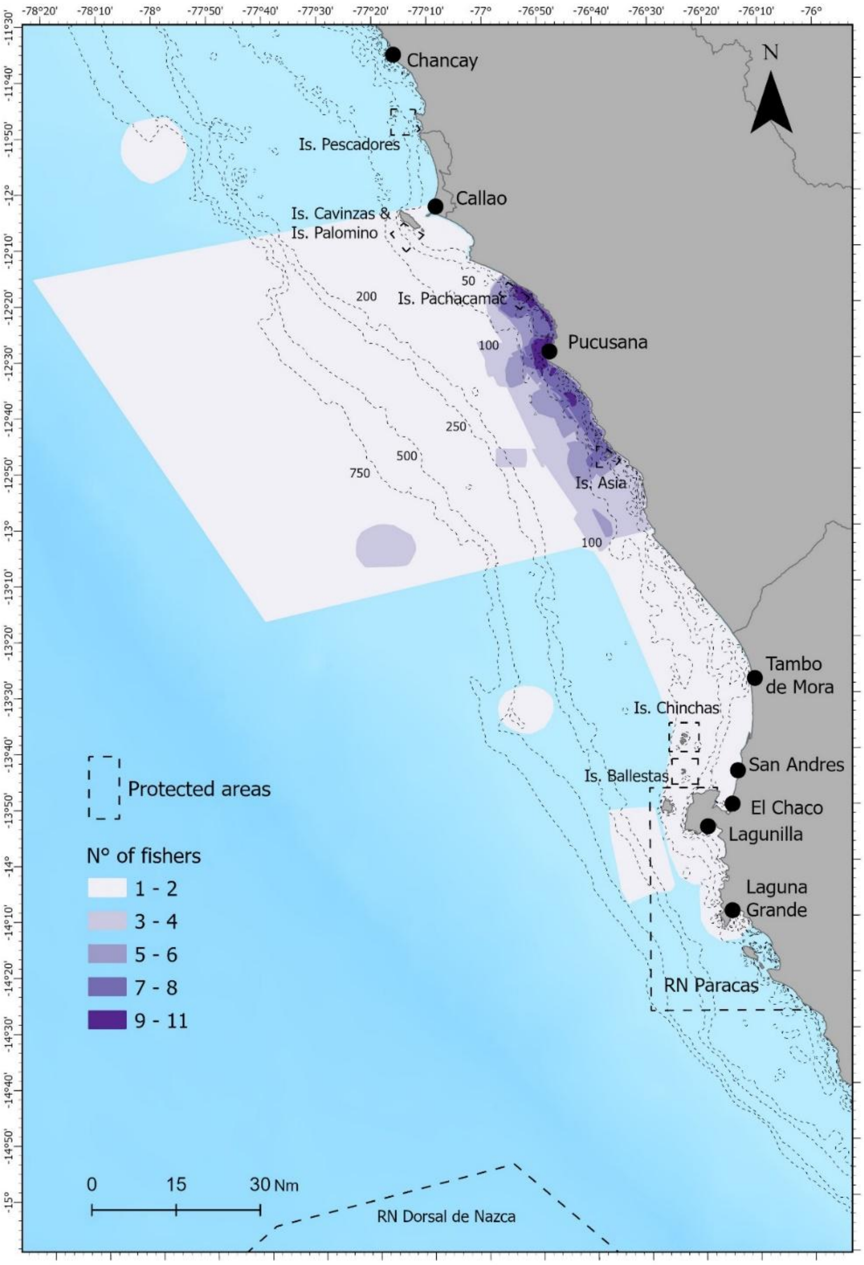


Figure 8. Burmeister's porpoise sighting areas identified by fishers during interviews conducted in the port of Pucusana.

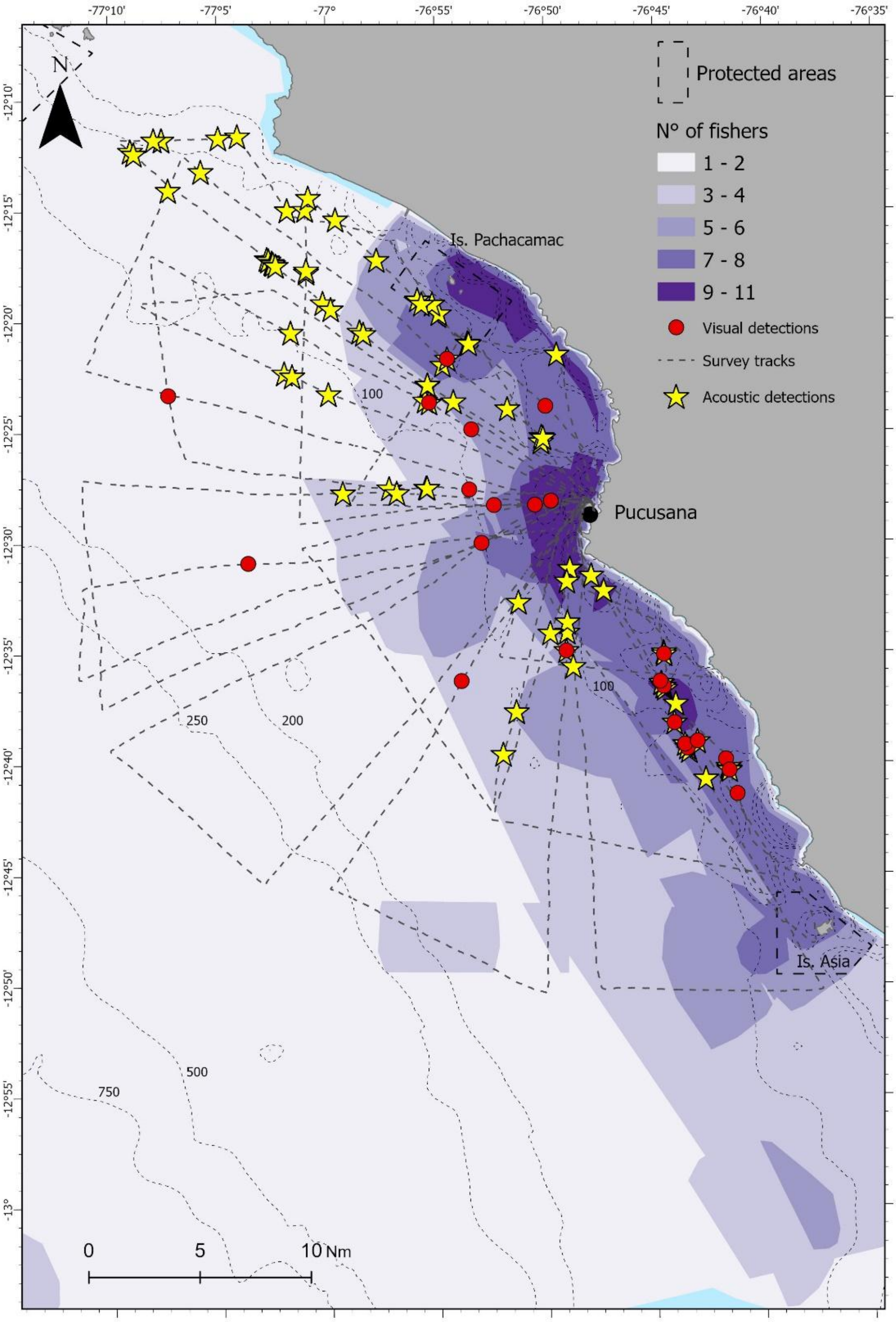


Figure 9. Burmeister's porpoise sighting areas identified by fishers overlapped with visual and acoustic sightings during at-sea surveys.

Regarding bycatch, 25% (n=13) of interviewed fishers reported having incidentally captured Burmeister's porpoises. Among these, 70% (n=10) reported that these events mainly occurred within 30 mn (56 km) from the coast. Most fishers indicated that bycatch occurred while targeting Eastern Pacific bonito, dolphinfish and/or elasmobranchs, using net mesh sizes of 4 and 6 inches. Bycatch areas identified by fishers are primarily within the 15nm (28 km) within the 200 m depth contour (**Figure 10**). However, some fishers report areas extending up to 60 nm (111 km) offshore and south of Asia island.

The overlap of bycatch areas with visual and acoustic detections of Burmeister's porpoises clearly demonstrates the convergence of fishing areas and the potential distribution of porpoises (**Figure 11**). This overlap may result from similarities in the distribution and habit use of porpoises and the target fish species. For instance, both Burmeister's porpoises and the Eastern Pacific bonito feed on anchovies (*Engraulis ringens*) (Garcia-Godos et al., 2007; Alegre et al., 2014). This shared prey could explain the overlap in distribution and habitat between these species and consequently, the overlap of fishing activities and the distribution of porpoises.

A total of 7 porpoises were reported as captured, with an average of 0.13 (± 0.44) porpoises estimated captured per vessel over the past year. The average was calculated including all 53 interviews (**Table 3**). The low bycatch rate may reflect the predicted low abundance of Burmeister's porpoises in the area, estimated at 296 individuals, which reduces the likelihood of entanglements. Other factors potentially influencing porpoise entanglements include the smaller mesh sizes used by most fishers, typically ranging from 4 to 7 inches, compared to the larger 7 to 10-inch mesh size used in ports like Salaverry (located in northern Peru at 8.2128°S 78.9768°W, 20 km north of the port of Morin), which have higher reported bycatch rates (Mangel et al., 2010; 2013). Additionally, the soaking time of nets might be limited to 40 min during daily bonito fishing trips, in contrast with the overnight soaking time used by fishers from Salaverry (Mangel et al., 2010; 2013).

To the question about animal condition of porpoises when found entangled, 62% (n=8) of fishers, reported finding them dead and 54% (n=7) alive (**Table 3**). About porpoise fate after bycatch, 53% (n=7) of fishers reported more than one option. All fishers who found porpoises alive reported that releasing them alive was among their options. Additionally, 46% (n=6) of fishers said they discarded dead animals, while 38% (n=5) reported using dead animals for consumption either at home (n=4) or on the boat (n=1) (**Table 3**). The practice of using porpoise meat for consumption is common, has been documented for Pucusana since the early 1990s, and is a practice that continues to this day (Campbell et al., 2020).

Bycatch events were reported throughout the year, with higher frequencies observed in June, July, and the summer months between October and January (excluding December), as reported by more than 30% of fishers. Percentages of fishers were estimated based only on those fishers reporting fish during those months.

Future steps with the survey data should include validating bycatch areas with fishers and developing specific strategies that can aid in reducing bycatch events or in preventing porpoise mortality. For instance, preventing the setting of nets in areas with a high density of porpoises or the patrolling of nets in those areas to increase the chances to find porpoises alive.

Table 3. Bycatch of Burmeister's porpoise (BP) reported by fishers interviewed in Pucusana.

% fishers reporting BP bycatch (n)		24 (13)
Total # BP reported captured past year (max. # animals reported/vessel)		7
Average BP catch per vessel in past year ± SE+		0.13 ± 0.06
Distances from the coast where BP bycatch occurred (%) *	≤5 mn	38
	≤30 mn	38
	≤100 mn	23
BP condition when captured*	% fishers reporting animals alive	54
	% fishers reporting animals dead	62
BP fate*	% fishers releasing animals alive	54
	% fishers discarding animals dead	46
	% fishers using animals for consumption at home	31
	% fishers using animals for consumption in the boat	8
	% fishers using animals for sale	0
	% fishers using animals as bait	0

**Based on the number of fishers reporting Burmeister's porpoise bycatch. nm=nautical miles. + Based on all fishers interviewed with 0 as the minimum number reported in the past year.*

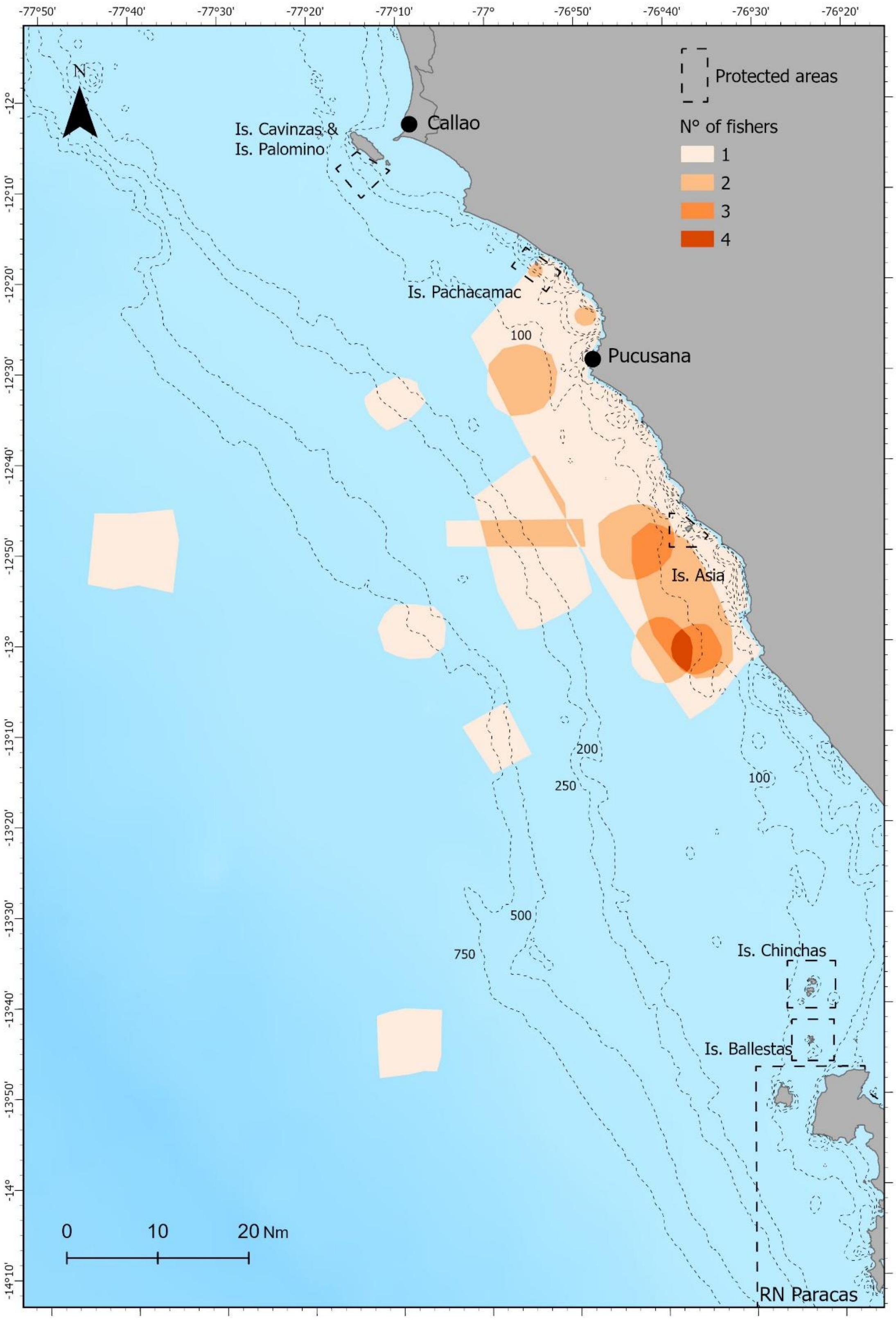


Figure 10. Burmeister's porpoise bycatch areas identified by fishers during interviews conducted in the port of Pucusana.

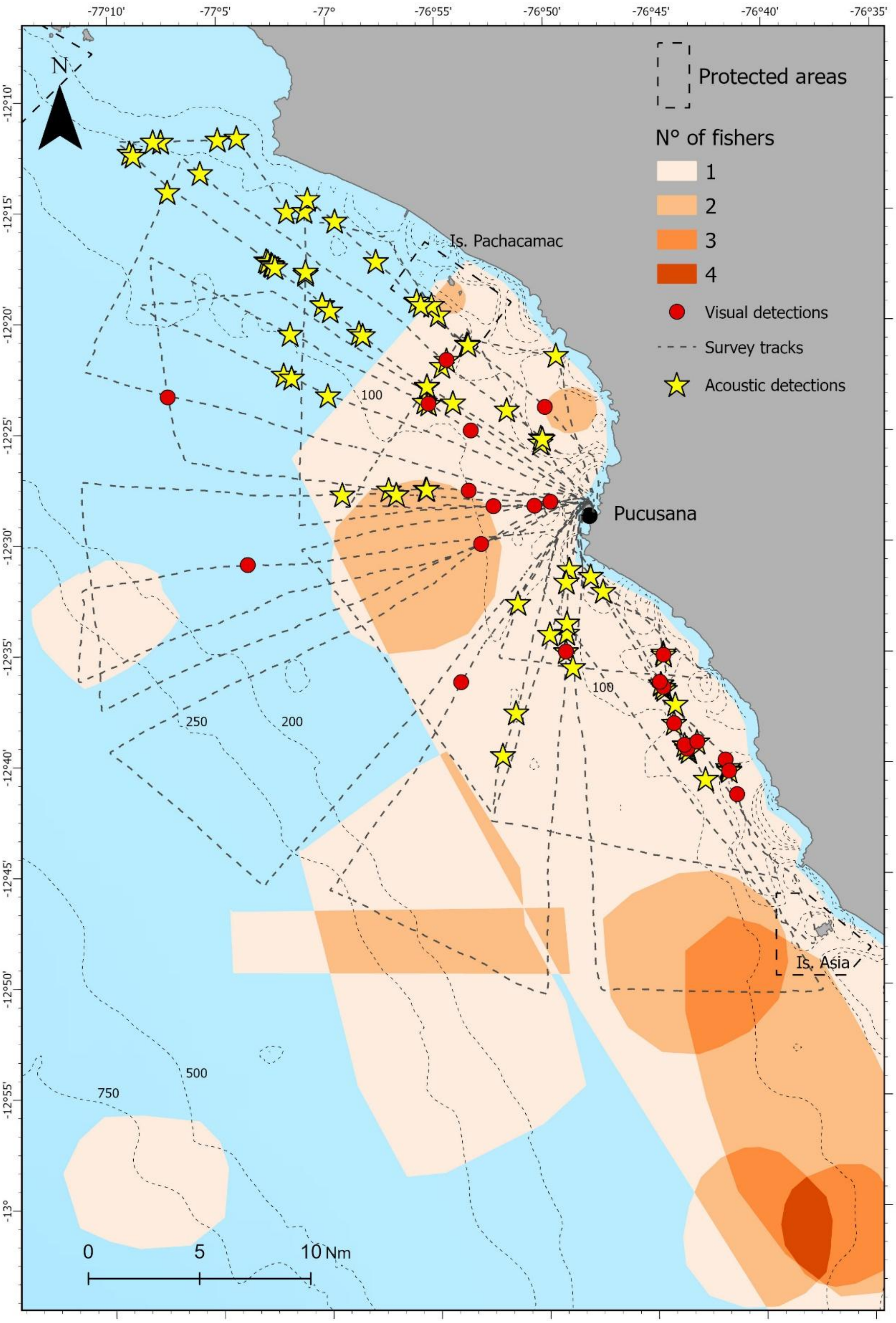


Figure 11. Burmeister's porpoise bycatch areas identified by fishers overlapped with visual and acoustic sightings during at-sea surveys.

In addition to collecting information on the bycatch of Burmeister's porpoises, we included a separate section to collect data on dolphin bycatch. Over 90% (n=52) of the interviewed fishers reported dolphin sightings within their fishing grounds (**Table 4**). Some fishers were able to distinguish between dolphin species during interviews, identifying dusky dolphins, common dolphins, and bottlenose dolphins, species that were also observed during our at-sea surveys.

Compared to porpoises, dolphins were mostly seen within 30 nm (56 km) from the coast, although sightings were reported as far as 100 nm (185 km) (**Table 4**). Fishers reported encountering dolphin groups ranging in size from fewer than 10 individuals to more than 1,000. However, a higher percentage of fishers reported groups of 20 or more, followed by groups exceeding 100 dolphins (**Table 4**).

Table 4. Percentage of fishers reporting dolphin sightings and group sizes.

% fishers reporting Dolphins' sightings (n)	Distances from the coast where dolphins' sightings occurred (%) (n=45)							
	≤5 mn	>5 nm	>15nm	≤30 mn	≤50 mn	>50 mn	≤100 mn	NR*
98 (52)	29	4	2	42	9	4	7	2
	Dolphins group size reported by fishers (%) (n=39)							
	≤10	≥20	≤30	≥50	≥100	≥200	≥1000	
	10	21	15	10	26	13	5	

*Percentage of fishers that do not respond to the question

Among the fishers who identified dolphin species, seven were able to provide information about sighting areas based on distance from the coast. Fishers reported that all species could be observed within the first 5 nm, which aligns with our at-sea survey observations (**Table 5**). Specifically, fishers noted that dusky and common dolphins are typically seen within 50 nm, while bottlenose dolphins were reported to be seen as close as 1 nm from the coast up to more than 30 nm (**Table 5**). About group sizes, 13 fishers distinguished between species. Dusky dolphins were reported to be in groups of fewer than 50 animals, with one fisher reporting groups of more than 1,000 animals. Common dolphins were reported in various group sizes, with the most frequent being groups of fewer than 20 animals. Bottlenose dolphins were only reported in groups of either fewer than 20 or fewer than 50 animals (**Table 5**).

Table 5. Percentage of fishers reporting sightings and group sizes per dolphin species.

	Distances from the coast where dolphin sightings occurred (%) (n=7)						Dolphin group sizes reported by fishers (%) (n=13)					
	>1 mn	≤5 mn	>5 nm	≤30 mn	>30 nm	≤50 mn	≤20	≤50	≤100	≤500	≤1000	>1000
Dusky dolphins	0	14	14	14	0	43	23	38	8	0	0	15
Common dolphins	0	14	29	0	0	43	46	15	8	15	8	0
Bottlenose dolphins	14	29	0	14	14	0	62	15	0	0	0	0

Over 74% of fishers reported having dolphin bycatch, with an estimated total number of 182 animals captured and a mean value of 3.4 (± 1.1) dolphins caught per vessel in the past year. Dolphin bycatch was more frequent than porpoise bycatch and, according to fishers, occurred over a larger area, extending up to 100nm from the coast (**Table 6**). The average dolphin catch per vessel in the past year and average was calculated including all 53 interviews. Similar to Burmeister's porpoises, dolphin bycatch was reported while fishing for Eastern Pacifico bonito, sharks, dolphinfish and/or billfishes. The most frequently reported net mesh size used when dolphin bycatch occurred was 4 inches. Most fishers reported finding dolphins dead (90%) with only 28% encountering them alive. In contrast to Burmeister's porpoises, a small percentage of fishers reported using dolphins for sale (3%) or as bait (10%) (**Table 6**). The consumption of dolphin meat, either on the boat or at home, was also commonly reported.

Table 6. Percentage of fishers reporting dolphins bycatch events, mean bycaught animals and distance from the coast of occurrence.

<table>
<tr><td colspan="2">% fishers reporting dolphin bycatch (n)</td><td>74 (39)</td></tr>
<tr><td colspan="2">Total # dolphins reported captured past year (max. # animals reported/vessel)</td><td>182</td></tr>
<tr><td colspan="2">Average dolphins catch per vessel in past year ± SE</td><td>3.4 ± 1.1</td></tr>
<tr><td rowspan="5">Distances from the coast where dolphins bycatch occurred (%)</td><td>≤5 mn</td><td>10</td></tr>
<tr><td>≤30 mn</td><td>28</td></tr>
<tr><td>≤100 mn</td><td>41</td></tr>
<tr><td>>100 mn</td><td>13</td></tr>
<tr><td>NR</td><td>8</td></tr>
<tr><td rowspan="2">Dolphins condition when captured</td><td>% fishers reporting animals alive</td><td>28</td></tr>
<tr><td>% fishers reporting animals dead</td><td>90</td></tr>
<tr><td rowspan="6">Dolphins fate</td><td>% fishers releasing animals alive</td><td>15</td></tr>
<tr><td>% fishers discarding animals dead</td><td>59</td></tr>
<tr><td>% fishers using animals for consumption at home</td><td>41</td></tr>
<tr><td>% fishers using animals for consumption in the boat</td><td>18</td></tr>
<tr><td>% fishers using animals for sale</td><td>3</td></tr>
<tr><td>% fishers using animals as bait</td><td>10</td></tr>
</table>

In addition, to the field work conducted in Pucusana and to address Objective 4, we developed a custom written app using the online version of the Cybertracker software. The app is divided into three main sections and was designed to minimize the time and input required from fishers. The first section gathers fisheries-related information including details about fishing gear used, target species, and departure port. The second section is focused on collecting data on sightings of Burmeister's porpoises and other cetaceans, including number of animals and offering the option to take a picture when possible. The last section is designed to record data on bycatch of Burmeister's porpoises and other cetaceans. Information to be gathered include species and number of animals bycaught and their fate. The option for taking a picture is also available.

The app automatically collects geographic coordinates of every event entered. However, based on suggestions from some fishers, an option was included to log past sightings and bycatch events only by entering coordinates manually. This option allows fishers to enter geographic coordinates of past events.

The app is accessible via a link or QR code requiring only the prior download of the free Cybertracker software on any smartphone or tablet device. Cybertracker is available in the app store for Android and iOS devices.

To encourage the use of the app, team member Nelly Pena has been conducting in-person training with fishers from Pucusana. Training sessions cover cetacean identifications and data collection, with trained fishers receiving a cetacean identification guide. Two fishers have started using the app and initial reports include four sightings including 4 sea lions, 1 sperm whale, 1 humpback whale and 3 Burmeister's porpoises. Burmeister's porpoises were reported south of the area monitored with at-sea surveys and were recorded at ~2 nm from the coast (-13.164, -76.417). We also continue to gather feedback on the user experiences of fishers with the app to refine it and to promote its broader use among the fishing community. Possibly this work will be presented to the next SOLAMAC either as a poster or an oral presentation.

QR Code

CyberTracker Online

Version: 2024071102
Pescadores

CONCLUSIONS AND IMPLICATIONS

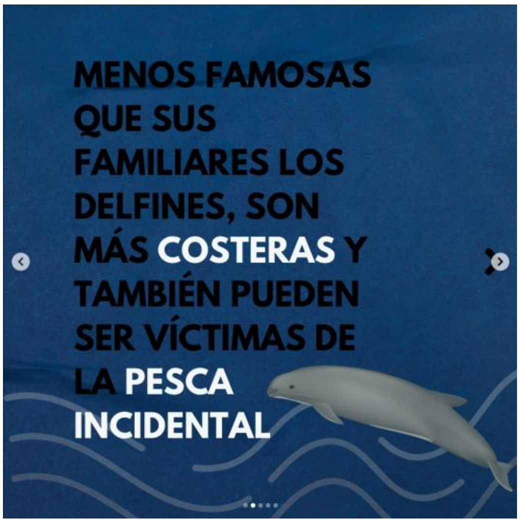
1. This study provides new insights into the distribution and abundance of Burmeister's porpoises in Pucusana, Peru. The predicted low abundance in the study area may be linked to the historical bycatch and direct capture of porpoises and other small cetaceans in the area around Pucusana. Although the predicted abundance might be underestimating actual abundance (given the

discrepancies with the acoustic data), our results establish a baseline to guide future research and conservation initiatives. The implementation of regular surveys in the same area and the use of stationary acoustic devices in areas with high densities of Burmeister's porpoises could contribute to determining if there are seasonal changes in habitat use, distribution, and abundance.

2. The use of towed acoustic devices during at-sea surveys for Burmeister's porpoises was a valuable complement to this study. Acoustic devices allowed the detection of this species when sea conditions were unfavourable or when the presence of other species hindered visual detection.
3. There is a clear overlap between gillnet fisheries and the habitat of Burmeister's porpoises. However, the reported bycatch appears to be low, which could be explained by the low abundance of porpoises. Further exploration of factors related to porpoise bycatch, such as fishing gear type or other aspects of the fishing practice (e.g., soaking time) could help to develop better strategies to reduce the frequency of bycatch events or to prevent porpoise mortality. For instance, promoting the patrolling of nets in areas with a high density of porpoises could increase the chances of finding porpoises alive. Future efforts should also include validating bycatch areas with fishers and encouraging the development of bycatch mitigations strategies in collaboration with the fishing community.
4. The study area off Pucusana is home to a rich diversity of marine megafauna, with much of this concentrated within 15nm (28 km) from the coast. In Peru, the first 5 nm are designated as a zone for protection of fauna and flora. Our results highlight the need to strengthen the protection and management of human activities within this area. Improvements could include for example, improving the monitoring of fisheries, regularly assessing the impact of fishing gears allowed in this zone, or preventing the use of gears that could have a negative impact on species that sustain the food web. Likewise, monitoring other human activities, such as the tourism, is important. Inadequate tourism practices can negatively impact marine fauna by altering habitat use or distribution patterns of marine species.
5. The implementation of at-sea surveys in Peru is a feasible monitoring activity. However, bureaucratic hurdles in obtaining permits may pose significant limitation due to the lack of clear regulations for conducting these types of studies. The participation of fishermen (e.g, through mobile apps, participatory monitoring, citizen science programs), would likely help avoid reduce costs and increase engaging of key stakeholders.
6. The introduction of the online Cybetracker app within the fishing community of Pucusana marks the potential beginning of a citizen science program aimed at collecting data on Burmeister's porpoise and small cetaceans. This initiative could later be expanded to include other ports. Engaging fishers in data collection offers an opportunity to establish continuous monitoring, which could enhance our understanding of the habitat use and distribution of porpoises and dolphins, as well as identify potential seasonal variations. Additionally, such a program can raise awareness among fishers about small cetacean conservation, possibly leading to the collaborative development and implementation of bycatch mitigation strategies. However, one of the main challenges of citizen science programs is the rigor and validity of the data collection process (Garcia-Soto et al., 2017). Continuous training and supervision of fishers, along with cross-validation of data collected are key to maintaining data accuracy and reliability. This could be accomplished, for example, by encouraging photo documentation of bycatch or sighting events when possible. Finally, citizen science provides a way to overcome the bureaucratic obstacles associated with the implementation of at-sea surveys.

OUTREACH OUTPUTS

1. Infographics about small cetacean species and main project results have been and will continue to be produced and shared through ProDelphinus social media (see below).



2. On the last day of field work, Clara Ortiz Alvarez shared the preliminary survey results with the fishing crew and introduce the online version of the Cybertracker app (**Figure 12**). Organising a presentation to other fishers in the community proved challenging in February due to the high level of fishing activity during this period, which limited their availability to participate.

Figure 12. Presentation of preliminary results to crew members after successful completion of the field surveys.

3. Although it was not possible to coordinate a presentation with fishers during the project period due fishers time limitation. Instead, we presented the results in a conference of educators called "Risunchis", held in Pucusana, and organized by the Association "Creation Space from the Arts Peru – EsCaPe". Two members of the Pro Delphinus team conducted a presentation focused on the biology of small cetaceans along with some details and preliminary results of the project focused mainly on the port of Pucusana. Among the participants were journalists, teachers of all educational levels, psychologists, graphic designers and biologists who work as educators. Of particular importance to the project was the participation of teachers from the Miguel Grau Seminario 6009 and Manuel Calvo Pérez school which have the largest student populations in Pucusana, with many students likely joining the fishing sector as their job in the near future. The workshop had the participation of 27 attendees (e.g., teachers, journalists) from a multidisciplinary range of subjects and included a round of questions related to the exhibition. The exchange produced a series of suggestions for initiatives and comments from the teachers who wanted to apply the subject matter in their classes in different ways such as: the use of informative materials in various subjects such as art, mathematics, literature (writing stories), among others; use of applications to monitor marine species in support of children, promoting knowledge of local species and, above all, to bring the scientific method to the various activities they carry out in their classes. We recommend recurrent exchanges like this in schools to promote knowledge, science and conservation of threatened species and to support teachers in using local examples to illustrate the multidisciplinary aspects of sustainability.

Figure 13. Presentation to teachers during ‘Risunchis’ event in Pucusana.

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Appendix: Project photographs

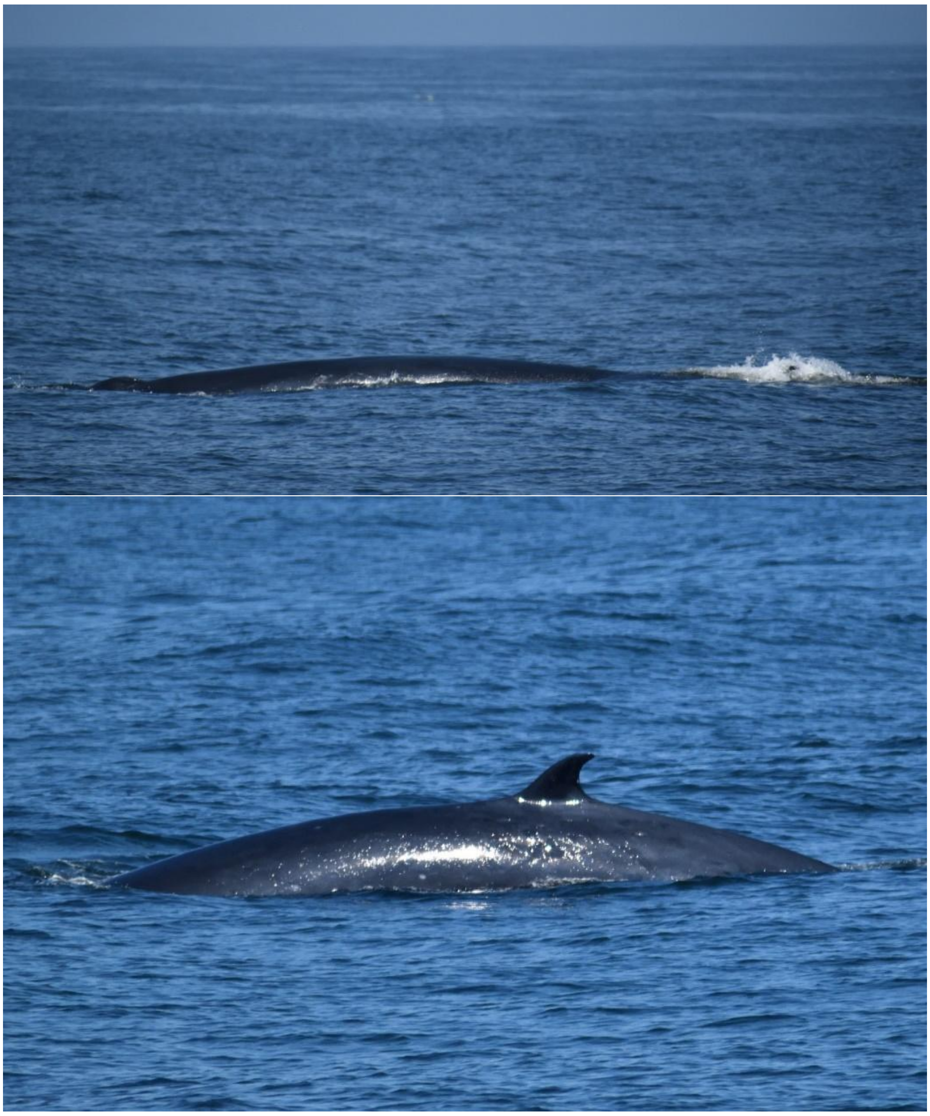
(left) Crew members recording data using the Cybertracker app and observers standing at the viewing platform. (right) The survey team on the first and last days of at-sea surveys.

(left) Survey vessel and Mr. Feliciano, captain of the vessel. (right) Crew members deploying the hydrophone and team members before starting one our last surveys.

Some marine mammals sighted during at-surveys in Pucusana

Dusky dolphins (*Lagenorhynchus obscurus*)

Common dolphins (*Delphinus delphis*)



Baleen whales

South American sea lion (*Otaria byronia*)