Small cetacean captures and CPUE estimates in artisanal fisheries operating from a port in northern Peru, 2005-2007

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ABSTRACT

This work provides the first direct, at-sea monitoring of small cetacean interactions with Peruvian artisanal drift gillnet and longline vessels. A total of 253 small cetaceans were observed captured during 66 fishing trips (480 sets) monitored from March 2005-July 2007 in the port of Salaverry, northern Peru. Interactions consisted of 231 animals caught in gillnets, 1 in a longline and 21 direct takes by harpooning for use as bait. The most commonly captured species were long-beaked common dolphins *Delphinus capensis,* dusky dolphins *Lagenorhynchus obscurus*, common bottlenose dolphins *Tursiops truncatus* (offshore stock) and Burmeister's porpoises *Phocoena spinipinnis*. Overall bycatch CPUE (catch per unit effort) was estimated to be 0.677 animals/set and 0.007 animals/set for gillnet and longline vessels, respectively. Based upon total fishing effort for the port, we estimated the average of small cetacean bycatch at 2,623 animals/year (CI 2,061-3,185) for 2002-2007. This work indicates that, in at least one Peruvian port, bycatch and harpooning of small cetaceans persist at high levels and on a regular basis, particularly in driftnet vessels. The formerly unknown practice of at-sea discarding of carcasses stands in sharp contrast with current, high small cetacean discard rates (49%) found in this study. That, combined with high prices/lack of availability of traditional bait fish suggest that small cetacean bycatch and harpooning could now potentially be reduced through the implementation of bycatch mitigation measures and greater accessibility to preferred bait.

KEYWORDS: Direct capture, effort, fisheries, gillnets, incidental catches, conservation, catch per unit effort, South America, Pacific Ocean

INTRODUCTION

International legal measures to ban the take of dolphins and porpoises in fisheries have acted as a protective measure to reduce declines of cetacean populations. However, cetacean bycatch remains a concern for fisheries worldwide (Lewison *et al.*, 2004, Read *et al.*, 2006). Moreover, artisanal fisheries may contribute significantly to cetacean mortalities caused at sea (Read *et al.*, 2006). Gillnet fisheries in particular have been cited as significant causes of small cetacean mortality (Jefferson and Curry, 1994; Dawson and Slooten, 2005; Read *et al.*, 2006).

In Peru, previous research into small cetacean captures has focused on monitoring of landings of carcasses and monitoring fishmarkets for presence of small cetacean products (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990, 1994; Van Waerebeek, 1994; Van Waerebeek *et al.*, 1997, 2002a). This long-term monitoring work has been extremely valuable in documenting the changes in fisheries interactions and in developing estimates of small cetacean captures for the country, besides collecting much needed natural history data. The species primarily affected included long-beaked common dolphin *Delphinus capensis*, dusky dolphin *Lagenorhynchus obscurus*, Burmeister's porpoise *Phocoena spinipinnis*, and common bottlenose dolphins *Tursiops truncatus* (both inshore and offshore forms), although low numbers of at least another ten species were also taken (see Van Waerebeek *et al.*, 1988; Van Waerebeek and Reyes, 1994).

Before ministerial decrees came into force in 1990 and 1994 and, failing, were reinforced by a national law in 1996 (Anonymous, 1996), prohibiting the take, landing and sale of small cetaceans in Peru, the bycatch and directed take could be monitored in Peruvian fishing ports (reviewed in Van Waerebeek *et al*., 1994). Indeed, discards were minimal because of the important commercial value of fresh dolphin meat. When cetaceans gradually disappeared from view in fishmarkets with the implementation of the ban of small cetacean exploitation, other methods were required to tally catches. Here we report on recent at-sea observations of artisanal gillnetting and longlining activities allowing direct estimates of bycatches per unit of effort for artisanal fisheries operating from a Peruvian port.

Captures of small cetaceans were thought to have peaked in the period 1990-1993 when estimates of total takes ranged between 15,000 and 20,000 animals per annum (Van Waerebeek and Reyes, 1994). However, this legislation is not fully enforced and the capture and trade of small cetaceans continues (e.g. Van Waerebeek *et al.*, 2002a, unpublished data; This paper). Moreover, updated data on numbers of cetaceans caught and the spatial and temporal distribution of cetaceans and bycatch are essential in defining the scale of this continuing problem and in designing appropriate national and regional management and conservation measures. The IUCN Cetacean Specialist Group (CSG) and the IWC Scientific Committee have all at some point listed both the Peruvian dusky dolphin and Burmeister´s porpoise as priorities for cetacean bycatch reduction. Likewise, the IUCN-CSG noted the need for reliable estimates of fisheries related mortality of small cetaceans (Reeves *et al.*, 2003, 2005).

Building upon this previous work and in line with recommendations for small cetacean research needs in Peru, the objective of this project was to assess the effectiveness of the existing ban on the capture and trade of small cetaceans by placing onboard observers on fishing vessels to directly record and characterize incidental and direct takes of dolphins and porpoises. The study provides a more direct and thus more accurate estimate of CPUE rates than was possible from landings and provides insights into aspects of the contrast between the legal requirements of a ban on small cetacean captures and the realities of virtually unavoidable bycatches and short-sighted local fishing practices.

MATERIALS AND METHODS

At-sea observers

All observers were biologists and were trained in data collection methods and marine mammal identification. Data sheets, GPS units and all other necessary equipment were provided. Datasheets were designed to gather information on fishing operation, the vessel specific gear used (longline or gillnet) and the bycatch obtained during the fishing trip. Biological samples were also collected from many captured small cetaceans. Tissue samples (muscle or skin) were packed in salt and stored in individual containers for future genetic analysis. Observers were provided with disposable cameras in order to photograph unusual or unidentifiable captures for later species identification. Common dolphins *Delphinus* spp. were not identified to species in the boats, nor were *Tursiops truncatus* (further referred to as 'bottlenose dolphins') assigned to inshore/offshore morphotype, considering there was a degree of uncertainty about positive identification among observers. All observer data were managed in a Microsoft Access relational database.

All vessels upon which observers operated were voluntary participants in the project. Observers did not take part in fishing activity. They worked throughout the year in order to account for changes in target species and to account for any possible seasonal and spatial variation. Observers monitored both longline and gillnet vessels. Observer effort varied by month depending on various factors such as the availability of boats and observers, weather conditions and project funding.

From March 2005 to July 2007 these observers monitored a total of 66 artisanal fishing trips (480 sets) for small cetacean bycatch. Artisanal fisheries are defined here, according to Peruvian fisheries regulations, as containing boats with a maximum of $32.6 m^3$ of storage capacity, 15m of length, and principally based on the use of manual work during fishing operations (Ley General de Pesca, 2001). Trips monitored were on gillnet and longline vessels originating from the port of Salaverry (8°14'S, 78°59'W). Captures of seabirds, sea turtles and pinnipeds were also recorded but are not reported here. Bycatch per unit effort (CPUE) was calculated as bycatch/set and bycatch/trip. Longline CPUE was also reported as catch/1000 hooks. Descriptive statistics are presented ± standard deviation (SD) and with 95% confidence intervals (CI) unless specified otherwise. Statistical tests were performed using SPSS 15.0. All spatial analyses and maps were prepared using ESRI ArcMap 9.1, MATLAB and Hawth's Tools (Beyer, 2004). Bathymetry values were determined with Global Gridded Relief Data (ETOPO2v2) with 2' minute resolution (USDOC, 2006). Quartic kernal and 90% probability contour analyses were performed using 2km grid spacing and least squares cross validation derived optimised smoothing factors for longline (23km) and gillnet (24km) sets and a person selected smoothing factor of 35km for small cetacean capture locations.

Shore-based observers

Shore based observers were employed in Salaverry to monitor daily fishing activity from September 2001 to March 2008. Observers collected data on the daily number of fishing trips, locations of fishing activity and associated catch and bycatch. Data collection was based upon interviews with fishermen and monitoring of dockside activity.

Fishermen interviews

In Salaverry from July to October 2006 Pro Delphinus researchers also conducted guided interviews with fishing captains and crew of gillnet and longline vessels regarding the frequency of small cetacean harpooning and use as bait and reasons for this practice. Interviews were held at the port over the course of three days with fishermen who agreed to participate. While not a representative sample of the Salaverry fishery generally, the purpose of the interviews was to provide more detail on small cetacean interactions than could be obtained solely through the work of onboard observers. Respondents were asked in ten questions to describe the fishery in which they worked (target species, fishing areas, etc.) as well as types of bait used, frequency of small cetacean harpooning, reasons small cetaceans are used as bait, species targeted and use of small cetaceans as a food source.

RESULTS

Gillnets characteristics
This project monitored 46 trips (342 sets) by artisanal drift gillnet vessels. All monitored trips targeted sharks and rays (mainly smooth hammerheads *Sphyrna zygaena*, eagle rays *Myliobatis spp.*, blue sharks *Prionace glauca*, short-fin makos *Isurus oxyrinchus* and thresher sharks *Alopias vulpinus*). The average duration of trips was 8.2±2.4 days (range: 3-13). The average number of sets per gillnet trip was 7.4±2.4 (range: 2-11). Gear was typically set in the afternoon and retrieved the following morning. Gillnet sets averaged 14.5±5.0 hours (range: 0.78-38.6). The only reported bait used was small cetacean blubber or meat (see Results and Discussion). Gillnets observed were made of multifilament nylon cord. Nets were made of panels averaging 48.3±15.0 fathoms (Range: 30-80 fathoms) in length by 6 to 7m in depth. Vessels deployed an average of 20.7±4.4 panels (Range: 10-36). Stretched mesh sizes ranged from 4.5 to 10 inches (11.2 x 25.4cm).

Longline characteristics
A total of 20 trips by artisanal longline vessels (138 sets; 167,670 hooks) were monitored. Sixteen of 20 trips (80%) targeted dorado *Coryphaena hippurus* with the remaining 4 trips targeting sharks (mainly blue and shortfin mako). The average duration of trips was 10.3±2.6 days (range: 5-14). The average number of sets per longline trip was 6.9±2.3 (range: 3-11). Longline sets averaged 9.15±2.6 hours (Range: 2.1-18.7). Gear was typically set in the morning and recovered the same day in the late afternoon. An average of 1,215±268.5 hooks was deployed per set (Range: 600-1,650). Mainlines were set at the sea surface. Mainlines were made of multifilament nylon rope. Branchlines were made of narrow diameter nylon multifilament cord. Leader materials used were either nylon monofilament when targeting dorado or metal cable when targeting sharks. Average length of branchlines was 3.8±1.9 fathoms (range: 2.5-10 fathoms). Bait used included jumbo flying squid *Dosidicus gigas* and small cetacean blubber or meat (see Results and Discussion).

Summary of small cetacean interactions
A total of 253 dolphins and porpoises were recorded captured during the study period. Eighty percent of gillnet trips (37 of 46 trips) and 5% of longline trips (1 of 20) reported small cetacean bycatch. In addition, 15% of longline trips also harpooned dolphins for use as bait (Table 1). No fishing trips that targeted dorado reported small cetacean bycatch. Three quarters of all captured animals were either common dolphins (47%) or dusky dolphins (29%). Captures also included Burmeister's porpoises, bottlenose dolphins, Risso's dolphins *Grampus griseus*, unidentified small cetaceans and 'Cachalotillo' (which could refer to pilot whales *Globicephala* spp., Risso's dolphin or *Kogia* spp.) (Table 1). A subsample of available photos examined indicated long-beaked common dolphins *D. capensis* and no evidence of short-beaked common dolphins *Delphinus delphis*. We therefore believe that interactions were largely, if not wholly, with long-beaked common dolphins.

All entangled dolphins and porpoises were captured in 105 sets during 38 fishing trips undertaken by 18 different vessels. All but one of these capture events were by gillnet vessels. For sets with dolphin or porpoise captures, the mean number captured per set was 2.24±1.65 (range: 1 to 9 animals/set, n=105 sets). The average reported water temperature for sets with captures was 19.1±1.9^{o}C (Range: 15 to 25^{o}C).

Common dolphins, dusky dolphins and bottlenose dolphins were mainly either discarded dead or used for bait (Table 2). Of known fate individuals, a majority of bottlenose dolphins and common dolphins were discarded dead. Half of known fate dusky dolphins were used for bait with the remaining half distributed among the other fate categories. Final fate of Burmeister's porpoises differed from the other three common bycatch species with 71.5% reported as either consumed by the boat crew or brought to shore to be eaten at home.

Four gravid females were entangled in gillnets. These consisted of 2 dusky dolphins (October 2005), 1 Burmeister's porpoise (March 2005) and 1 common dolphin (April 2005).

A total of 21 dolphins were harpooned, of which 16 were by longline vessels. These events occurred on 3 trips by 3 different boats and included takes of 8, 6, and 2 individuals. The remaining five animals were killed by gillnet vessels. The gillnet events also occurred over three trips and three different boats and included takes of 3, 1, and 1 individuals. Thirty-eight percent of harpooned animals were dusky dolphins (Table 2). All harpooned animals were used for bait.

Spatial distribution
The unreliability of remote sensing bathymetry data in coastal zones (<200m) makes detailed interpretation of the depths of captures difficult since most captures were in less than 250m depth (Cracknell, 1999; Malthus and Mumby, 2003). However, several general patterns do emerge when examining fishing effort and small cetacean capture locations. Gillnet sets were more coastal than longline sets (Figure 1a) with gillnet trips occurring over the continental shelf and longline trips occurring on the continental slope or pelagic. All small cetacean interactions appear to take place on the continental shelf or near the slope. There was a statistically significant difference in perpendicular distance to shore of captures between the four most commonly taken species (H=52.117, Kruskal-Wallis, P=0.000). Captures of Burmeister's porpoises were the most nearshore, occurring in a small area fronting Salaverry and an average of 16.9±15.3km from shore (Range: 3.2-52.5.0km; Figure 1e). Bottlenose dolphin interactions occurred furthest from shore at an average of 97.8±46.1km (Range: 49.4-191.3km; Figure 1d). Locations of captures of bottlenose dolphins also indicate that animals were from offshore as opposed to the inshore (coastal) population (sensu Van Waerebeek *et al.*, 1990; Sanino *et al.*, 2005). There was no significant difference (Z=-0.380, Mann-Whitney, P=0.704) in capture locations of common (Average=63.2±30.5km; Range: 3.2-170.0km) and dusky dolphins (Average=67.4±35.9km; Range: 10.7-191.3km), with both species more dispersed throughout the continental shelf (Figure 1a, b).

Fishermen interviews
Twenty-one interviews were conducted over three days in July, September and October of 2006. Nine respondents were crew members on longline vessels and 12 were from gillnet vessels. Respondents indicated that the preferred bait for longlines was mackerel *Scomber japonicus* (47%) or jumbo flying squid (47%). Small cetacean was also listed as a bait type but was not preferred (6%). For gillnet respondents, 38% indicated that they used small cetaceans as bait. Seventy-nine percent of gillnet respondents indicated that small cetacean meat was the bait used for catching sharks because of its high blood and fat content. When asked why they used small cetaceans for bait, 29% reported it was because other bait was not available and another 14% stated that small cetaceans were inexpensive to buy or harpoon. Sixty-two percent of respondents indicated that they eat small cetaceans at home. The most frequently captured species reported was the bottlenose dolphin (50%). When asked if they were interested in stopping the use of small cetaceans as bait 86% agreed. When asked for possible solutions to the use of small cetaceans as bait, 67% responded that other types of bait must be found to replace dolphin meat.

CPUE and fishing effort
Gillnets
Gillnet CPUE of small cetaceans was 0.677±1.37 animals/set (CI 0.531-0.824) or 5.02±4.58 animals/trip (CI 3.66-6.38). These calculations exclude the six dolphins harpooned by gillnet vessels. The overall interaction rate for gillnet vessels (including entangled and harpooned animals) was 5.13±4.59 animals/trip (CI 3.77-6.49). Bycatch rates per species are presented in Table 3.

Gillnet entanglements made up 91.3% of small cetacean captures. Ninety-seven percent of gillnet entangled animals were recovered dead and approximately half (49%) of all gillnet entangled animals were discarded. A large number (31%) of entangled animals were used for baiting gillnets. Half of all gillnet interactions were with common dolphins with the remaining half divided among Burmeister's porpoises, dusky dolphins, bottlenose dolphins, and unidentified species. Entangled animals were also used for sale in local markets, for consumption in the boat or at home, released alive or were given to other vessels for use as bait (Table 2).

Longlines
Longline CPUE (which consisted of 1 dusky dolphin) was 0.007±0.080 animals/set or 0.05±0.224 animals/trip, i.e. about 1% of the bycatch rate in gillnets. The dusky dolphin observed had become entangled around its flukes or tail stock and, while captured alive, was killed and used for bait. This project observed 167,670 hooks and yielded a bycatch estimate of 0.006 animals/1000 hooks. The overall interaction rate for longline vessels (including bycatch and harpooned animals) was a relatively high 0.85±0.52 animals/trip due to the common habit of harpooning dolphins for bait.

Salaverry fishing effort
Based upon daily shore based monitoring of fishing effort in Salaverry we calculated that there were an average of 518.2±90.0 gillnet trips (range: 411 to 620 trips/year) and 300.7±25.2 longline trips (range: 272 to 341 trips/year) per annum, for the years 2002 to 2007.

Knowing total monthly fishing effort and total monthly observer effort for the period March 2005 – July 2007 we were then able to calculate the percent of fishing trips observed. Observer effort averaged 3.4±2.6% (range: 0-10%) of monthly gillnet trips (March 2005-July 2007) and 3.7±4.6% (range: 0-17%) of monthly longline trips.

Based upon our bycatch estimates and the data on the total annual Salaverry fishing effort we are able to estimate the total number of small cetacean interactions for the gillnet and longline fleets. The average number of sets per observed gillnet and longline trip were 7.4 and 6.9 respectively. Combining this information with the data on annual total trips we estimated the total number of sets per year (Tables 3-5). For the years 2002 to 2007 the estimated annual number of small cetaceans captured in gillnets and longlines in the port of Salaverry was 2,608 (CI 2,046-3,170) and 15 animals, respectively (Table 4). Based upon the per species bycatch rates calculated (Table 4) we then estimated annual per species bycatch (Table 5).

DISCUSSION

Small cetacean interactions

Previous work monitoring the take of small cetaceans in Peru's artisanal fisheries focused largely on dockside monitoring of landing, monitoring of fishmarkets for small cetacean products and assessing beach cast carcasses for evidence of fishery interactions (Read *et al.*, 1988; Van Waerebeek and Reyes, 1990, 1994; Van Waerebeek, 1994; Van Waerebeek *et al.*, 1997, 2002a). The work presented here provides the first direct, at-sea monitoring of small cetacean interactions with Peruvian artisanal gillnet and longline vessels. It has shown that, in at least one port in northern Peru, bycatch and harpooning of small cetaceans persist at high levels and on a regular basis, particularly in driftnet vessels, despite the existence since the mid-1990s of national legislation banning the capture of marine mammals and commerce in their products. Many opportunistic interviews with fishermen in Pucusana by one of us (KVW) over the past few years suggest that the situation of continued bycatches and harpoonings, despite much reduced landings, is similar on Peru's central coast.

Similar to previous work, we found that small cetacean interactions took the forms of bycatch and harpooning. The four most common small cetacean bycatch species reported, both then and now, were long-beaked common dolphins, dusky dolphins, bottlenose dolphins and Burmeister's porpoises. The most frequently entangled species in the current study was the common dolphin which made up 50% of gillnet interactions. The dusky dolphin was the second most frequently captured species with 28% of gillnet interactions.

For 1991-1993 Van Waerebeek (1994) noted a decline in the catch composition proportion of dusky dolphins and an increase in the proportion of common dolphins (also Van Waerebeek *et al.*, 2002a). The author suggested that the proportional decline in dusky dolphins captures could be a result of several decades of exploitation by Peruvian fisheries. The higher proportion of common dolphins found in the current study could be indicative of this continued decline but may also be due to the fact that the present study occurred at a port near the northern limit of the species' known range (Van Waerebeek, 1992a, 1992b).

Van Waerebeek and Reyes (1994) and Van Waerebeek *et al.* (1997) provide the only previously available description of small cetacean interactions for the port of Salaverry. Both studies reported that Burmeister's porpoise was the most frequently landed species (in 1994, 75% of 73 identified cetaceans), with landings occurring on an almost daily basis. In the present study, Burmeister's porpoise was the fourth most commonly captured species at 6% of all captures. Given the paucity of information on Burmeister's porpoise abundance, distribution or fishery interactions it is not clear why this discrepancy in catch frequency may exist but we note that many gillnet sets tended to be further offshore than the narrow coastal area in which Burmeister's porpoise bycatch occurred (figure 2d). Usual fishing grounds may have moved further offshore as the density of fish schools closer to port may have decreased due to high fishing pressure.

The present study also supports previous findings that fishery interactions come in the forms of bycatch and harpooning. Our results indicate that bycatch of small cetaceans is a much more important cause of mortality than harpooning. Bycatch occurred in both gillnet and longline vessels and while longline entanglement is almost negligible (1%) compared to gillnet entanglement, harpooning is more common on longliners. Almost all gillnet bycatch was recovered dead and approximately half of all entangled small cetaceans were discarded at sea. Thus, while half of carcasses were used opportunistically as bait or for consumption, the fact that the other half of all bycatch was discarded indicates that interactions with small cetaceans are often unwanted. This stands in sharp contrast with the 1985-1994 situation when discards were rare and most carcasses were landed to be sold, openly or covertly (e.g. Van Waerebeek and Reyes, 1994). This suggests that the promotion and implementation of bycatch avoidance measures in the gillnet fishery may now, perhaps for the first time, be acceptable to fishermen as a means of reducing unwanted catch.

Clearly though, a demand for small cetacean products in the form of bait and meat persists. Bait was collected from entangled animals but also from animals harpooned specifically to collect bait. Harpooning for bait occurred on both gillnet and longline vessels. When used in gillnets, pieces of dolphin blubber and meat were tied to the center of the net pane, with this being repeated for each pane. Dolphin blubber and meat was the only bait reported used in gillnets during the study and was used specifically due to its claimed effectiveness in attracting blue and short-fin mako sharks. Use of small cetaceans as bait was also reported during interviews with fishermen (both in Salaverry and Pucusana) where they noted dolphin meat's particular effectiveness for catching sharks given its high blood and fat content. Previous work also reported on this usage and warned that increasing demand for small cetacean meat and blubber as shark bait could offset any reductions in small cetacean take as a result of the ban on capture and commerce (Van Waerebeek *et al.*, 1997; Van Waerebeek *et al.*, 2002a). The capture of small cetaceans for use as bait has also been reported in coastal communities in Colombia (Mora-Pinto *et al.*, 1995) and Argentina (Goodall *et al.*, 1994), but the practice is common worldwide.

In discussions with fishermen regarding their use of small cetaceans for bait, a large number indicated that one reason for the use of dolphins and porpoises was the high cost of traditional bait fishes like mackerel. These fishermen indicated that they would, in fact, prefer to use their traditional bait. Given that all observed harpooning events in this study were to collect bait, that preference suggests that if these, or effective alternative, baits could be provided cheaper, then harpooning of small cetaceans could perhaps largely be avoided.

Small cetaceans were also reported as either consumed by boat crews or brought to shore for consumption at home or sale in markets. Of the four species, the Burmeister's porpoise was the most preferred as a food source with 5 of the 7 porpoises for which fate is known, were consumed either by the boat crew or by family at home. Interviews with fishermen revealed that a majority of respondents eat small cetacean meat at home.

Additional research conducted by Pro Delphinus biologists at fishmarkets in the ports of Salaverry and Chimbote indicates that small cetacean meat is available on an regular basis and consisted of the same four species documented here and in previous market studies (Pro Delphinus unpublished data; Van Waerebeek *et al.*, 2002a; Van Waerebeek *et al.*, 1997; Van Waerebeek and Reyes, 1990, 1994; Read *et al.*, 1988).

CPUE and fishing effort

The four most common small cetacean species involved in bycatch are distributed along most of the Peruvian coast where they overlap with artisanal fishing activity. Dusky dolphins and Burmeister's porpoises have been encountered along the entire Peruvian coast up to Salaverry and Bahia de Paita (05°01'S) respectively (Reyes and Van Waerebeek, 1995; Van Waerebeek *et al*., 1997, 2002b). Inshore bottlenose dolphins are documented along most of Peru's coast and offshore bottlenose dolphins are thought to form a continuous distribution from southern Ecuador to at least central Chile (Van Waerebeek *et al*., 1990; Sanino *et al*., 2004). *Delphinus* spp. are also distributed along the entire Peruvian coast (Van Waerebeek *et al.*, 1988, 1994). Data from two research cruises (respectively from 4°-12°S and from 3°-18°S) to 100-150nm offshore, conducted by Peru's marine research agency IMARPE in 1998, indicated that common dolphins, dusky dolphins and bottlenose dolphins were the most commonly encountered small cetaceans from approximately 5°S to 18°S (Sánchez *et al.*, 1998; Sánchez and Arias-Schreiber, 1998).

Also distributed along the entire Peru coast are the 122 ports and landing sites used by the artisanal fishery. A survey of the artisanal fleet conducted in 2004-2005 found that there were 9,667 artisanal vessels operating in Peru (Estrella, 2007). This represents a 54% increase in the size of the artisanal fleet from 1996-1997 (Escudero-Herrera, 1997). Longline vessels increased from 3.5% of the fleet in 1996-1997 to 9.8% of the fleet in 2004-2005. The number of longline trips also showed an increase and for the second half of 1999, 1,968 longline trips were recorded (Estrella *et al.*, 2000). For the entire year of 2002, 11,316 trips were conducted (IMARPE, unpublished data). This suggests substantial growth in the longline fishery since 1999. The increase in the size of the longline fleet came in part due to efforts in the 1990s to promote longlining as a means to reduce small cetacean interactions in artisanal fisheries (Reyes, 1993). However, even though the percentage of gillnet vessels in the fleet declined from 1996-1997 to 2004-2005, the absolute number of vessels increased from 2,520 to 3,190. Gillnets were the most frequently used fishing methods reported in both studies. During 1999, 63,083 gillnet trips were conducted (Estrella *et al.*, 1999, 2000).

Given the high rates of small cetacean interactions reported here for one port (an estimated average annual take of 2,608 animals in gillnets for the years 2002-2007) and the distribution of small cetaceans along the coast overlapping with the large number of artisanal fishing trips, it is feasible that, at the national level, interactions between artisanal fisheries and small cetaceans remain very substantial. Indeed, it is possible that total mortality by the artisanal fishery is on the order of that which was occurring in 1990-1993 when there was an estimated take of 15,000-20,000 small cetaceans annually for all of Peru including captures by industrial purse-seiners (Van Waerebeek and Reyes, 1994), prior to the implementation of the ban on captures in the mid-1990s. We believe, however, that the CPUE estimate for longline bycatch obtained in this study may be an overestimate. For example, onboard observer monitoring of 193 longline trips (1,324 sets) from the port of Ilo in southern Peru by Pro Delphinus observers documented a bycatch of one small cetacean. In addition, harpooning has not been observed (Pro Delphinus unpublished data). The overall interaction rate for longline vessels remains relatively high though, given the frequency of harpooning off Salaverry.

It is possible, but unlikely given historical perspectives, that results presented here for Salaverry are not representative of interaction rates for the rest of Peru. However, we note that a study based upon monitoring of 15 artisanal landing sites in 1999-2001 in northern and central Peru reported that small cetacean landings were still commonplace (Van Waerebeek *et al.*, 2002a). It is also in central and northern Peru where gillnet activity is greatest due to the greater width of the continental shelf in comparison with the south of the country. Results of recent market sampling conducted in the port of Chimbote in 2006-2007 indicated that small cetacean meat was available on a regular basis (Pro Delphinus unpublished data). Given the size of the artisanal and industrial fleets operating out of Chimbote, it is likely that small cetacean products originated there as opposed to being transported from Salaverry. Furthermore, genetic analyses of Burmeister's porpoises captured in the ports of Salaverry and Chimbote found a weak but significant nuclear DNA differentiation between the two harbours (Rosa *et al.*, 2005). One proposed explanation for this result was that fishing vessels from the two ports were using distinct fishing grounds.

Future directions

This research makes clear that small cetacean bycatch and direct take continues despite the existence of national legislation prohibiting capture and commerce in their products. We believe these results show the need for renewed interest on the part of all stakeholders to expand the scope of research and monitoring of small cetacean populations and their interactions with Peru's artisanal fleet. This study demonstrates the feasibility and use of independent observer programmes onboard artisanal fishing boats, and we strongly recommend that such surveys be continued and expanded. Priority should be given to increased monitoring of gillnet fisheries in the center and north of the country where the fleet is concentrated. Given the large number of ports and landing sites used by the artisanal fleet it may be more practicable to choose a number of 'index' ports distributed along the coast and to focus on maximizing onboard observer coverage in these locations. Babcock *et al.* (2003) recommended 20% observer coverage for creation of accurate estimates for common species and 50% for rare species. Observer effort should optimally be continuous in order to account for any temporal variations in interactions, or should at least ensure an adequate coverage of all seasons. Special attention should be paid to interactions with dusky dolphins and Burmeister's porpoises since previous research indicate that the Peruvian populations of these species form reproductively and genetically isolated stocks that should be subject to stock specific management measures (Van Waerebeek, 1992a, 1993; Cassens *et al.*, 2003, 2005; Rosa *et al.*, 2005). The population status of long-beaked dolphins off Peru is unknown but is currently under study.

While large, the artisanal fishery is one of several fisheries operating in Peruvian waters and potentially interacting with small cetaceans. One must also consider interactions with other fisheries, most notably industrial purse-seine vessels targeting small schooling fish, especially anchovy. Based upon onboard observer effort of 2% of the fleet in 2002, van Oordt and Alza (2006) reported an average capture rate of 0.041 dolphins/set. They noted that small cetacean captures in the fishery could be significant given the estimated 80,000 fishing trips per year. Data on fishing effort for all fisheries operating in Peru's coastal waters need to be compiled in order to have a clear understanding of the overall impacts on small cetacean populations.

Two promising findings stand out from this research. First, it is apparent, given the high discard rates observed, that small cetacean bycatch was often undesirable or unusable. Fishermen may therefore be open to using mitigation methods to reduce small cetacean bycatch. Closure of fishing areas to gillnetting or modification of gillnets (Dawson, 1991) seem hardly implementable in Peru. The use of acoustic alarms has been shown to reduce gillnet bycatch in some dolphin and porpoise populations (Kraus *et al.*, 1997; Kastelein *et al.*, 2001; Cox *et al.*, 2003; Barlow and Cameron 2003; Koschinski *et al.*, 2006; Leeney *et al.*, 2007). Acoustic alarms should also be trialed in the Peru gillnet fishery. Second, discussions with fishermen indicated that small cetacean meat and blubber was used as bait in part due to the high cost of traditional bait Finding an appropriate, low-cost substitute bait to cetacean meat and blubber could reduce harpooning in both the longline and gillnet fleets and could further promote the use of bycatch mitigation measures by gillnet vessels.

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Table 1. Small cetacean species composition and capture methods of all observed fisheries interactions (% in parentheses), March 2005-July 2007.

Species captured	n (%)	Net Entangled	Longline entangled	Harpooned*
Common dolphin	120 (47)	116 (50)	0	4 (19)
Dusky dolphin	73 (29)	64 (28)	1 (100)	8 (38)
Bottlenose dolphin	33 (13)	30 (13)	0	3 (14)
Burmeister's porpoise	16 (6)	16 (7)	0	0
Unidentified cetacean	8 (3)	2 (1)	0	6 (29)
'Cachalotillo'	2 (1)	2 (1)	0	0
Risso's dolphin	1 (0.4)	1 (0.4)	0	0
Total	253	231 (91.3)	1 (0.4)	21 (8.3)

*16 animals harpooned by longline vessels, 5 by gillnet vessels.

Table 3. Gillnet bycatch rates (catch/set) of the four most commonly captured species.

Species	mean	CI
Common dolphin	0.340	0.236 - 0.444
Dusky dolphin	0.188	0.097 - 0.278
Bottlenose dolphin	0.088	0.040 - 0.136
Burmeister's porpoise	0.047	0.015 - 0.079

Table 4. Estimated annual small cetacean bycatch by gillnet and longline vessels for the port of Salaverry.

	Gillnets			Longlines		
Year	# trips	Estimated # sets	estimated captures (CI)	# Trips	Estimated # sets	estimated captures*
2002	411	3,054	2,069 (1,623-2,514)	319	2,201	15
2003	620	4,607	3,121 (2,448-3,793)	289	1,994	14
2004	421	3,128	2,119 (1,663-2,575)	341	2,353	16
2005	572	4.250	2,879 (2,259-3,499)	298	2,056	14
2006	593	4,406	2,985 (2,342-3,628)	285	1,967	14
2007	492	3,656	2,477 (1,943-3,010)	272	1,877	13
Average	518	3,850	2,608 (2,046-3,170)	301	2,075	15

*95% CI not presented for longline captures because it is considered unreliable given only 1 bycatch event.

Table 5. Estimated annual catch of the four most common bycatch species by gillnet vessels for 2002-2007, mean (CI). Most (if not all) common dolphins are *D. capensis*.

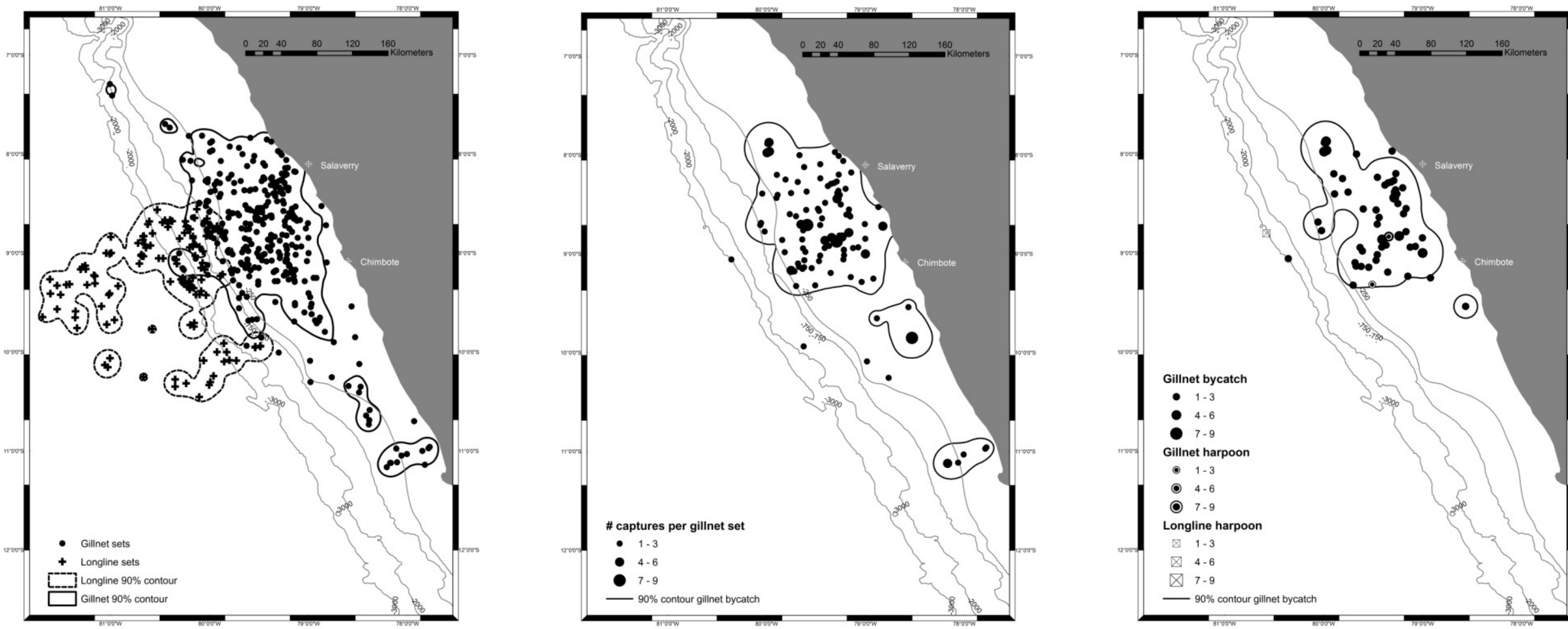
Year	Common dolphin	Dusky dolphin	Bottlenose dolphin	Burmeister's porpoise
2002	1,039 (772-1,356)	573 (296-850)	269 (122-416)	143 (45-242)
2003	1,567 (1,089-2,045)	865 (447-1,282)	405 (184-627)	216 (67-365)
2004	1,064 (740-1,389)	587 (304-870)	275 (125-426)	147 (46-248)
2005	1,446 (1,005-1,887)	798 (413-1,183)	374 (169-578)	199 (62-337)
2006	1,499 (1,042-1,956)	827 (428-1,226)	388 (176-600)	207 (64-349)
2007	1,244 (864-1,623)	686 (355-1,017)	322 (146-498)	172 (53-290)

Table 2. Species composition, capture methods and use of small cetacean carcasses of all interactions (longline & gillnet, bycatch & harpoon), March 2005-July 2007.

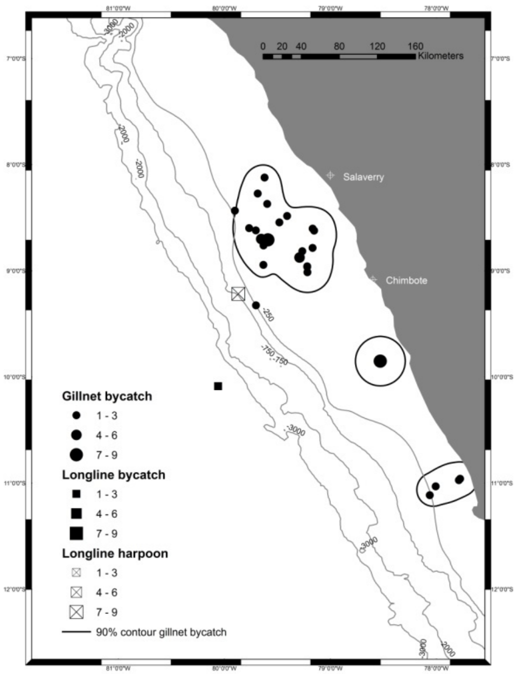
		# harpooned for bait			# bycaptured									
Species captured	Total n	% Male	Longline	Gillnet	% Male	Discarded Dead	For net bait	For longline bait	For sale	To eat at home	To eat in boat	Released alive	Given to other boat	Unspecified
Common dolphin	120	66.7	2	2	63.6	58	17	4	10	5	0	1	0	21
Dusky dolphin	73	62.5	8	0	43.8	15	28	3	4	1	1	1	2	7
Bottlenose dolphin	33	0.0	0	3	47.1	17	13	0	0	0	0	1	0	2
Burmeister's porpoise	16	-	0	0	66.7	1	1	0	0	3	2	0	0	9
Unidentified	8	-	6	0	-	0	0	0	0	0	0	0	0	2
"Cachalotillo"	2	-	0	0	0	0	0	0	0	0	0	0	0	2
Risso's dolphin	1	-	0	0	-	1	0	0	0	0	0	0	0	0
Total	253	50.0	16	5	55.5	92	59	7	14	9	3	3	2	43

Figure 1. Locations of all monitored sets by vessel type (a) and set locations of all captures of the four most common bycatch species (b-f). Also presented in each pane are 90% probability contours of fishing sets and gillnet bycatch (250m, 750m, 2,000m and 3,000m isobaths are indicated).

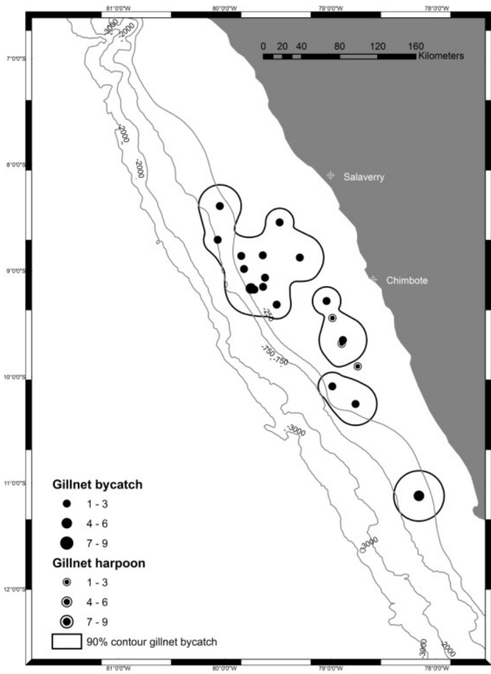
(a) All fishing sets | (b) All gillnet captures | (c) Common dolphin



(d) Dusky dolphin



(e) Bottlenose dolphin



(f) Burmeister's porpoise