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Small cetacean captures in Peruvian artisanal fisheries: High despite protective legislation

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ABSTRACT

We detail the first direct, at sea monitoring of small cetacean interactions with Peruvian artisanal drift gillnet and longline fisheries. A total of 253 small cetaceans were captured during 66 monitored fishing trips (Gillnet: 46 trips; Longline: 20 trips) from the port of Salaverry, northern Peru (8°14′S, 78°59′W) from March 2005 to July 2007. The most commonly captured species were common dolphins (*Delphinus* spp.) (47%), dusky dolphins (*Lagenorhynchus obscurus*) (29%), common bottlenose dolphins (*Tursiops truncatus*) (13%) and Burmeister's porpoises (*Phocoena spinipinnis*) (6%). An estimated 95% of common dolphin bycatch was of long-beaked common dolphins (*Delphinus capensis*). Overall bycatch per unit effort for gillnet vessels (mean ± sd) was estimated to be 0.65 ± 0.41 animals.set^{-1} (range 0.05–1.50) and overall catch (bycatch and harpoon) was 4.96 ± 3.33 animals.trip^{-1} (range 0.33–13.33). Based upon total fishing effort for Salaverry we estimated the total annual average small cetacean bycatch by gillnet vessels as 2412 animals.year^{-1} (95% CI 1092–4303) 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, despite the existence since the mid-1990s of national legislation banning the capture of marine mammals and commerce in their products. It is concluded that the coast of Peru is likely still one of the world's principal areas for concern regarding high small cetacean bycatch and there is clearly an urgent need to increase the geographic scope of observer effort to elucidate the full magnitude of this issue.

1. Introduction

Small scale coastal, or artisanal, fisheries make up the vast majority of global fishers, produce about half of global annual fish catch and provide most of the fish for human consumption in the developing world (Berkes et al., 2001). These fisheries are typically highly dispersed and are particularly prevalent in developing nations where regulations to monitor or manage these fisheries are frequently underdeveloped, unenforced or non-existent (Berkes et al., 2001). Despite their size and importance, however, artisanal fisheries remain under-studied in comparison with large scale industrial fleets (Berkes et al., 2001; Lewison et al., 2004; Pauly, 2006; Soykan et al., 2008).

Fisheries bycatch has been of growing concern in recent decades (Brothers, 1991; Northridge, 1991; Perrin et al., 1994). The bycatch of long-lived, late maturing, low fecundity species like marine mammals, seabirds, and sea turtles have received particular attention and it is now clear that fisheries interactions pose one of the greatest risks to the survival of many populations (Spotila et al., 2000; Lewison et al., 2004; Read, 2008). While initial attention was often primarily focused on bycatch by large industrial fleets like tuna purse-seines, and high seas driftnets (Hall et al., 2000), efforts have been intensifying to estimate the rates and evaluate the impacts of bycatch in artisanal fisheries (D'Agrosa et al., 2000; Moreno et al., 2006; Peckham et al., 2007, 2008; Alfaro Shigueto et al., 2008) and those working in coastal seas (D'Agrosa et al., 2000; Slooten, 2007).

Due to their circumglobal and coastal distributions, small cetaceans are subject to human exploitation both from bycatch and direct take (Jefferson and Curry, 1994; Reeves et al., 2003; Read et al., 2006; Clapham and Van Waerebeek, 2007; Read, 2008). National and international legal measures to ban the take of dolphins and

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porpoises in fisheries are meant to act as a protective measure to reduce declines of cetacean populations (Northridge and Hofman, 1999). However, cetacean bycatch remains a concern worldwide (Reeves et al., 2003; Lewison et al., 2004; Read et al., 2006; Read, 2008). Moreover, artisanal fisheries may contribute significantly to cetacean mortality (Read et al., 2006). Gillnet fisheries in particular have been cited as probably the most significant cause globally of small cetacean mortality (Jefferson and Curry, 1994; Dawson and Slooten, 2005; Read et al., 2006).

Independent onboard observer programs have been widely used as an effective means to quantify bycatch (e.g. Gales et al., 1998; Beerkircher et al., 2002; Carretta et al., 2004; Rogan and Mackey, 2007), and have been specifically recommended in the case of small cetacean captures in Peru (Reeves et al., 2005). Updated data on numbers of cetaceans caught and the spatio-temporal distribution of cetaceans and bycatch are essential in defining the scale of any problem and in designing appropriate national and regional management strategies (Reeves et al., 2003, 2005). Moreover, the IUCN Cetacean Specialist Group (CSG) and the IWC Scientific Committee have both listed the Peruvian dusky dolphin and Burmeister's porpoise as priorities for cetacean bycatch reduction.

In Peru, previous research into small cetacean captures has focused on the monitoring of landings of carcasses and fishmarkets for the presence of small cetacean products (Read et al., 1988; Van Waerebeek and Reyes, 1990, 1994; García-Godos, 1992; Van Waerebeek, 1994; Van Waerebeek et al., 1997, 2002; Majluf et al., 2002). Captures of small cetaceans were thought to have peaked in the period 1990–1993 when estimates of total take by artisanal and commercial fisheries ranged between 15,000 and 20,000 animals per annum (Van Waerebeek and Reyes, 1994), making it one of the largest small cetacean takes in the world. Ministerial decrees (1990 and 1994) reinforced by a national law in 1996 (Anonymous, 1996), prohibit the intentional take, landing and sale of small cetaceans in Peru (reviewed in Van Waerebeek et al., 1994), but this legislation is not fully enforced and the capture and trade of small cetaceans continues (e.g. Van Waerebeek et al., 2002). The legislation did, however, have the effect of reducing reported landings and pushing the continuing trade in small cetaceans into the black market which was much more difficult to monitor (Van Waerebeek et al., 1997, 2002). In addition it was expected that, unlike before, at least some fishermen would simply discard cetacean bycatch offshore so as to avoid any problems with landings of legal fish catches. As a result, other methods are required to quantify the continuing catch of small cetaceans. Here we report on recent at sea observations of artisanal gillnet and longline activities allowing the first direct effort-corrected estimates of bycatch for artisanal fisheries operating from an important Peruvian port.

2. Materials and methods

2.1. Onboard observer scheme

From March 2005 to July 2007 observers monitored a total of 66 artisanal fishing trips (480 sets; 439 fishing days) 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, less than 15 m 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), an artisanal port in northern Peru and home to over 100 fishing vessels (Alfaro-Shigueto et al., unpublished results). Skippers ($N = 21$) upon whose vessels observers operated were voluntary participants in the project. Observers did not take part in fishing activity. Observers worked in all months of the year over a total period of 29 months, in order to account for possible seasonal variation in magnitude and spatial patterns of effort.

2.2. At sea observers

All observers were biologists and were trained in relevant data collection methods including marine mammal identification. Data were gathered on specific gear used (longline or gillnet), the timing and position (using GPS) of each set and any bycatch occurring. All observers were equipped with cameras and photographed unusual or unidentifiable captures for later species identification. Common dolphins *Delphinus* spp. were not identified to species in the boats, nor were *Tursiops truncatus* assigned to inshore/offshore morphotype, considering there was a degree of uncertainty about positive identification among observers.

Photos of *Delphinus* spp. ($n = 38$) examined by the authors indicated bycatch of 36 long-beaked common dolphins *Delphinus capensis* (94.7%) and two short-beaked common dolphins *Delphinus delphis* (5.2%). This composition estimate is used in our extrapolation to the wider estimate of take (Table 4). The overwhelming preponderance of *D. capensis* found here is broadly consistent with the more than 99% of *Delphinus* catches belonging to *D. capensis* in Peru based on a sample of 1067 common dolphins taken in coastal fisheries in the period 1984–1993 (Van Waerebeek, 1994).

2.3. 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 total number of fishing trips departing and returning per day and per vessel type, locations of fishing activity and associated catch and bycatch. Data collection was based upon daily interviews with fishermen and monitoring of dockside activity. Respondents were informed that the information would be kept anonymous and be used strictly for research purposes. Fishermen returning from fishing trips were queried regarding vessel type, fishing effort, target catch, and incidents of bycatch of small cetaceans, sea turtles or seabirds. Resulting data therefore are a census of fishing effort by gear type over the study period.

2.4. Data analysis

All observer data were managed in a Microsoft Access database. Bycatch per unit effort (CPUE) was calculated on a per trip and per set basis for both fishing gears. For gillnet vessels, CPUE was also presented per length (km) and per area (km^2) of net set. Descriptive statistics are presented as mean ± standard deviation (SD) or with 95% confidence intervals (CI) unless specified otherwise. Statistical tests were performed using SPSS 15.0 and Genstat 10. For temporal analyses of total bycatch we used General Linear Models (GLMs) with normal errors, where CPUE was the dependent variable with season and year as factors. In this instance CPUE was calculated on a trip by trip basis by dividing the number of bycatch incidents by the number of sets made. When it came to analysis of the bycatch for individual species the date distributions departed significantly from normality and there were significant differences in variances among groups. We therefore used raw count data as our dependent variable, with number of sets included as a covariate (to account for variation in effort across seasons/years) along with season and year as factors. We also employed GLMs for these analyses but fitted them with Poisson errors and a log link function. Season was divided as follows: season 1 = November–January; season 2 = February–April; season 3 = May–July; season

4 = August–October. All spatial analyses and maps were prepared using ESRI ArcMap 9.1, MATLAB 7.6 and Hawth's Tools (Beyer, 2004). Bathymetry values were determined with Global Gridded Relief Data (ETOPO2v2) with 2 minute resolution (USDOC, 2006). Quartic Kernel and 50% and 75% probability contour analyses were performed using 2 km grid spacing and least squares cross validation derived optimized smoothing factors for longline and gillnet sets (25 km) and a smoothing factor of 35 km for small cetacean capture locations.

2.5. Estimating bycatch rates and total bycatch

Gillnet bycatch data for the study were grouped by month in order to derive monthly stratified CPUE estimates. These rates were calculated in terms of catch.trip^{-1}, catch.set^{-1}, and to facilitate comparison with other studies, catch.km of net length^{-1}, and catch.km^2 of net area^{-1} were also calculated. Given the small sample size we did not prepare similar monthly stratified catch estimates of longline bycatch.

Based upon the catch rates derived in this study and the data on monthly Salaverry fishing effort from 2002 to 2007, we were able to estimate the number of small cetacean captures (overall and per species) for the gillnet fleet. To derive these values we applied the monthly CPUE rates calculated in this study to the estimated number of monthly gillnet sets for the years 2002–2007. Monthly number of sets was estimated by multiplying the known number of trips per month by the average number of sets per trip as determined by this study. Month specific CPUE calculations were used to generate an estimate. Bycatch data for each individual month were pooled to derive monthly CPUE values. As bycatch data were left skewed, the monthly bycatch estimates were calculated by multiplying the CPUE of sets with bycatch by the total number of sets multiplied by the proportion of sets in that month estimated to have bycatch (as determined in this study). Monthly catch estimates for each year were then summed to arrive at annual totals.

3. Results

3.1. Gillnet characteristics

This project monitored 46 trips (341 sets; 319 fishing days) by artisanal drift gillnet vessels (Table S1). A detailed summary of trip and net characteristics is presented in Table S1. All monitored trips targeted sharks and rays (mainly smooth hammerheads (*Sphyrna zygaena*), eagle rays (*Myliobatis* spp.), blue sharks (*Prionace glauca*), short-fin mako sharks (*Isurus oxyrinchus*) and thresher sharks (*Alopias vulpinus*)). Gillnets observed were made of multifilament nylon cord of varying mesh sizes. Nets were set at the ocean surface and were typically set in the afternoon and retrieved the following morning. The average number of sets.trip^{-1} was 7.4 ± 2.4 (range: 2–11). Total net length per set averaged 1948 ± 512 m (range: 1097–3072). The only observed bait used was small cetacean blubber or meat.

3.2. Longline characteristics

A total of 20 trips by artisanal longline vessels (138 sets; 167,670 hooks; 129 fishing days) were monitored (Table S1). Sixteen of 20 trips (80%) targeted dorado (*Coryphaena hippurus*) with the remaining four trips targeting sharks (mainly blue and shortfin mako). Mainlines for all trips were set at the sea surface and were made of multifilament nylon rope. While trip lengths were similar, vessels targeting sharks typically had more and longer sets and deployed fewer, more widely spaced hooks than vessels targeting dorado. Branchlines were made of narrow diameter nylon multifilament cord, with branchline length of vessels fishing for sharks approximately double that of vessels fishing for dorado. Leader material used was either nylon monofilament when targeting dorado or metal cable when targeting sharks. Jumbo flying squid (*Dosidicus gigas*) was used as bait for both sharks and dorado while small cetacean blubber and meat was also used as bait by vessels targeting sharks.

3.3. Summary of small cetacean interactions

A total of 253 dolphins and porpoises were observed by onboard observers as captured during the study period (Table 1). Bycatch in gillnets accounted for 91.3% of all interactions recorded with another 6.3% (n = 16), 2.0% (n = 5) and 0.4% (n = 1) coming from longline harpooning, gillnet harpooning and longline bycatch, respectively.

3.3.1. Gillnets

Eighty percent of gillnet trips (37 of 46 trips; 104 sets) experienced small cetacean bycatch and the majority of captures were of two species (common dolphins 50.2%; dusky dolphins 27.7%). Captures also included common bottlenose dolphins (13.0%; n = 30), Burmeister's porpoises (6.9%; n = 16), Risso's dolphins (*Grampus griseus*) (0.4%; n = 1), and unidentified small cetaceans (1.7%; n = 4; Table 2). Mean CPUE of small cetaceans was 0.65 ± 0.41 animals.set^{-1} (range: 0.05–1.50) or 4.96 ± 3.33 animals.trip^{-1} (range: 0.33–13.33) (Table S2). In addition to bycatch, three common bottlenose dolphins and two common dolphins were harpooned for bait on three gillnet fishing trips by three different vessels.

Table 1
Species composition, capture methods and use of small cetacean carcasses of all interactions (n[%]) with gillnet and longline vessels. Percentages are read across for capture methods and uses while species composition of gillnet bycatch subtotal and grand total (2nd and last columns from left) are tallied by column. The fate category "unknown" refers to animals for which final fate was not recorded.

Species	Grand total	Longline harpoon	Longline bycatch	Gillnet harpoon	Gillnet bycatch							
					For bait	Discarded dead	Released alive	Sold	Eaten (boat)	Eaten (home)	Unknown	Gillnet subtotal
Delphinus spp.	120 (47)	2 (1.7)	0	2 (1.7)	22 (18.3)[a]	58 (48.3)	1 (0.8)	10 (8.3)	0	5 (4.2)	20 (16.7)	116 (50.2)
L. obscurus	73 (29)	8 (11.0)	1 (1.4)	0	35 (47.9)[b]	15 (20.5)	1 (1.4)	4 (5.5)	1 (1.4)	1 (1.4)	7 (9.6)	64 (27.7)
T. truncatus	33 (13)	0	0	3 (9.1)	10 (30.3)	17 (51.5)	1 (3.0)	0	0	0	2 (6.1)	30 (13.0)
P. spinipinnis	16 (6)	0	0	0	1 (6.3)	1 (6.3)	0	0	2 (12.5)	3 (18.8)	9 (56.3)	16 (6.9)
Unidentified	10 (4)	6 (60.0)	0	0	0	0	0	0	0	0	4 (40.0)	4 (1.7)
G. griseus	1 (0.4)	0	0	0	0	1 (100)	0	0	0	0	0	1 (0.4)
Total	253 (100)	16 (6.3)	1 (0.4)	5 (2.0)	68 (26.9)	92 (36.4)	3 (1.2)	14 (5.5)	3 (1.2)	9 (3.6)	42 (16.6)	231 (100)

[a] Four animals sold to longline vessel while at sea.
[b] Two animals given to another gillnet vessel and two stored for use on a subsequent longline trip.

Table 2
Estimated annual bycatch of small cetaceans by gillnet vessels for the port of Salaverry for the years 2002–2007, mean (CI). Values are derived from annually pooled monthly estimates of bycatch and known levels of monthly fishing effort for the port. Presented estimates are of total estimated small cetacean captures and of the four most commonly captured species.

Year	# Trips	Estimated # sets	Total estimated bycatch	*D. capensis*	*L. obscurus*	*T. truncatus*	*P. spinipinnis*
2002	411	3054	2002 (845–3776)	690 (431–1011)	812 (189–1979)	189 (112–266)	191 (94–769)
2003	620	4607	3212 (1356–6047)	1168 (709–1713)	1284 (279–3188)	311 (187–435)	263 (148–982)
2004	421	3128	2118 (945–3839)	825 (437–1334)	759 (155–1845)	213 (98–328)	183 (86–629)
2005	572	4250	2518 (1247–4323)	1186 (680–1892)	619 (173–1368)	303 (129–477)	237 (134–677)
2006	593	4406	2636 (1278–4505)	1158 (619–1931)	773 (216–1719)	285 (129–441)	228 (115–756)
2007	492	3656	1987 (881–3330)	814 (372–1418)	662 (156–1666)	255 (158–352)	129 (56–385)
Average	518	3850	2412 (1092–4303)	973 (541–1550)	818 (195–1961)	259 (136–383)	205 (105–699)

3.3.2. Longlines

Small cetacean bycatch was only observed on one (5%) longline fishing trip by a vessel targeting sharks and using small cetacean meat as bait. The bycatch was of a dusky dolphin, the branchline having been entangled around its flukes/tail stock. In addition, however, on three of four longline trips targeting sharks (15% of total observed trips), dolphins were harpooned for bait (Table 1). While we did not prepare monthly stratified catch estimates, the overall interaction rate for longline vessels targeting sharks was a relatively high 4.25 ± 3.86 animals.trip^{-1} (range: 0–8, $n = 20$) due to the common practice of harpooning dolphins for bait.

3.4. Fates of captured cetaceans

All harpooned animals, both by gillnet and longline vessels, were used as bait (Table 1). Also, the one dusky dolphin bycaught by a longline vessel, while captured alive, was killed and used as bait. Twenty-nine percent of gillnet bycatch was used as bait, including 54.7% of dusky dolphins. Ninety-seven percent of gillnet entangled animals were recovered dead. Of these, the most frequent fate of the carcass was for it to be discarded at sea (39.8%). Half of all common dolphins (50.0%) and a similar proportion of common bottlenose dolphins (56.7%) bycaught in gillnets were discarded dead. Gillnet entangled animals were also used for bait on subsequent sets during the trip, later sold in local markets, consumed on the boat or at home, released alive, or were given or sold to other gillnet or longline vessels for use as bait. Although constituting a small part of the total, there is a suggestion that Burmeister's porpoises may be preferred for human consumption, with 71.5% of known fate animals either consumed by the boat crew or brought to shore to be eaten at home.

3.5. Spatial distribution

The scarcity of reliable bathymetry data in coastal zones (<200 m) makes detailed interpretation of the depths of captures difficult since most captures were in less than 250 m 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 (Fig. 1a and b) 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 (Fig. 1c). All harpooning and longline bycatch events occurred within their respective 90% probability contours of set locations. There was a statistically significant difference in perpendicular distance to shore of captures among the four most commonly taken species ($H = 42.9$, df = 3, Kruskal–Wallis, $p < 0.001$), with captures of Burmeister's porpoises significantly nearer to shore than other species, occurring in a small area fronting Salaverry (Fig. S1a–d).

3.6. Temporal distribution

Total bycatch trip^{-1} varied seasonally ($F_{3,42} = 4.4$, $p = 0.009$) but not annually, nor was there a significant interaction between season and year (Fig. S2a). Post hoc Scheffe tests indicate that total bycatch in season 4 (August–October) was much higher than in other months (means ± SE: season 1 = 0.19 ± 1.9; season 2 = 0.61 ± 0.14; season 3 = 0.77 ± 0.15; season 4 = 1.18 ± 0.2). In the case of common dolphin bycatch, both season (Wald = 11.12, df = 3, $p = 0.11$) and year (Wald = 8.75, df = 2, $p = 0.13$) have significant effects, with number of sets and the season × year interaction having no significant influence (Fig. S2b). In this instance, pairwise comparisons indicate that season 1 has lower bycatch than other seasons ($p < 0.05$. Estimated marginal means (EMMs) ± SE: season

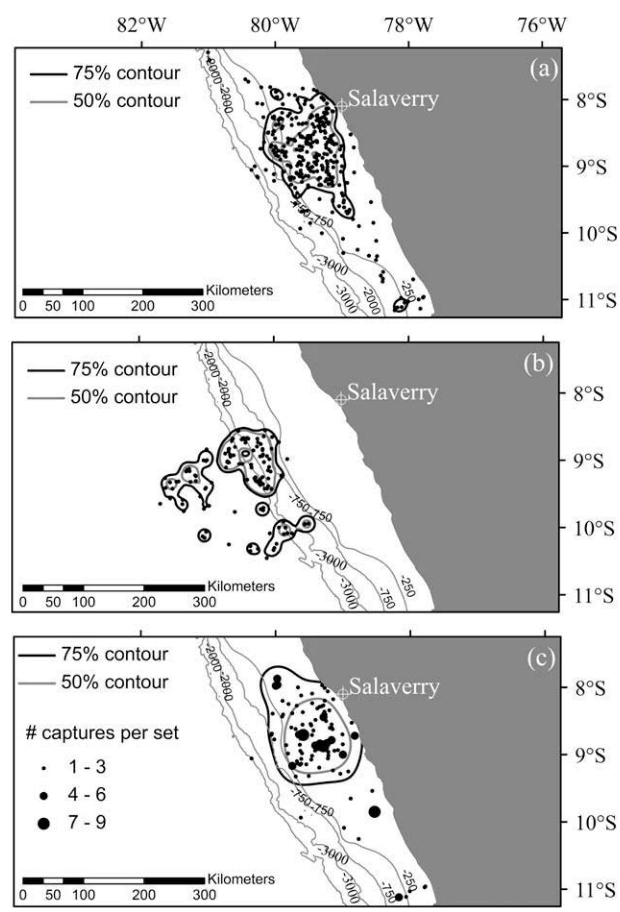

Fig. 1. Set locations by (a) gillnet vessels, (b) longline vessels, and (c) of all gillnet bycatch. Also presented in each pane are 50% and 75% probability contours of fishing sets and gillnet bycatch (250 m, 750 m, 2000 m and 3000 m isobaths are indicated).

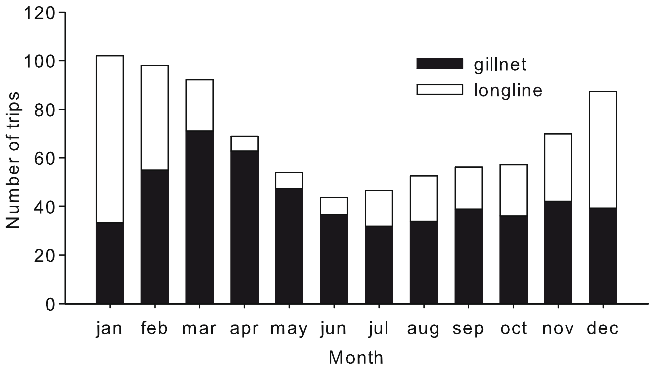

Fig. 2. Monthly average number of trips by gillnet and longline vessels for the years 2002–2007 determined from daily dock-side monitoring of fishing activity.

1 = 0.67 ± 0.28; season 2 = 1.94 ± 0.38; season 3 = 2.59 ± 0.48; season 4 = 1.66 ± 0.44) and that bycatch in 2007 was much lower than in 2006 and 2005 ($p < 0.05$. EMMs ± SE: 2005 = 2.23 ± 0.43; 2006 = 2.39 ± 0.35; 2007 = 0.67 ± 0.28). Only year had a significant effect on dusky dolphin bycatch (Wald = 46.1, df = 3, $p < 0.001$). In this instance the highly significant effect is driven by multiple differences among seasons. Dusky dolphin bycatch was significantly lower in seasons 1 (EMM ± SE = 0.13 ± 0.12) and 2 (0.44 ± 0.17) than in seasons 3 (1.5 ± 0.33) and 4 (4.37 ± 0.74) (Fig. S2c). In contrast, the bycatch of bottlenose dolphins (Fig. S2d) shows no strong seasonal patterns but year (Wald = 7.5, df = 2, $p = 0.025$) and total sets (Wald = 20.2, df = 1, $p < 0.001$) are both significant, with higher bycatch in 2007 (EMM ± SE = 0.97 ± 0.37) than in 2006 (0.32 ± 0.11) and 2005 (0.34 ± 0.14). For Burmeister's porpoises (Fig. S2e) there were no bycatch incidents observed in 2006 and 2007 so year is not included in the analysis. The bycatch of this species shows a very weak seasonal effect (Wald = 6.2, df = 2, $p = 0.047$) with lower bycatch in seasons 2 (EMM ± SE = 0.40 ± 0.28) and 3 (0.33 ± 0.33) than in seasons 1 (2.00 ± 0.70) and 4 (2.00 ± 0.70). However, the sample size for this last species is small and thus these results should be treated with some caution.

3.7. Estimating annual totals

Based upon daily shore-based monitoring of fishing effort in Salaverry we determined that there were an average of 518.2 ± 90 gillnet trips (range: 411–620 trips.year^{-1}) and 300.7 ± 25.2 longline trips (range: 272–341 trips.year^{-1}) per annum, for the years 2002–2007 (Table 2, Fig. 2). For the years 2002–2007 the estimated annual number of small cetaceans bycaught by gillnet vessels in the port of Salaverry was 2412 (95% CI 705–4415). The number of small cetaceans harpooned by gillnet vessels was estimated to be on the order of some tens of animals.

4. Discussion

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, a sizeable level of bycatch, direct take through harpooning, and consumption of small cetaceans, continue despite the existence since the mid-1990s of national legislation banning the capture of marine mammals and commerce in their products. Previous work monitoring the take of small cetaceans in Peru's artisanal fisheries focused largely on dock-side 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; Van Waerebeek, 1994; Van Waerebeek et al., 1997, 2002). Take observed here consisted of the same species assemblage documented in previous market studies (Read et al., 1988; Van Waerebeek and Reyes, 1990, 1994; Van Waerebeek et al., 1997, 2002).

4.1. The magnitude of the issue

Our results indicate that, for this site, bycatch in gillnets is the main cause of mortality with CPUE higher than published accounts from the California driftnet fleet off the United States Pacific coast (Barlow and Cameron, 2003), the Spanish driftnet fleet in the western Mediterranean (Silvani et al., 1999), and Ecuadoran artisanal gillnets (Félix and Samaniego, 1994) and comparable to CPUE for the large scale Moroccan driftnet fleet in the southwest Mediterranean (Tudela et al., 2005). CPUE in the Irish driftnet fleet in the northeast Atlantic was higher than observed here (Rogan and Mackey, 2007), however total annual estimated catch was about half that we have estimated for the port of Salaverry. As in other studies both in Peru (Ilo; Alfaro-Shigueto, unpublished results), and in the southern ocean (Kock et al., 2006), South Georgia (Ashford et al., 1996), and Hawaii (Forney and Kobayashi, 2007) cetacean bycatch rates at the vessel level in longlines were considerably lower than those of gillnet vessels. The overall interaction rate for longline vessels in Peru has the potential to be high, however, given the frequency of harpooning observed in Salaverry (three of four trips targeting sharks).

The Peruvian artisanal fleet has more than doubled in size from 1997–2005 to 9667 vessels and vessels in the port of Salaverry represent only ca. 1% of that fleet and ca. 2% of gillnetters (Escudero, 1997; Estrella et al., 1999, 2000; Estrella, 2007). It is feasible therefore that, at the national level, interactions between artisanal fisheries and small cetaceans remain globally significant. Indeed, it is conceivable that total mortality by the artisanal fishery is of the order or greater than that estimated in 1990–1993 (15,000–20,000 small cetaceans annually for all of Peru, Van Waerebeek and Reyes, 1994). An annual catch rate of this magnitude would be one of the highest estimated takes globally, on the order of that reported for Japan, Sri Lanka, or the large scale Morrocan driftnet fleet (Bjorge et al., 1991; Leatherwood, 1994; Reeves et al., 2003; Tudela et al., 2005). For the port of Salaverry alone, our estimate of small cetacean captures is approximately equivalent to that of all recorded fisheries in the United States of America (Read et al., 2006).

4.2. Challenges to and opportunities for take reductions

Almost all gillnet bycatch was recovered dead and approximately 40% of all entangled small cetaceans were discarded at sea. Thus, while 60% of carcasses were used opportunistically as bait or for consumption, the fact that the other 40% of all bycatch was discarded indicates that interactions with small cetaceans are often unwanted. This also points to the mixed success of Peru's protective legislation. That legislation succeeded in reducing landings and shrinking the market for small cetacean products, but does not appear to have reduced small cetacean captures at sea. Current practice 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. Given prevailing levels of poverty, the extent and size of the fishery and the resources available for natural resource management, closure of fishing areas to gillnetting or modification of gillnets (Dawson, 1991) appear unimplementable. The use of acoustic alarms has been shown to have potential in reducing gillnet bycatch in some cetacean populations (Kraus et al., 1997; Kastelein et al., 2001; Barlow and Cameron, 2003; Cox et al., 2003; Koschinski et al., 2006; Leeney et al., 2007) and should be trialed in the Peruvian gillnet fishery.

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 each net pane. Dolphin blubber and meat was the only bait observed 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 and its characteristic, unlike some fish bait, to remain intact and attached even after extended periods of soaking (this study; Van Waerebeek, unpublished results). Previous work also reported 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, 2002). The use of small cetaceans as bait has also been reported in coastal communities inter alia in Colombia (Mora-Pinto et al., 1995; Avila et al., 2008), Argentina (Goodall et al., 1994), Chile (Lescrauwaet and Gibbons, 1994), Mexico (Zavala-González et al., 1994) and the Philippines (Dolar, 1994), but the practice is common worldwide. In discussions with fishermen during this study 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 their preferred traditional bait fishes like mackerel (*Scomber japonicus*). Although challenging, finding an appropriate, low-cost substitute bait to cetacean meat and blubber may reduce harpooning. This is particularly urgent given recent evidence that the practice of harpooning small cetaceans for use as longline bait is prevalent along the entire Peruvian coast, most recently being reported in the southern port of Ilo in November 2008 (Bernedo, personal communication).

4.3. Future directions

The current study makes clear that small cetacean bycatch and direct take continues despite the existence of national legislation prohibiting capture and commerce in their products. Our results mandate 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. Our study demonstrates the feasibility and use of independent observer programs onboard artisanal fishing boats, and we strongly recommend that such surveys be continued and expanded throughout all fisheries of concern across the full geographic scale. 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. 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, 1992, 1993; Cassens et al., 2003, 2005; Rosa et al., 2005).

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 and artisanal purse-seine vessels targeting small schooling fish, especially anchovy. Based upon onboard observer effort of 2% of the industrial fleet in 2002, van Oordt and Alza (2006) reported an average capture rate of 0.041 dolphins.set^{-1}. They noted that small cetacean captures in the fishery could be significant given the estimated 80,000 fishing trips.year^{-1}. Data on fishing effort for all fisheries operating in Peru's coastal waters need to be compiled in order to more effectively set the research agenda towards building a clearer understanding of the possible impacts on small cetacean populations.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2009.09.017.

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