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Seabird bycatch by small-scale fisheries in Ecuador and Peru

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ABSTRACT

Fisheries bycatch is the primary anthropogenic threat to many seabird species at sea but its incidence in small-scale fisheries is little studied. We detail the first at-sea monitoring of interactions of seabirds with small-scale longline and gillnet fisheries in Ecuador and Peru. A total of 115 seabirds were captured during monitoring of 450 longline (seven fisheries) and 213 gillnet trips (two fisheries). Five of the nine monitored fisheries had seabird bycatch (four longline and one gillnet). Bycatch included at least 16 species, including one Critically Endangered, one Endangered, six Vulnerable, and four Near Threatened species. Of the fisheries with bycatch, c. 10% of trips and 3% of sets had bycatch. Seabird mortality rates were 14 - 80%. Bycatch rates for the Ecuadorian longline fisheries (Mean ± SD; 0.105 ± 0.644 seabirds 1000 hooks^{-1} and 0.241 ± 1.259 seabirds 1000 hooks^{-1}) were approximately 3 - 10x higher than those for Peruvian longline fisheries. Given the vast sizes and distributions of these fisheries and the observed catch rates of seabirds, many of which are globally threatened, we conclude that to better understand and mitigate these interactions there is an urgent need for more intensive, regional efforts, some of which are currently underway.

1. INTRODUCTION

Fisheries bycatch is the primary anthropogenic threat to many seabird species at sea but its incidence in small-scale fisheries is little studied (Tuck et al. 2001, Lewison et al. 2004, Moreno et al. 2006, Soycan et al. 2008, Zydelis et al. 2009). In comparison, the bycatch of seabirds in industrial longline and net fisheries has been widely documented (Brothers 1991, Nel & Taylor 2003). Given the global distribution of small-scale fisheries, there is growing concern about the impacts they may be having on populations of seabirds and of other long-lived species such as marine mammals and turtles (Peckham et al. 2007, Mangel et al. 2010, Alfaro-Shigueto et al. 2010, Cardoso et al. 2011).

Small-scale fisheries along the Pacific coast of South America are extensive (Alvarez, 2003). In Ecuador and Peru there are an estimated 15,000 and 10,000 small-scale fishing vessels in operation, respectively (Arriaga & Martinez 2003, Alfaro-Shigueto et al. 2010). The 10,000 vessel fleet size for Peru represents a 54% increase from 1995 to 2005, with the longline fishery growing by 357% over the same period (Escudero 1997, Estrella 2007, Alfaro-Shigueto et al. 2010). These fisheries are difficult to monitor because they are typically open access, widely distributed, often work from remote locations, and are subject to weak management and enforcement regimes (Salas et al. 2007; Berkes 2001, Chuenpagdee et al. 2006).

Documentation of seabird interactions with these fisheries is limited and largely from shore based surveys and interviews with fishermen (Majluf et al. 1991, Jahncke et al. 2001, Baquero 2009, pers. comm.). These authors found that considerable levels of bycatch may have been occurring in both longline and gillnet fisheries and may have been impacting threatened species including albatrosses and penguins. More recently, Awkerman et al. (2006) reported that incidental and direct take of waved albatrosses (*Phoebastria irrorata*) by Peruvian small-scale fisheries may have accounted for the increased adult mortality observed at the nesting colony.

The objective of this working document was to describe and quantify, through the use of onboard observers, the bycatch of seabirds by these small-scale fleets. Particular emphasis was placed upon monitoring fishery interactions with the Critically Endangered waved albatross. An additional objective was to monitor the distribution, abundance and behavior of waved albatrosses around the fishing vessels. This work also addresses various recommended priority actions of the Waved Albatross Action Plan (items 6.1.1, 6.1.2, 6.1.4, 6.4.5).

2. METHODS

2.1 Onboard observer scheme

Seabird bycatch and fishing effort data were collected by onboard observers. All observers were biologists, fisheries technicians or fishermen trained in relevant data collection methods, including seabird identification. Data were gathered on the specific gear used (longline or gillnet), the timing and position (using GPS) of each set, and any bycatch occurring. Bycatch characteristics recorded included timing of event (set, soak, haul), species and quantity of bycatch, location of hooking or entanglement (beak, wing, etc.), and state (live, dead) and fate (released alive, discarded dead, etc.) of the seabird. All observers were equipped with cameras and photographed unusual or unidentifiable captures for later species identification. Observers did not participate in fishing activity and the crews and vessels that hosted observers were all voluntary participants in the project.

Observers also conducted periodic counts of waved albatross (WAAL) abundance and behavior around the fishing vessel. Observers in Ecuador and Peru conducted set and haul counts that entailed counting all WAAL around the vessel at the time of the completion of either the setting or hauling of gear. Additionally, observers in Peru monitored WAAL behavior around gillnets. This consisted of quantifying the number of WAAL in the area of the vessel, within 5m of the net, those that made contact with the net, and if any food was retrieved from the net. Times, positions, water and weather conditions were also recorded for each event. Peru based observers also conducted hourly 10 minute transect counts of WAAL and other seabirds in the vicinity of the vessel as it was traveling to or from port or moving between set locations.

2.1.1 Ecuador: From November 2008 to April 2011 a total of 354 fishing trips (900 sets, 568 fishing days) were monitored for seabird bycatch in Ecuador (Table 1, 2, Figure 1a). Trips monitored were on longline and driftnet fishing vessels operating from the ports of Santa Rosa (02.21S 80.96W) and Anconcito (02.33S 80.89W). Surface, midwater and demersal longline fisheries were monitored and targeted yellowfin tuna (*Thunnus albacares*), dolphinfish (*Coryphaena hippurus*), escolar (*Lepidocybium flavobrunneum*), South Pacific hake (*Merluccius gayi*), and Pacific bearded brotula (*Brotula clarkae*). Driftnet vessels monitored were targeting skipjack tuna (*Katsuwonus pelamis*), striped bonito (*Sarda orientalis*), and dolphinfish. Detailed diagrams of these gear types are provided in Appendix A.

2.1.2 Peru: From May 2005 to May 2011 a total of 309 fishing trips (2156 sets, 1990 fishing days) were monitored for seabird bycatch in Peru (Table 1, 2, Figure 1b,c). Trips monitored were on longline and driftnet fishing vessels operating from the ports of Salaverry (08.23S, 78.98W) and longline vessels from the port of Ilo (17.65S, 71.35W). Driftnet vessels targeted primarily blue (*Prionace glauca*), shortfin mako (*Isurus* oxyrinchus), thresher (*Alopias vulpinus*), and smooth hammerhead sharks (*Sphyrna zygaena*), and eagle rays (*Myliobatis* spp.). Longline vessels set their gear at the ocean surface and seasonally targeted either blue and mako sharks (March to November) or dolphinfish (December to February). Ilo based vessels regularly move along the Peru coast to exploit the annual southerly movements of dolphinfish and as a result observers in this fleet also worked out of the ports of Chimbote (09.08S 78.60W), Ancon (11.77S 77.17W), Callao (12.05S, 77.13W), Pucusana (12.48S, 76.78W), and Matarani (16.99S, 72.12W). A detailed summary of characteristics of these gear types is provided in Appendix B.

2.2 Data analysis

Observer data were managed in Microsoft Access databases. Bycatch per unit effort (CPUE) was calculated per set for longline and gillnet fisheries and, additionally, per 1000 hooks for longline fisheries. Descriptive statistics are presented as mean ± standard deviation (SD). All spatial analyses and maps were prepared using ESRI ArcMap 9.2. Bathymetric values were obtained from the Global Bathymetric Chart of the Oceans (GEBCO, www.gebco.net, IOCIHO et al. 2003).

3. RESULTS

3.1 Seabird bycatch

Five of the nine monitored fisheries had observed seabird bycatch (Tables 1, 3). These included all three fisheries monitored in Peru: driftnets; surface longlines targeting sharks; and surface longlines targeting dolphinfish. In Ecuador seabird bycatch was observed in the surface longline fishery targeting yellowfin tuna and the demersal longline fishery targeting South Pacific hake.

Five species of albatrosses were observed captured. WAAL were caught by the greatest number of observed fleets: the surface and demersal longline fleets in Ecuador and the Peruvian driftnet fleet. WAAL were the most frequently reported seabird bycatch species in Ecuador while white-chinned petrels were the most common bycatch species in Peruvian fisheries (black-browed albatrosses were the most frequently captured albatross by Peru fisheries). The driftnet fishery in Salaverry had the greatest diversity of seabird bycatch and included albatrosses, petrels, shearwaters, boobies, cormorants, terns and penguins, however it is important to note that the Peru dataset is of longer duration than Ecuador's.

Seabird mortality was highest in the Peruvian driftnet fishery with 80% of seabird bycatch recovered dead (Table 4). This compares with mortality rates of 14% in the Peruvian dolphinfish longline fleet, 25% in the Ecuadorian yellowfin tuna surface longline fleet, 44% in the Ecuadorian South Pacific hake demersal longline fleet, and 55% in the Peruvian shark surface longline fleet (Table 4). Seabirds recovered alive were typically released alive while those recovered dead were discarded. Approximately one third of all recovered seabirds in the Peru driftnet fleet were retained as food. The most frequent hooking location across all longline fisheries was in the throat while wing entanglements were the most frequent cause of capture in driftnets. The majority of bycatch was reported as occurring during the haul for all fisheries except Peruvian surface longlines for sharks.

The spatial distribution of bycatch largely reflects fleet fishing locations. Seabird bycatch in the Peruvian driftnet fleet was clustered over the continental shelf in front of the port (Fig. 2). Albatross bycatch appears clustered along the shelf break in front of both Salaverry and Ilo (Fig. 3). It is also interesting to note that most seabird bycatch by the Ilo fleet occurred directly offshore of the port (Fig. 2) even though a large number of fishing sets, particularly during the shark season, occurred hundreds of kilometers to the south (Fig. 1b). Humboldt penguins were most often caught very near the coast (Fig. 3). Seabird bycatch in the Ecuadorian demersal hake fishery is concentrated in a small area because the fishery targets very specific locations (Fig. 4). Bycatch locations for the surface tuna fleet were more broadly distributed, as is the fishing effort (Fig. 5).

Seabird bycatch rates were lowest by all measures in the Peruvian surface longline fleet for dolphinfish. Each of the other four fleets registered seabird bycatch in c. 10% of trips and 3% of sets (Table 5). Among the four longline fleets, the Ecuador surface fishery for tuna had the highest CPUE at 0.241 ± 1.229 seabirds 1000 hooks^{-1} (range: 0 to 8.3, n = 110), followed by the Ecuadorian demersal fishery for hake at 0.105 ± 0.644 seabirds 1000 hooks^{-1} (range: 0 to 7.5, n = 417), the Peru surface fishery for sharks at 0.084 ± 0.528 seabirds 1000 hooks^{-1} (range: 0 to 7.1, n = 651) and the Peru surface fishery for dolphinfish at 0.011 ± 0.140 seabirds 1000 hooks^{-1} (range: 0 to 3.0, n = 591).

3.2 Waved albatross at-sea abundance

3.2.1 Set and Haul counts: WAAL in the vicinity of the fishing vessel were counted by onboard observers in surface longline vessels in Salaverry, Peru (Sep 2006 to Aug 2007), driftnet vessels in Salaverry, Peru (Apr 2009 to May 2011), and by all observed fisheries in Ecuador (Aug 2010 to Apr 2011). A total of 737 and 734 counts were conducted at the completion of fishing sets and hauls, respectively (Table 6, Fig. 6a). In Peru and Ecuador, WAAL were present in 39% and 67% of counts at the end of the set, respectively. WAAL were present in 57% and 77% of counts completed at the end of the haul for Peru and Ecuador, respectively. Over the entire data set, WAAL were approximately three times as abundant during the haul as during the setting of gear (Table 6). WAAL were also approximately three times more abundant during set and haul counts during the 3rd and 4th quarters of the year (Jul to Dec) compared to the 1st and 2nd quarters (Jan to Jun).

3.2.2 Net interactions: Net interactions were monitored in the Peruvian driftnet fleet in Salaverry. WAAL were observed floating near the net on 92% of observed sets (Table 7). During 25% of cases WAAL were seen approaching within 5m of the net. And in 20% of cases there was contact of the WAAL with the net. However, WAAL were only observed obtaining food from the net during 1% of observed instances. Similar to the set and haul counts, numbers of WAAL around the vessel were highest during the 4th quarter of the year and considerably lower the remainder of the year (Table 7).

The number of WAAL in the vicinity of the boat during catch processing (cleaning fish and discarding offal) was also monitored. Catch processing typically occurs at the end of the haul while the boat was either stationary or moving to the next set location. Over the entire study period there were an average of 16 ± 21 WAAL (max: 117, n = 295) counted near the vessel during catch processing (Table 7).

3.2.3 Transect counts: WAAL transect counts were conducted in the Peru driftnet fleet in Salaverry. Over the entire study period WAAL were observed during 60% of 10 minute transect counts. The number observed was stable throughout the study (Table 8, Fig. 6b).

4. DISCUSSION

We provide the first direct, at-sea monitoring of seabird bycatch with small-scale longline and gillnet fisheries in Ecuador and Peru. Bycatch regularly occurred in multiple fisheries and included numerous species categorized as threatened on the IUCN Redlist, including the Critically Endangered waved albatross. We show that, despite numerous challenges, it is possible to rigorously monitor small-scale fisheries and their seabird bycatch using onboard observers.

4.1 Seabird bycatch

The highest longline bycatch rate observed in this study was for the Ecuadorian surface yellowfin tuna fishery (0.241 per 1000 hooks). This was about double the rate observed for the Ecuadorian hake fishery and 3 – 10x higher than the rates observed for the Peruvian longline fisheries. The most frequently captured species in Ecuadorian fisheries was the waved albatross (62% of observed seabird bycatch). This is the first documented bycatch of waved albatrosses by Ecuadorian fisheries and represents a previously unreported source of mortality for the species.

All seabird bycatch observed in the Ecuadorian demersal longline hake fishery occurred from August to December, and all WAAL bycatch occurred in the months of August to October. WAAL bycatch coincided with the peak in set and haul counts observed in the 3rd and 4th quarters of the year seen in both Ecuador and Peru and corresponds with the end of the species' annual breeding cycle which runs from April to December.

The hake fishery occurs at specific fishing locations that serve to aggregate fishing vessels into small areas. Each vessel typically makes three to four sets in a day. This grouping of vessels attracts large congregations of seabirds, including WAAL, that move from vessel to vessel over the course of a day as boats set and haul their gear and discard used bait. This concentration of fishing effort and seabirds leaves the birds prone to entanglement or hooking. In the hake fishery, unlike in the other observed fisheries in Ecuador, during the 3rd and 4th quarters of the year it was common to have groups of 25 to 30 WAAL around the fishing vessels.

As hooked hake are hauled to the surface their swim bladders expand causing them to float. Due to inadequate line weighting, these fish can float at the ocean surface at considerable distances from the fishing vessel. In addition, fishing gear from adjacent boats frequently become entangled, which slows down the haul. These circumstances give seabirds extended opportunities to attempt to pull the fish or unused bait off the hook and this is the main time period during which entanglements and hooking occur in this fishery.

Movements of satellite tracked WAAL (Anderson et al. 2003, see also Fig. 1 of Action Plan for Waved Albatross 2008) as well as the set, haul and transect counts from this study (Fig. 6) indicate that WAAL can be found both near the coast from central the Ecuador to northern Peru and also in more oceanic waters off Northern Peru. These movements put the WAAL at risk of interacting with the fishing fleets operating in southern Ecuador as well as the longline and gillnet fleets operating in Peru. Set and haul counts clearly showed that WAAL aggregate at the fishing vessels. In Peru, these densities were much higher than WAAL counted during transect counts, suggesting that WAAL from a large area are attracted to fishing activity, particularly at the end of the haul. As a result, the timing and practice of gear setting and hauling as well as how and when used bait and catch are processed may influence how many seabirds attend the vessel and presents potential opportunities to implement bycatch mitigation measures.

While there were no observed captures of WAAL by Peruvian longline vessels, these vessels did have bycatch of other albatross species. This suggests that longline bycatch of waved albatrosses may occur, but more intense observer effort within the WAAL distribution would be necessary. However, to some degree, the relatively coastal foraging distribution of WAAL in Peru may serve to segregate them from longline fishing grounds which are typically in oceanic waters.

Seabird bycatch in the observed Peruvian longline fisheries consisted almost exclusively of albatrosses and white-chinned petrels. The most frequently captured albatross species was the black-browed albatross (47% bycatch in the shark fishery) but also included Chatham, grey-headed and Buller’s albatrosses. Bycatch in this fishery was concentrated in southern Peru but this is likely due in part to the fact that the majority of monitored sets occurred out of the port of Ilo. Bycatch in the driftnet fishery observed out of Salaverry also included bycatch of three species of albatrosses, including the WAAL, and also included regionally important species like penguins and guano birds as well as long distance migrants like pink-footed and sooty shearwaters. Gillnets had the highest mortality rate (80%) among the observed fisheries and was the only fishery in which a large percentage of bycatch was retained for human consumption. This may be due to a combination of potentially linked factors: gillnet vessels often embark with limited food supplies and some of the species captured, Humboldt penguins and guanay cormorants in particular, are regularly eaten in some coastal communities.

4.2 Regional impacts

The small-scale hake fishery in Ecuador is a relatively young fishery which only became operational within the last 5 years. The hake fleet in Santa Rosa comprises 15 to 25 boats, depending upon the season (Table 9), operating approximately 40 weeks per year and conducting three to four sets per trip. WAAL accounted for 65% of all seabird bycatch in this fleet. A conservative estimate of 2,400 trips per year (20 vessels x 40 weeks x 3 trips weekly) yields 264 trips with seabird bycatch (11% trips with bycatch, Table 6) from Santa Rosa alone. Although there are seasonal hake fisheries in Anconcito and Las Piñas, Santa Rosa's fleet is the largest, and the WAAL is markedly less common in the northern part of Ecuador, near Las Piñas.

Onboard observer effort in the Ecuadorian surface longline tuna fishery was comparatively low. But given the high bycatch rate observed and the larger fleet size (150 vessels in Santa Rosa alone, Table 9) it is of concern and warrants further attention. Taken together, WAAL mortality from these two fisheries may help explain the increase in adult mortality observed at the nesting colony (Awkerman et al. 2006).

In Peru, longline fisheries are the fastest growing sector of small-scale fisheries. The fleet has grew by over 350% from 1995 to 2005 (Alfaro-Shigueto et al. 2010) and annually sets approximately 80 million hooks. The focus of that growth has been in the ports of Paita and Ilo in the extreme north and south of the country, respectively. Given the catch rates observed in this study, the annual bycatch of seabirds likely numbers in the low thousands, approximately half of which would be albatrosses, primarily black-browed albatrosses. However, there is limited documentation of the small-scale fisheries operating from Chimbote north to the Ecuador border, that area which overlaps with the WAAL distribution (Anderson et al. 2003).

Annual gillnet fishing effort in Peru is c. 60,000 trips (Estrella et al. 1999, 2000). It is likely, given the catch rates observed here, that seabird bycatch in Peruvian net fisheries exceeds 10,000 seabirds annually.

4.3 Conclusions & Next steps

The small-scale fisheries monitored in this study varied in terms of fishing methods, spatial and temporal distributions, and target species, making it difficult to assess the scale of their impacts. Also, the logistical constraints associated with work in these fisheries (e.g., remoteness of the ports, small vessels) created additional challenges to our work. Nevertheless, we have shown the usefulness of onboard observer programs in assessing seabird bycatch in small-scale fisheries. Future work in these fisheries can benefit from the baseline data developed here on the fisheries themselves and their impact upon threatened seabird populations.

This collaborative, bi-national study has provided valuable information on at-sea threats to seabirds, WAAL in particular. Large datasets, such as those from RFMOs, can provide additional information and help widen the scope of our understanding of the WAAL pelagic and coastal distribution, and assist in identifying areas of high fishing effort throughout its distribution.

This study has presented results from onboard observer work in nine small-scale fisheries in Ecuador and Peru. Some of these had higher observer coverage than others and these fleets are a subset of the small-scale fisheries operating in the area. We recommend that similar programs be implemented in those fisheries with limited or no available bycatch assessments (i.e. Ecuadorian surface longlines for yellowfin tuna and surface longlines for sharks/dolphinfish in northern Peru), in particular those that overlap with the distribution of the WAAL.

This work was guided in part by the recommended priority actions identified by the Waved Albatross Action Plan, especially those related to bycatch and spatio-temporal assessments. There remain other threats and mortality sources also identifies in the Plan (such as the intentional take for human consumption), that remain to be addressed and further contextualized.

As this work has proceeded and our understanding of seabird bycatch has improved, potential mitigation measures have been identified and trials are currently underway or planned for the near future. These include (1) bottomset net lighting trials to reduce sea turtle and seabird bycatch, (2) introduction of weighted swivels into the Peruvian surface longline fleets to increase branchline sink rates and improve gear efficiency, and (3) trials with alternate weighting regimes in the Ecuadorian demersal hake fishery to increase sink rates and reduce the time hooked hake are at the surface, and to minimize the distance to the vessel at which the fish reach the surface.

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Table 1. Summary of observer effort by country and fishery.

Country	Fishery	Target species	Trips	Sets	Hooks	Fishing Days	Monitoring Period	Fishing season	Seabird bycatch?
Ecuador	Surface longline	Yellowfin tuna	47	110	20,807	97	May 2009 – Nov 2010	Aug - Dec	Yes
	Surface longline	Dolphinfish	27	64	25,880	55	Nov 2008 – Apr 2010	Dec – Mar	No
	Midwater longline	Escolar	56	111	48,082	111	Feb 2009 – Oct 2010	Jun - Dec	No
	Demersal longline	South Pacific hake	127	417	165,818	128	Sep 2009 – Apr 2011	Year-round	Yes
	Demersal longline	Pacific bearded brotula	17	33	69,682	17	Aug 2010 – Nov 2010	Year-round	No
	Driftnet	Bonito & dolphinfish	80	165	n/a	160	Nov 2008 – Apr 2011	Year-round	No
		SUBTOTAL	354	900	330,269	568			
Peru	Surface longline	Shark	87	651	536,158	647	May 2005 – May 2011	Mar - Nov	Yes
	Surface longline	Dolphinfish	89	591	601,840	544	May 2005 – May 2011	Dec - Feb	Yes
	Driftnet	Shark & ray	133	914	n/a	799	May 2005 – May 2011	Year-round	Yes
		SUBTOTAL	309	2,156	1,137,998	1,990			
		TOTAL	663	3,056	1,468,267	2,558			

Table 2. Summary of observed fisheries by country, fishing gear type and target species.

Country	Fishery	Target species		
		Spanish	English	Latin
Ecuador	Surface longline	Albacora	Yellowfin tuna	*Thunnus albacares*
	Surface longline	Dorado/perico	Dolphinfish	*Coryphaena hippurus*
	Midwater longline	Miramelindo	Escolar	*Lepidocybium flavobrunneum*
	Demersal longline	Merluza	South Pacific hake	*Merluccius gayi*
	Demersal longline	Corvina de roca	Pacific bearded brotula	*Brotula clarkae*
	Driftnet	Bonito barillete Bonito sierra Dorado/perico	Skipjack tuna Striped bonito Dolphinfish	*Katsuwonus pelamis* *Sarda orientalis* *Coryphaena hippurus*
Peru	Surface longline	Tiburon azul Tiburon diamante	Blue shark Short-fin mako shark	*Prionace glauca* *Isurus oxyrinchus*
	Surface longline	Dorado/perico	Dolphinfish	*Coryphaena hippurus*
	Driftnet	Tiburon azul Tiburon diamante Tiburon zorro Tiburon martillo Raya aguila	Blue shark Short-fin mako shark Thresher shark Smooth hammerhead Eagle ray	*Prionace glauca* *Isurus oxyrinchus* *Alopias vulpinus* *Sphyrna zygaena* *Myliobatis* spp.

Table 3. Summary of seabird bycatch by country and fishery. Fishery abbreviation "LL" refers to longline fisheries. Capture species IUCN conservation status is listed in parenthesis*. ACAP Annex 1 species are in bold.

		Ecuador		Peru		
Common name	Latin name	LL-demersal for hake	LL-surface for tuna	Driftnet for shark & ray	LL-surface for shark	LL-surface for dolphinfish
Waved albatross (CR)	*Phoebastria irrorata*	11	2	1	-	-
Black-browed albatross (EN)	*Thalassarche melanophris*	-	-	2	18	-
Chatham albatross (VU)	*Thalassarche eremita*	-	-	-	1	-
Grey-headed albatross (VU)	*Thalassarche chrysostoma*	-	-	1	1	-
Buller's albatross (NT)	*Thalassarche bulleri*	-	-	-	2	-
White-chinned petrel (VU)	*Procellaria aequinoctialis*	-	-	12	14	4
Parkinson's petrel (VU)	*Procellaria parkinsoni*	1	1	-	-	-
Storm petrel	*Oceanodroma* spp.	-	-	-	1	3
Unidentified petrel	-	-	-	2	-	-
Peruvian booby (LC)	*Sula variegata*	-	-	1	-	-
Blue-footed booby (LC)	*Sula nebouxii*	3	1	1	-	-
Guanay cormorant (NT)	*Phalacrocorax bougainvillii*	-	-	14	-	-
Southern skua (LC)	*Catharacta antarctica*	-	-	-	1	-
Inca tern (NT)	*Larosterna inca*	-	-	1	-	-
Humboldt penguin (VU)	*Spheniscus humboldti*	-	-	4	-	-
Pink-footed shearwater (VU)	*Puffinus creatopus*	2	-	4	-	-
Sooty shearwater (NT)	*Puffinus griseus*	-	-	6	-	-
	TOTAL	17	4	49	38	7

*CR=critically endangered, EN=endangered, NT=near threatened, VU=vulnerable, LC=least concern

Table 4. Summary by country and fishery of the mortality rates, capture times, locations of hooking or entanglement and final uses of all seabirds captured during the study. Fishery abbreviation "LL" refers to longline fisheries.

				Capture time (%)				Hook/entangle location (%)					Use (%)			
Country	Fishery	Total captures	% dead	Set	Soak	Haul	Unknown	Beak	Throat	Chest	Wing	Other	Released	Discarded	Eaten	Other
Ecuador	LL demersal: hake	17	44	47	-	53	-	-	100	-	-	-	56	44	-	-
	LL surface: tuna	4	25	-	-	100	-	25	75	-	-	-	75	25	-	-
Peru	Driftnet: shark & ray	49	80	2	41	53	4	11	11	11	47	21	20	41	35	4
	LL surface: shark	38	55	18	29	47	5	42	50	3	-	6	42	53	-	6
	LL surface: dolphinfish	3	14	-	57	43	-	25	75	-	-	-	75	25	-	-

Table 5. Observed seabird catch per unit effort (CPUE; mean ± SD) by country, fleet and target species. Fishery abbreviation "LL" refers to longline fisheries.

Country	Fishery	CPUE (catch set^{-1})	CPUE (1000 hooks^{-1})	% trips with bycatch	% sets with bycatch
Ecuador	LL-demersal: hake	0.041 ± 0.242 (range: 0 - 3; n= 417)	0.105 ± 0.644 (range: 0 - 7.5; n= 417)	11.0	3.4
	LL-surface: tuna	0.036 ± 0.188 (range: 0 - 1; n= 110)	0.241 ± 1.259 (range: 0 - 8.3; n= 110)	8.5	3.6
Peru	Driftnet: shark & ray	0.054 ± 0.526 (range: 0 - 12; n= 914)	n/a	10.5	2.5
	LL-surface: shark	0.058 ± 0.363 (range: 0 - 5; n= 651)	0.084 ± 0.528 (range: 0 - 7.1; n= 651)	12.6	3.7
	LL-surface: dolphinfish	0.012 ± 0.148 (range: 0 - 3; n= 591)	0.011 ± 0.140 (range: 0 - 3.0; n= 591)	4.5	0.85

Table 6. Waved albatross counts (mean ± SD) at the completion of gillnet setting and hauling pooled by quarter. Quarters were defined as: Jan-Mar=Q1, Apr-Jun=Q2, Jul-Sep=Q3, Oct-Dec=Q4.

Peru: Driftnet (April 2009 to May 2011)

	Q1	Q2	Q3	Q4
SET	2.3 ± 5.6 (max: 49, n= 79)	2.3 ± 3.8 (max: 21, n= 118)	4.2 ± 6.4 (max: 25, n= 44)	10.3 ± 12.6 (max: 57, n= 101)
HAUL	7.2±15.1 (max: 117, n= 79)	10.3 ± 15.9 (max: 69, n= 118)	13.1 ± 16.7 (max: 78, n= 44)	25.1 ± 26.1 (max: 91, n= 98)

Peru: Surface longline (September 2006 to August 2007)

	Q1	Q2	Q3	Q4
SET	0.1 ± 0.4 (max: 1, n= 7)	No data (max: nd , n=nd)	2.9 ± 3.1 (max: 12, n= 18)	1.8 ± 2.6 (max: 10, n= 30)
HAUL	0.1 ± 0.4 (max: 1, n= 7)	No data (max: nd, n=nd)	4.2 ± 4.2 (max: 15, n= 21)	4.2 ± 5.5 (max: 20, n= 30)

Ecuador: All fisheries (August 2010 to April 2011)

	Q1	Q2	Q3	Q4
SET	0.0 ± 0.0 (max: 0, n= 12)	0.1 ± 0.3 (max: 1, n= 16)	1.5 ± 2.5 (max: 14, n= 124)	1.1 ± 2.6 (max: 25, n= 188)
HAUL	0.0 ± 0.0 (max: 0, n= 12)	0.5 ± 1.0 (max: 3, n= 16)	8.5 ± 7.3 (max: 32, n= 124)	5.8 ± 6.3 (max: 38, n= 188)

Table 7. Waved albatross behavior and proximity to driftnets and during offal discards. Data are pooled by quarter (mean ± SD), and are for the period of April 2009 to May 2011. Quarters were defined as: Jan-Mar=Q1, Apr-Jun=Q2, Jul-Sep=Q3, Oct-Dec=Q4.

	Q1	Q2	Q3	Q4
All WAAL counted	11.2 ± 17.6 (max: 123, n= 66)	14.6 ± 18.8 (max: 89, n= 100)	17.2 ± 20.3 (max: 78, n= 44)	39.2 ± 37.7 (max: 136, n= 85)
Total within 5m of net	0.3 ± 2.1 (max: 17, n= 66)	1.1 ± 2.6 (max: 15, n= 100)	2.5 ± 5.4 (max: 28, n= 44)	3.3 ± 6.0 (max: 28, n= 85)
Net contact	0.3 ± 1.6 (max: 13, n= 66)	0.8 ± 2.4 (max: 13, n= 100)	1.6 ± 3.4 (max: 17, n= 44)	2.4 ± 4.9 (max: 23, n= 85)
Count during catch processing	8.7 ± 16.1 (max: 117, n= 66)	12.0 ± 16.8 (max: 69, n= 100)	13.0 ± 16.8 (max: 78, n= 44)	27.4 ± 27.1 (max: 91, n= 85)

Table 8. Average numbers (mean ± SD) of waved albatrosses counted during 10 minute transect counts from Salaverry, Peru driftnet vessels traveling to or from port or between fishing sets (April 2009 to May 2011). Quarters were defined as: Jan-Mar=Q1, Apr-Jun=Q2, Jul-Sep=Q3, Oct-Dec=Q4.

	Q1	Q2	Q3	Q4
WAAL Count	1.8 ± 3.8 (max: 35, n= 178)	1.7 ± 5.3 (max: 77, n= 230)	1.6 ± 1.7 (max: 9, n= 116)	1.6 ± 1.9 (max: 11, n= 245)

Table 9. Number of fishing vessels for the Ecuador fishing fleets and ports observed in the study.

Fishery	Port	Target species	# Vessels
Driftnet	Santa Rosa	Bonito, sailfish, marlin, yellowfin tuna	850
Surface longline	Santa Rosa	Dolphinfish	200
Surface longline	Santa Rosa	Yellowfin tuna	150
Demersal longline	Santa Rosa	South Pacific hake	20
Demersal longline	Anconcito	Pacific bearded brotula	5
Midwater longline	Santa Rosa	Escolar	100

Figure 1. Locations of observed fishing sets by country and vessel type.

(a) Ecuador: All fisheries

(b) Peru: Longline

(c) Peru: Driftnet

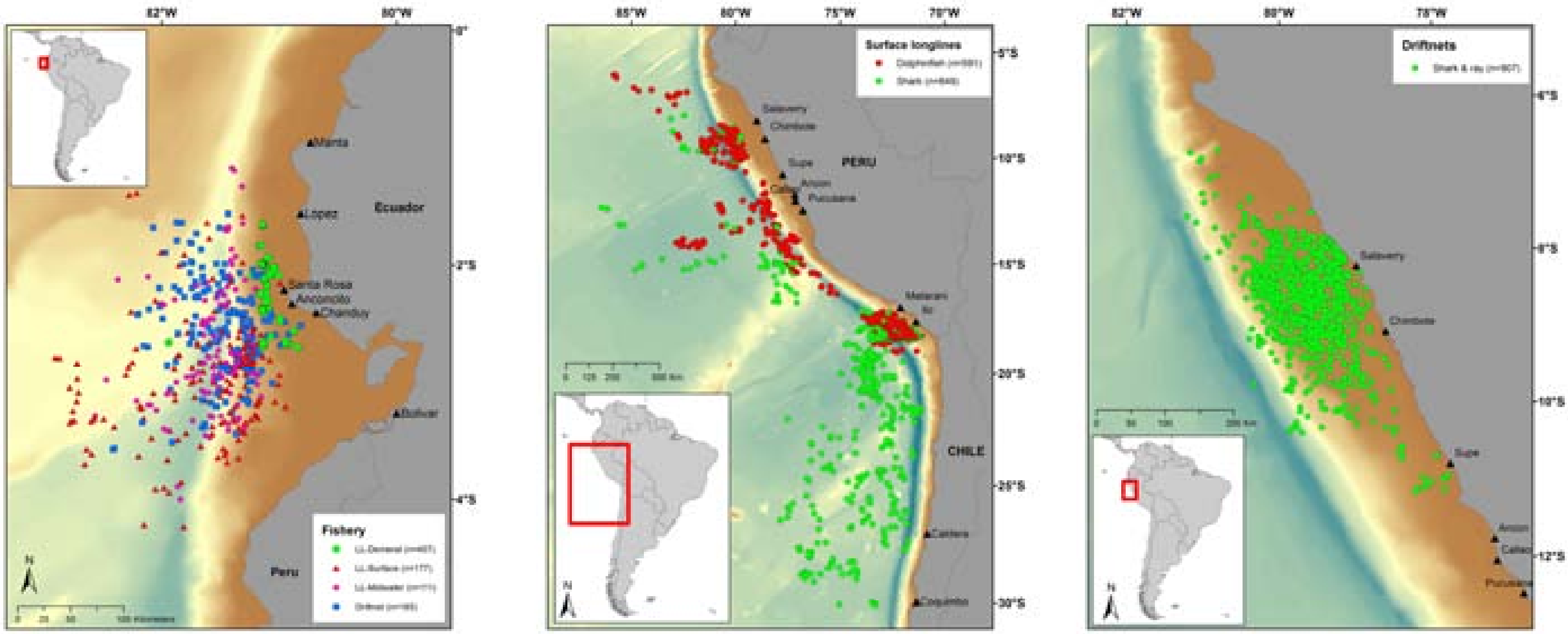


Figure 2. Locations and quantities of observed seabird bycatch by Peruvian surface longlines for shark (red circles, n = 38), surface longlines for dolphinfish (blue circles, n = 7), and driftnets (green circles, n = 49).

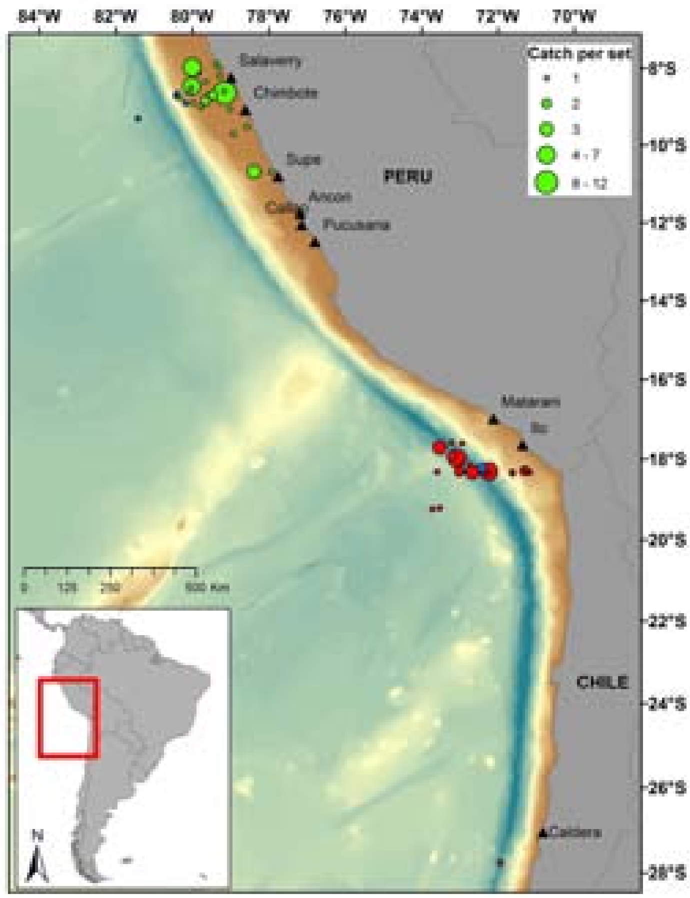


Figure 3. Locations and quantities of seabird bycatch by species groups and pooled for all observed Peru fisheries. (The bycatch of one black-browed albatross off Caldera, Chile is not shown). 1000m and 2000m isobaths are also shown.

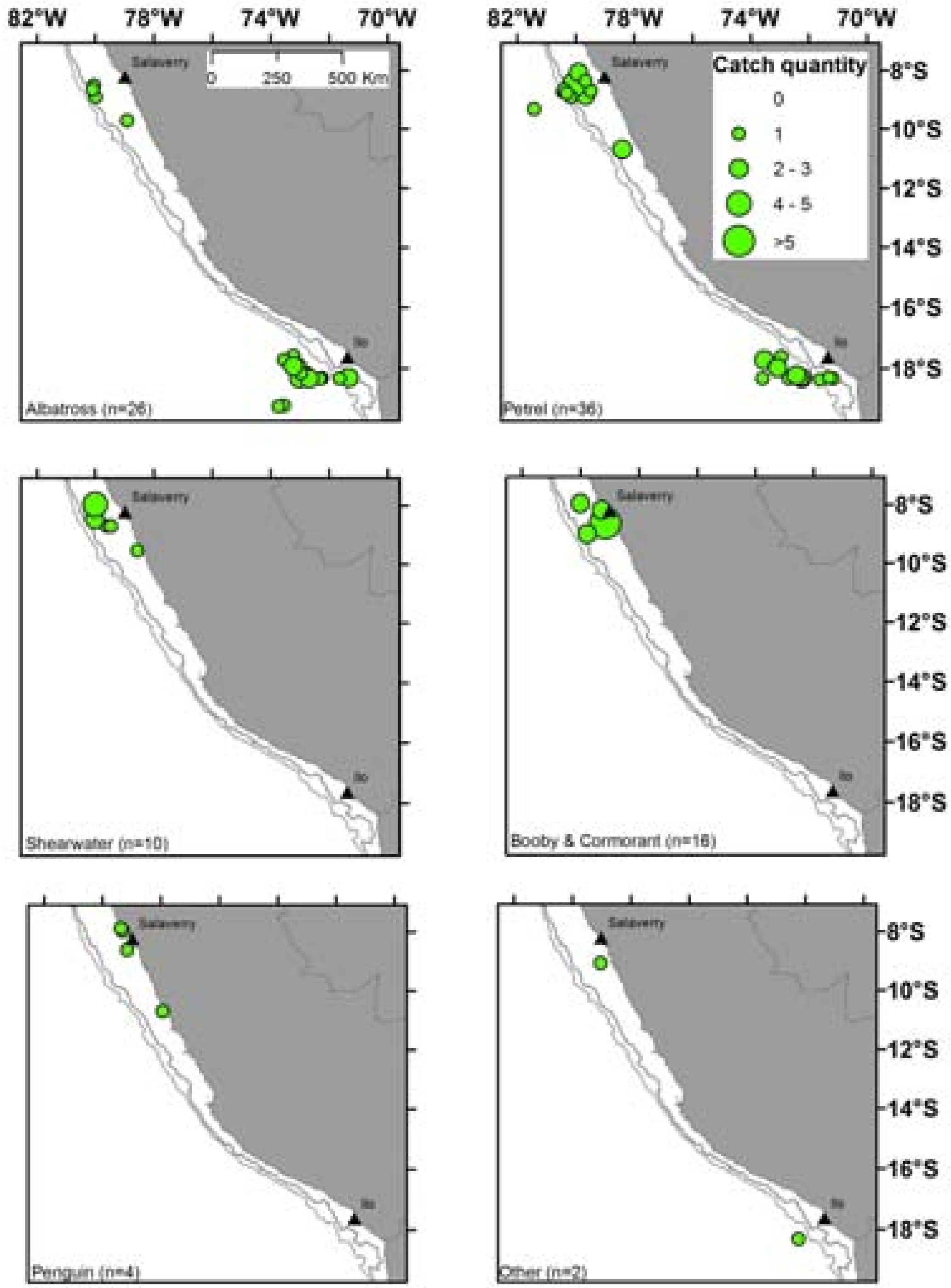


Figure 4. Primary fishing grounds and locations and quantities of seabird bycatch in the South Pacific hake dermersal longline fishery, Ecuador. The four panels to the right each displays one of the four observed bycatch species. The top left panel indicates the six main areas utilized by the hake fishery. 100m, 200m, 500m, 1000m and 2000m isobaths are also shown.

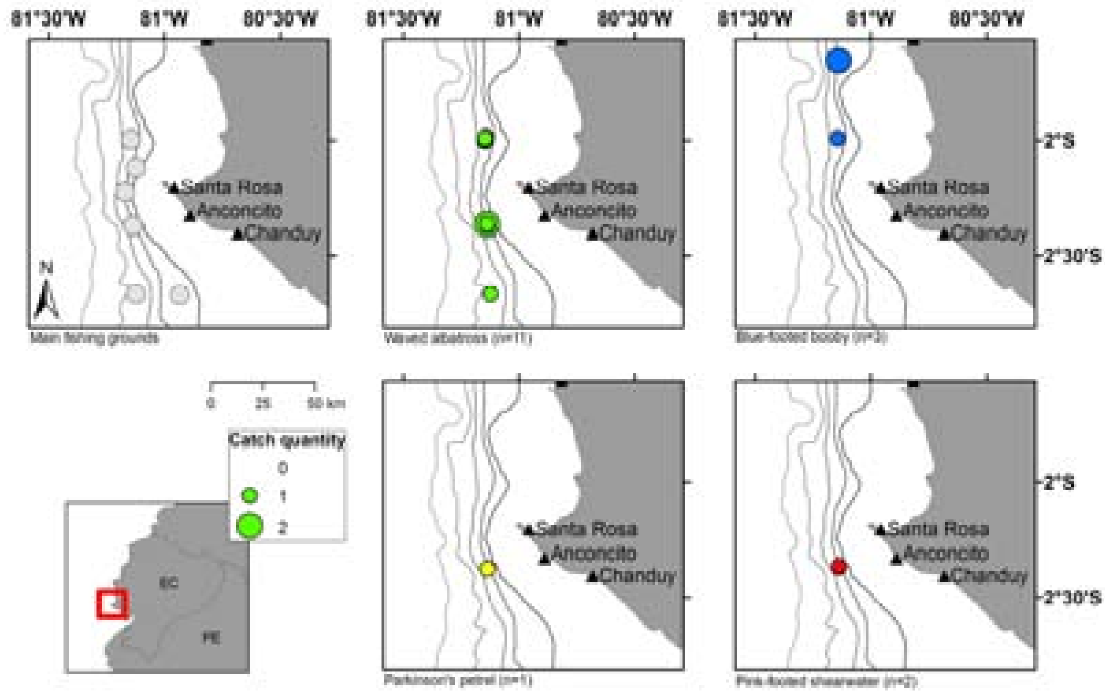


Figure 5. Locations of the four seabirds observed captured in the yellowfin tuna surface longline fishery, Ecuador. Capture species are waved albatrosses (green circles), Parkinson's petrel (yellow circle), and blue-footed booby (blue circle). A minimum convex polygon (grey shading) of all observed tuna sets is also shown. 100m, 200m, 500m, 1000m and 2000m isobaths are also displayed.

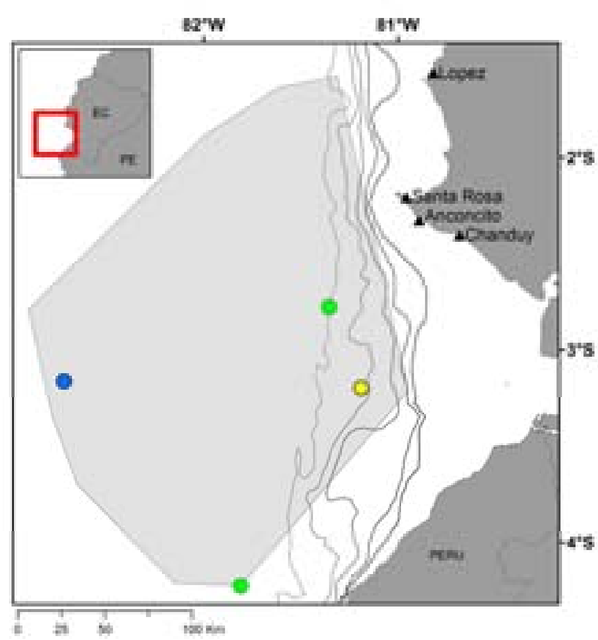
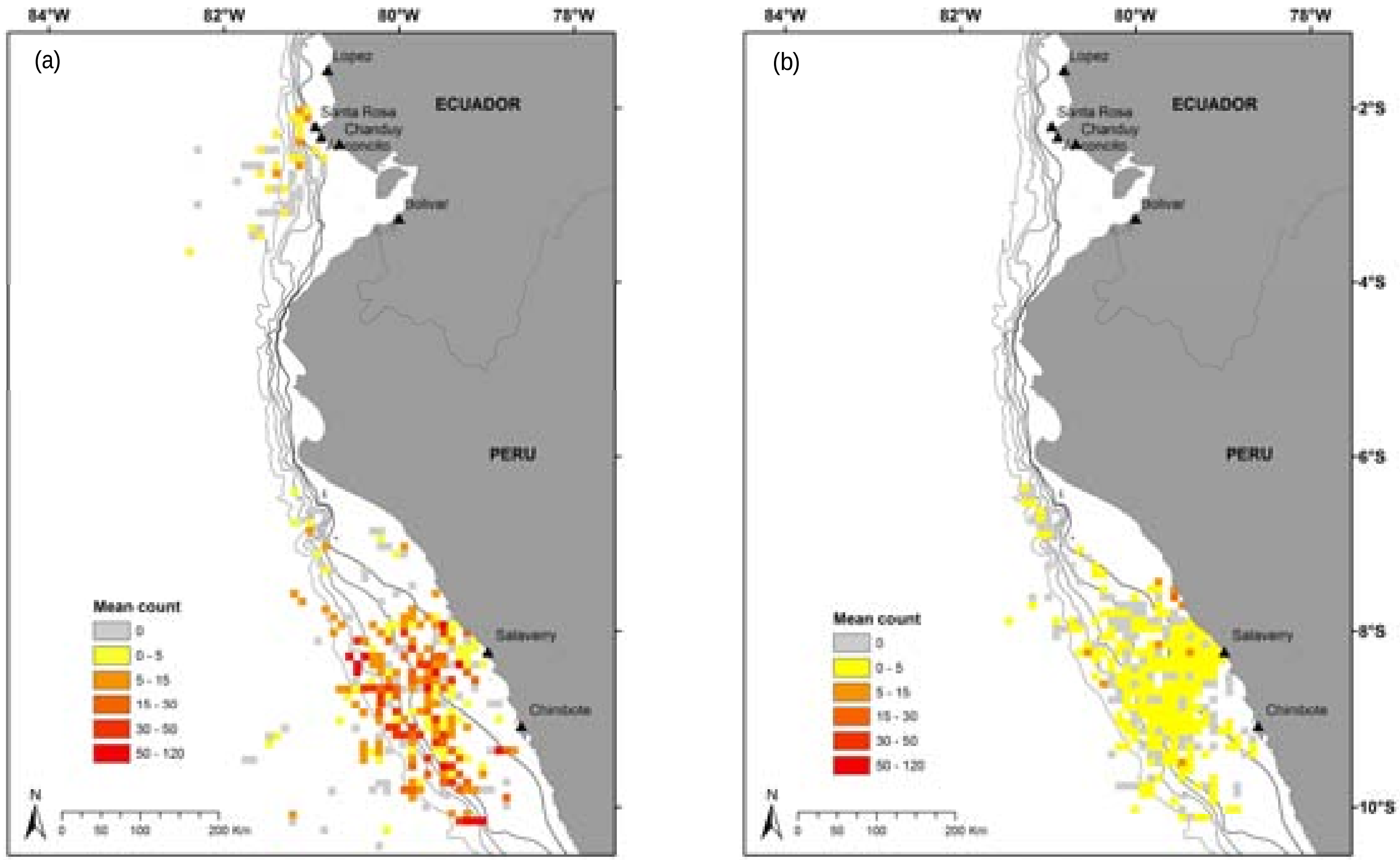


Figure 6. Average number of waved albatrosses counted at end of hauling of fishing gear (n = 339 counts, Pane A) and per 10 minute transect count (n = 772 counts, Pane B). Pane A groups available count data from all observed fisheries in Ecuador and Peru. Transect count data from Pane B are for the Salaverry, Peru driftnet fleet. Data presented are the averages of all counts occurring within each 100km^2 grid cell. Grid cells with zero counts are represented in grey. For annual variation see Table 8. 100m, 200m, 500m, 1000m and 2000m isobaths are also shown.



APPENDIX A: SCHEMATIC DIAGRAMS OF MONITORED FISHING GEARS, ECUADOR

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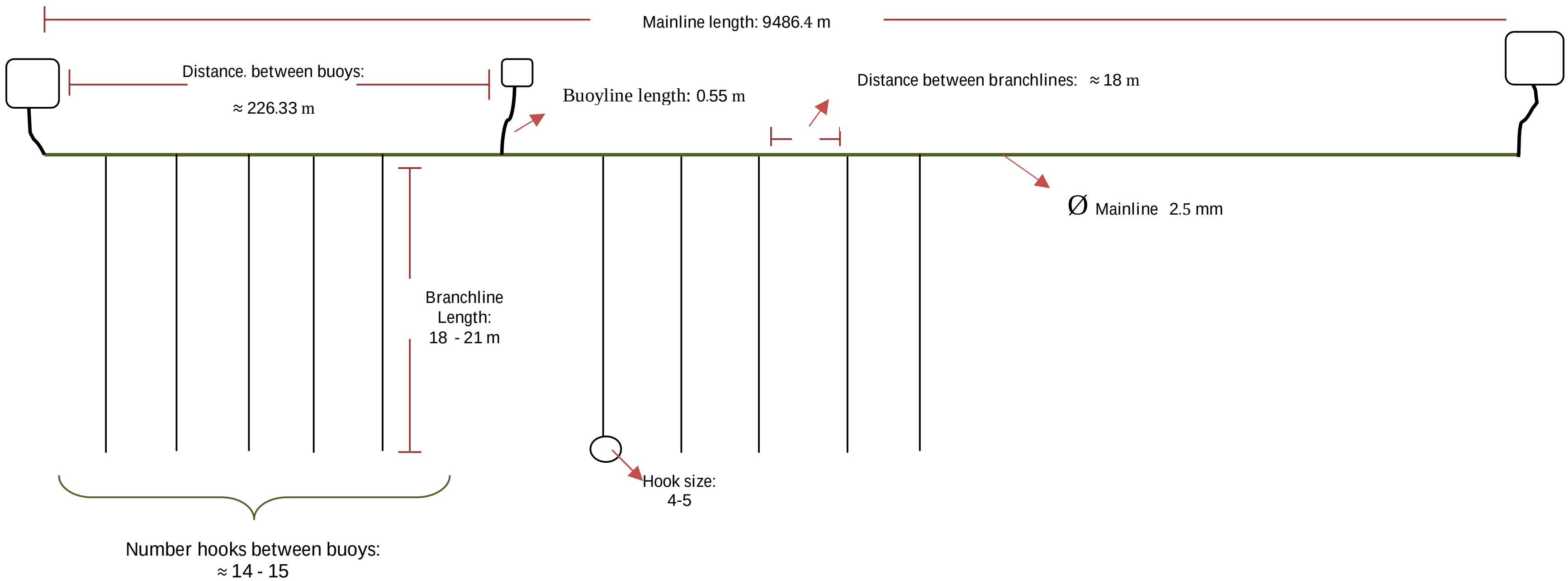
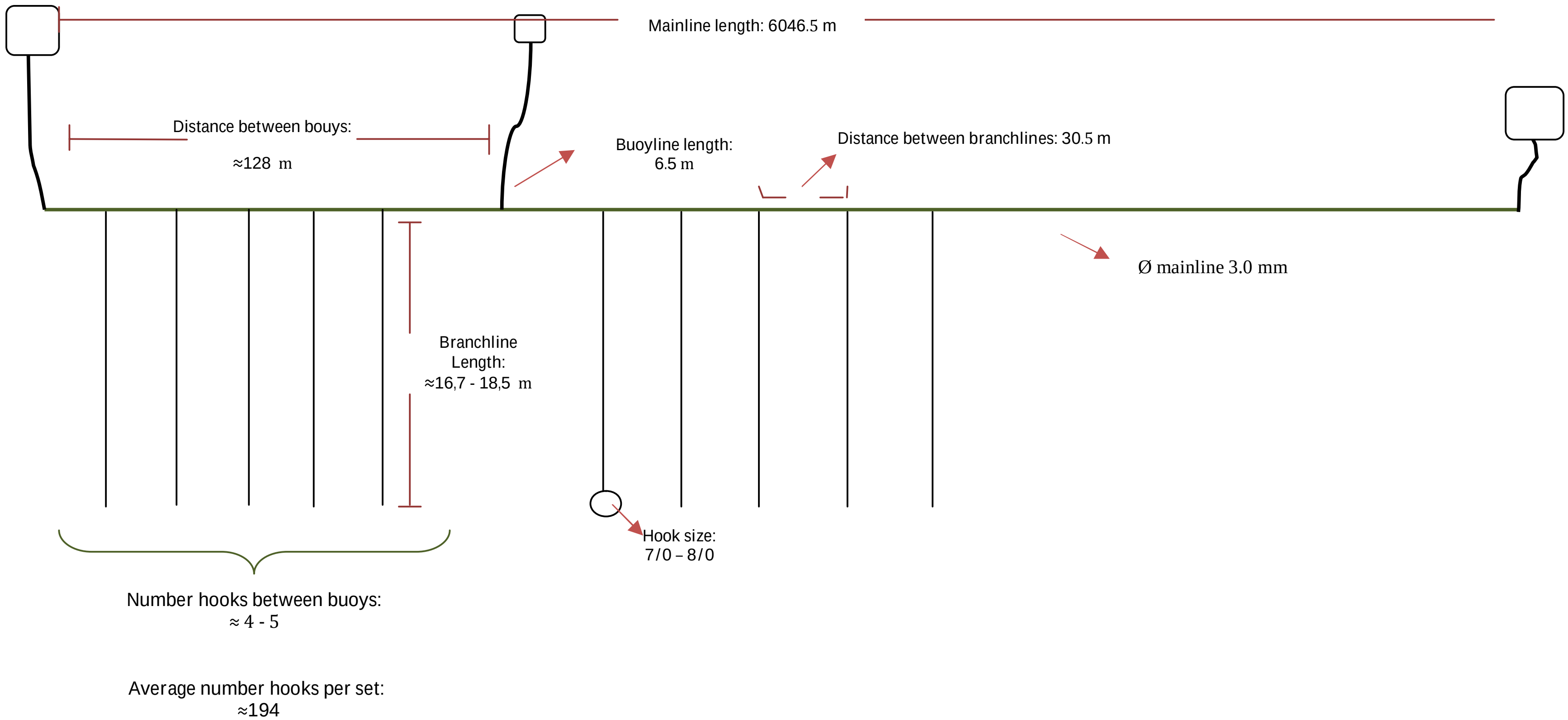
Surface longline: Dolphinfish, *Coryphaena hippurus*

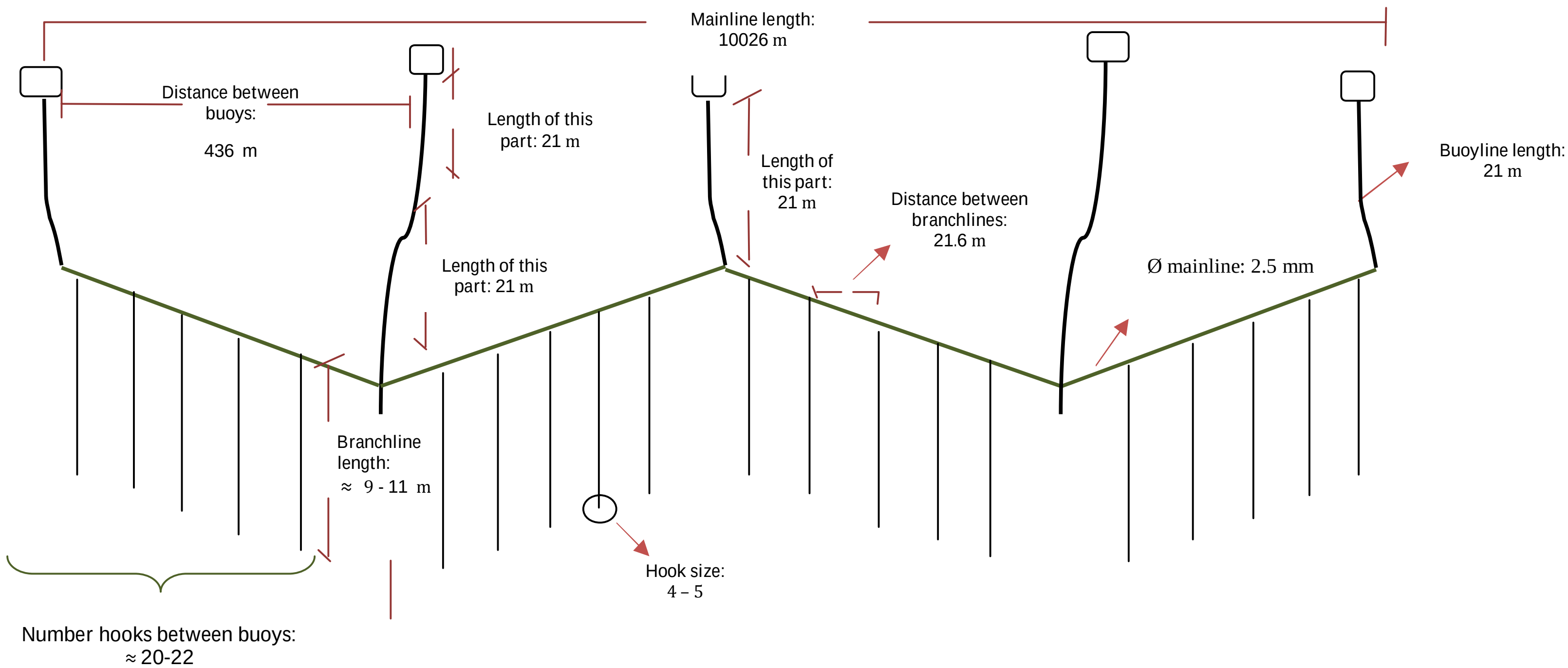


Average number hooks per set:
≈445

Surface longline: Yellowfin tuna, Thunnus albacares

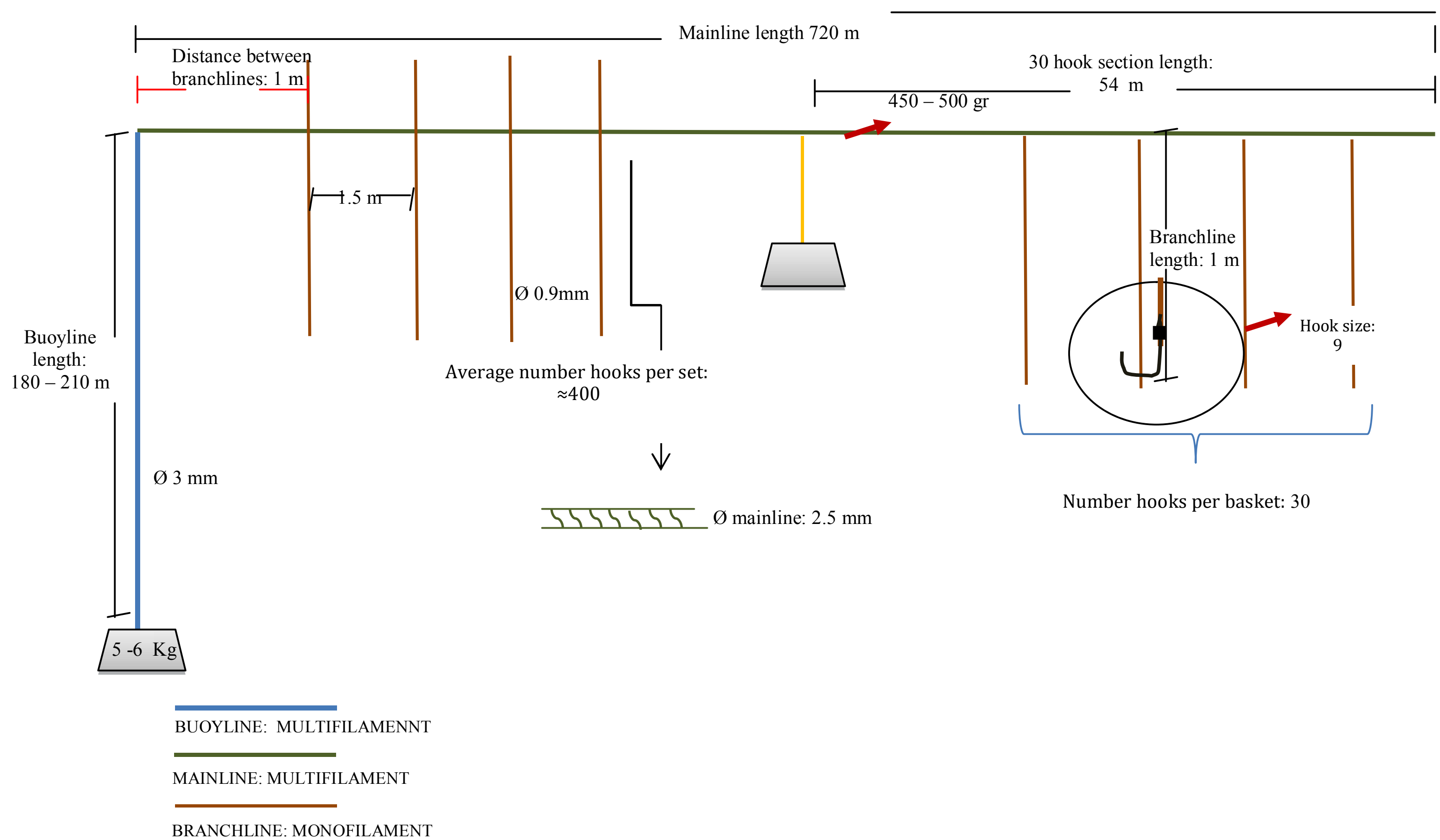


Midwater longline: Escolar, *Lepidocybium flavobrunneum*

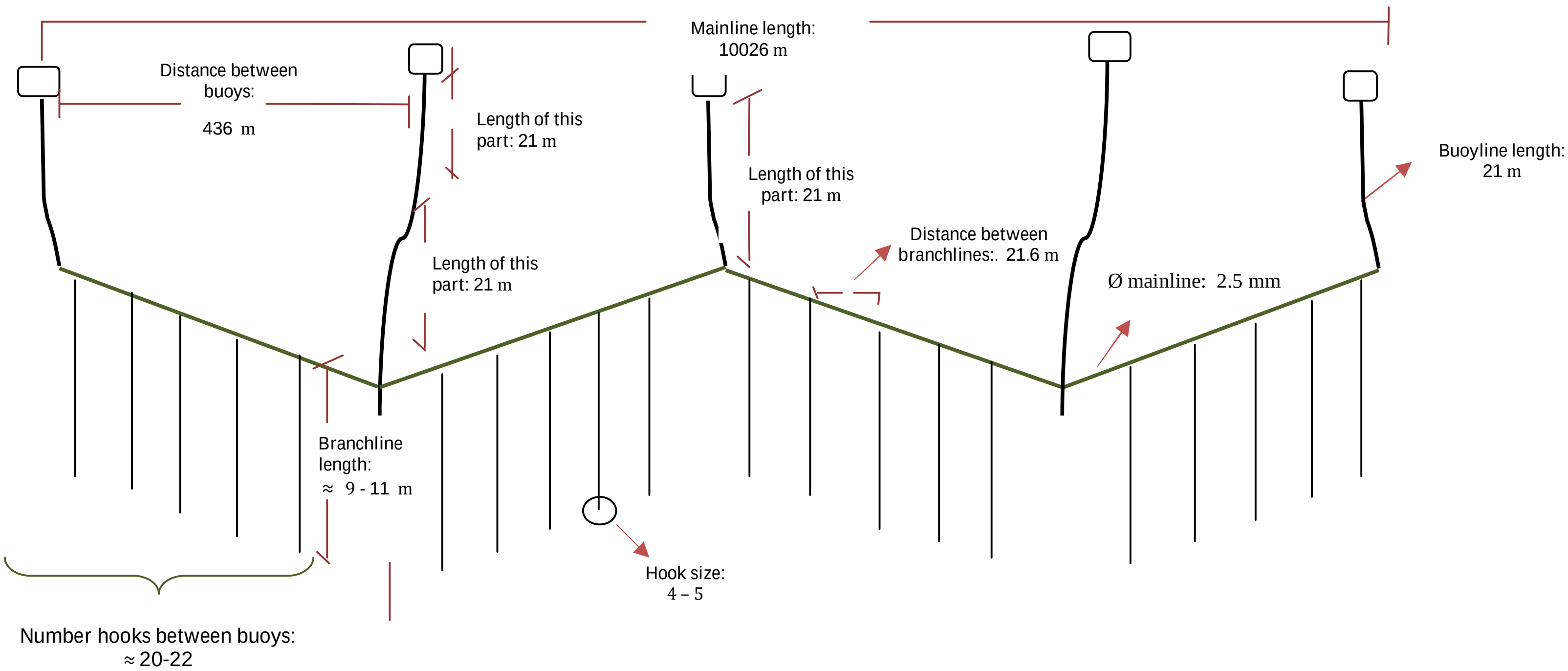


Average number of hooks per set:
≈430

Demersal longline: South Pacific hake, *Merluccius gayi*



Midwater longline: Escolar, *Lepidocybium flavobrunneum*



Average number hooks per set:
≈430

APPENDIX B: DETAILED CHARACTERISTICS OF MONITORED FISHING GEARS, PERU

(*NEXT PAGE*) Detailed characteristics of small-scale gillnet and longline fisheries in Peru. Data derived from onboard and shore-based observers (reproduced from Table 3, Alfaro-Shigueto et al. 2010). Fisheries observed in the present study are the columns for driftnets, longlines for dolphinfish, and longlines for sharks.

	Gillnet		Longline	
	Driftnet	Bottom set	For dolphinfish	For sharks
Vessel length (m)	8.0±0.9 (5.5-9.3, n=16)		10.2±2.1 (6.4-16.5, n=49)	
GRT	8.9±7.7 (2.2-6.5, n=15)		13.0±8 (2.1-32.5, n=44)	
Net/mainline length (km)	1.74±0.6 (0.8-2.6, n=56)	2.2±0.7(1.3-3.3, n=33)	5.2±2.1(1.9-11, n=117)	7.4±2.9 (1.8-18.8, n=101)
Target species	Sharks, rays Mahi mahi, bonito	Sharks, rays flounder, lobster	Mahi mahi	Blue and shortfin mako
Vertebrate bycatch:				
Turtles	✓	✓	✓	Low
Seabirds	✓	✓	✓	Low
Mammals	✓	✓	0	Low
Trips observed	56	33	117	116
Sets observed	369	39	922	846
Trip duration (days)	7.3±3.2 (1-13, n=55)	1.4±0.8 (1-5, n=31)	8.4±2.5 (2-17, n=117)	14.5±5.3 (2-27, n=115)
Set deployment	Neritic	Neritic	Oceanic	Oceanic
# sets/trip	6.5 ±3.1(1-11, n=55)	1.2±0.4 (1-2, n=33)	7.4±3 (2-16, n=137)	7.8±2.9 (2-14, n=98)
Branchline length (m)	-	-	9.1±3.1(5.5-18,n=117)	14±4.7 (4.6-38, n=101)
Distance between hooks	-	-	19.6±4.4 (10.9-29.2, n=117)	27±7.7 (9.1-45.7, n=101)
Branchline material	-	-	0.25 cm nylon monofilament	0.3 cm polypropylene multifilament with tar
Leader material	-	-	Nylon Monofilament (1.8mm)	Steel cable plastic coated (2.2mm)
Weighted swivels	-	-	39.7 to 42.2g of steel or nickel	
Total hooks observed	-	-	878,947	749,724
Hooks/set	-	-	955±444 (350-2,000)	
Net/mainline material	Multifilament 0.15- 0.5 cm Ø		0.6 cm Ø multifilament polyethylene	
Net color	Green, black, purple		-	-
# panels/set	20.2±4.3 (10-36, n=56)	38.5±11.4 (25-60, n=33)	-	-
Panel length (m)	86.8±26.3 (54.8-146.2, n=56)	57±5.8 (53-73.1, n=33)	-	-
Panel height (m)	11.2±3.1 (3.7-14.6, n=56)	3.7± 0.03 (3.6-3.7, n=33)	-	-
# weights/panel	6 units x 42gr/each	6 units x 2kg/each	-	-
Net area/set (km^2)	0.02±0.008 (0.003-0.036, n=359)	0.008±0.002 (0.004-0.01, n=39)	-	-
Total net observed (km^2)	7.86, n=359 sets	0.32, n=39 sets	-	-
Mesh size (cm)	10.2- 25.4 (17.5±3.9, n=56)	15.2-22.9 (21.5±2.3, n=33)	-	-
Hook type	-	-	J2, J3, J4, J5	J0, J1
Bait type	Small cetaceans	none	Giant squid, mackerel flying fish	Giant squid, mackerel, flying fish, cetaceans
Set time	14:53±3.1 hours (00:05-23:50, n=357)	13:13±0.1 hours (04:38-18:20, n=31)	08:06±3.1 hours (n=794)	08:35±2.3 hours (n=820)
Set duration (h)	-	-	2.2±1.0 (0.5-5.3, n=533)	2.7±1.1 (0.4-9, n=701)
Soak time (hours)	14.6±3.9 (1.8-23.6, n=341)	16.5±3.0 (11.4-22.6, n=24)	12.5±4.3 (4.1-23.7, n=526)	17.3±4.0 (4.9-38.7, n=691)
Haul time	07:36±4.1 hours (00:43-23:55, n=354)	06:15±0.9 hours (3:56 to 7:32, n=25)	2:42±3.7 hours (0:20 min-23:55h, n=905)	3:58±6.0 hours (0:30 min-22:24, n=810)
Haul duration (h)	-	-	5.3±2.6 (0.5-5.3, n=530)	6.1±3.1 (0.3-26, n=690)
# crew	4.1±0.8 (3-6, n=50) Mode 4	3.5±0.7(2-5, n=19) Mode 4	5±1.9 (3-11, n=230) Mode 4	
Gear investment ($US)	2,000-2,400 (based on materials cost for pane and an average number of panes of 20)		2,500-3,000 (based on material costs to equip a vessel with 1500 hooks)	
Gross gain/trip ($US)	1056.8±1224.2 (17.2-5544, n=46)	82±257.4 (0-1017.4, n=17)	3437.3±3236 (839-11250, n=25)	6294.4±6278(607-24091, n=17)
Net gain/trip ($US)	52% profit 489±183(-682 to 5044, n=46)	54.6% profit 103.8±311(-22.9 to 1035.7, n=11)	96.4% profit 1,286±2,176 (-2716 to 6536, n=28)	100% profit 2,163±3,472.6 (35.7 to 11393, n=21)
Trip cost ($US)	592.6±20.6 (120-700, n=46)	22.9±8.9 (12.5-35.7, n=12)	1958±1572(571-5991, n=28)	3811± 2780 (500-12698, n=21)
% crew blood related	16	100	6	3
% trips operating at loss	48	45.3	3.6	0
Safety equipment at sea	Limited	No	Yes	Yes