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Research Article

Incidental capture of sea turtles in the artisanal gillnet fishery in Sechura Bay, northern Peru

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ABSTRACT. Gillnets are recognized globally as one of the fishing gears with the highest levels of bycatch and mortality of sea turtles. Through onboard observer monitoring from July 2013 to June 2014 we assessed the bycatch of sea turtles by an artisanal gillnet fishery operating from Sechura Bay, Peru. One hundred and four sea turtles were incidentally caught in 53 observed fishing sets. The observed species composition of bycatch was green turtle *Chelonia mydas* (n = 100), hawksbill *Eretmochelys imbricata* (n = 3) and olive ridley *Lepidochelys olivacea* (n = 1). Bycatch occurred in 62.3% of monitored sets, with an average of 1.96 turtles caught per set. For all sea turtles combined, 28.8% of individuals were dead and 71.2% were alive at the time of retrieval. The majority of individuals caught were classified as juveniles and sub-adults, with an average carapace length (CCL) of 57.3 ± 0.9 cm for green turtles and 40.2 ± 2.4 cm for hawksbills. The mean annual catch per unit effort (CPUE) of sea turtles was 1.11 ± 0.31 turtles km^{-1} 12 h^{-1}), but varied by seasons. These results suggest that Sechura Bay is an important developmental habitat for juvenile and sub-adult green turtles and hawksbill turtles, but one subject to intense fishing interaction pressure. The development of monitoring programs, local awareness-raising activities, and enhanced management and protection of this critical foraging area and developmental habitat is recommended.

Keywords: sea turtles, CPUE, gillnet, bycatch, Sechura Bay, Peru.

INTRODUCTION

Five species of sea turtles are known to occur in the Peruvian waters, the olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) (Hays-Brown & Brown, 1982; Eckert & Sarti, 1997; Alfaro-Shigueto *et al*., 2004, 2010a; López-Mendilaharsu *et al*., 2006; Castro, *et al*., 2012). Research suggests that the Peruvian waters are primarily used as a foraging habitat (Hays-Brown & Brown, 1982; Alfaro-Shigueto *et al*., 2002; Santillan, 2008), although recent studies have confirmed the presence of green and olive ridley turtles nesting along Peru's highly developed northern coastline, making Peruvian coast the southernmost sea turtle nesting habitat in the eastern Pacific (Kelez *et al*., 2009; Velez-Zuazo *et al*., 2014, SWOT, 2015).

In recent years, it has become apparent that vessels from small-scale fisheries (SSF) using trawls (Lewison *et al*., 2004), gillnets (Murray, 2009), seine nets, pound nets (Gilman *et al*., 2010), longlines (Casale, 2008, 2010; Alfaro-Shigueto *et al*., 2011), and many other gears types all incur in sea turtle bycatch (Moore *et al*., 2010). Fisheries bycatch has been identified as an important factor in many population declines, included of sea turtles. These populations can decline over short timescales, often without detection (Lewison *et al*., 2004). This situation poses a serious threat to many sea turtle populations and their conservation efforts (Lewison *et al*., 2004; Alfaro-Shigueto *et al*., 2008; Dutton & Squires, 2008; Koch *et al*., 2013).

Within the Peruvian fisheries sector, SSF are particularly important because of their role in food security, but also as a source of employment (Mangel *et al*., 2010; FAO, 2010; Alfaro-Shigueto *et al*., 2011). Operating along the entire Peruvian coastline, the gillnet fishery comprise the largest component of Peru's small-scale fleet and it is conservatively estimated to set 100.000 km of net per year (Alfaro-Shigueto *et al*., 2010b). Recent studies show that gillnet fisheries in Peru have high interaction rates with sea turtles and exert significant pressure on sea turtle populations throughout the Pacific (Wallace *et al*., 2010; Alfaro-Shigueto *et al*., 2011; Lewison *et al*., 2014). The frequency of interactions depends on spatiotemporal overlap between critical habitat for a given species and fishing activities, encompassing a wide range of fishing methods and gear characteristics (Wallace *et al*., 2008, 2010). The purpose of the present research was to evaluate the incidental capture of sea turtles in the artisanal gillnet fishery in Sechura Bay, northern Peru, considering this bay is an important area for development of small scale fishery, but also an important foraging area of juvenile sea turtles.

MATERIALS AND METHODS

Study area and data collection

Sechura Bay is located on the northern coast of Peru in Sechura Province, Piura Department (5°12'-5°50'S and 80°50'-81°12'W) (Fig. 1). Is the largest bay in Peru and an important and traditional zone of artisanal fishing and mariculture (GORE - Piura, 2012; Morón *et al*., 2013).

The study was conducted in Sechura Bay from July 2013 to June 2014. Data was collected by trained onboard observers as part of a program to monitor the small-scale bottom set gillnet fleet operating from Constante port (5°35'S, 80°50'W).

Fishing boats ranged in length from 6 to 10 m and each trip consisted of setting of bottom set gillnets. Bottom set gillnets were made of multifilament twine and were composed of multiple net panes that measured 56.4 m long by 2.8 m high, with a stretched mesh of approximately 24 cm (Alfaro-Shigueto *et al*., 2010b; Ortiz *et al*., 2016). Typical to this fishery, nets were deployed in the late afternoon, soaked overnight and retrieved the following morning. The soak time ranged from 12 to 24 h (López-Barrera *et al*., 2012; Ortiz *et al*., 2016). The target species in this fishery are flounder *Paralichthys* spp., guitarfish *Rhinobatos planiceps* and other species of ray from the Batoidea superorder as common stingray *Dasyatis* spp. and round ray *Urotrygon* spp. (Tume *et al.*, 2012; Ortiz *et al*., 2016). Onboard observers recorded specific data about the fishery operation, including information on gear characteristics (*e.g.*, net size and number of panes, number of sets), environmental data for each set (*e.g.*, location, time of set and haul, sea surface temperature, water depth, and water visibility), and information on each sea turtle bycatch event.

Incidental capture, morphometric data and sea turtle handling

Incidentally captured sea turtles were brought onboard the boat for handling. We proceeded to untangle each individual and assessed its basic condition (alive, inactive/drowned or dead). Those individuals recorded as inactive/drowned, were rehabilitated following the handling and resuscitation techniques described on the NOAA Southeast Fisheries Science Center website for onboard observers (www.sefsc.noaa.gov/seaturtlefisheriesobservers.jsp). Information collected for each turtle included species identification, the geographical position (latitude and longitude) of capture, capture condition and final fate (released alive or discarded dead), and curved carapace length (CCL; measured from the nuchal notch to posterior-most tip) (Bolten, 2000). Measurements were made using a metric tape (±0.1 cm). Sea turtles determined to be in good condition were tagged with Inconel tags applied to the trailing edge of both front flippers and were released. Dead turtles were measured and then discarded at sea. For all sea turtle individuals, skin sample were taken for further studies.

Individuals of *C. mydas*, with a CCL $\leq$69 cm. were considered as juveniles, individuals with 69 $\leq$ CCL <85 cm. were considered as sub-adults, and individuals with a CCL $\geq$85 cm. were categorized as adults (Zarate *et al*., 2013). Individuals of *E. imbricata*, with a CCL $\leq$74 cm were considered as juveniles, individuals with 74 $\leq$ CCL <81.6 cm. were considered as sub-adult, and individuals with a CCL $\geq$81.6 cm were categorized as adults (Liles *et al*., 2011). Finally, individuals of *L. olivacea*, with a CCL $\leq$59.2 cm were considered as juveniles, individuals with 59.2 $\leq$CCL < 64.9 cm. were considered as sub-adult and individuals with a CCL $\geq$ 64.9 cm were considered as adults (Barrientos-Muñoz *et al.*, 2014).

Data analysis

Sea turtle bycatch per unit effort (CPUE) was determined as: CPUE = number of turtles captured / (net length [km]) × (soak time of net [12 h]) (Wang *et al*., 2013). Gillnet bycatch data for the study was grouped by month in order to derive monthly stratified CPUE estimates. These data were calculated in terms of catch set^{-1} (Mangel *et al*., 2010). However, to facilitate comparison with other studies, catch per km h^{-1} was also calculated. Descriptive statistics are presented as mean ± standard deviation (SD).

The annual bycatch rate in Constante port was also calculated, according to Alfaro-Shigueto *et al.* (2011) applying their same estimates of fleet size and fishing effort (8 fishing vessels, 30 sets per month), the best available estimates this fishing fleet's size and effort for this port.

Maps of fishing effort and turtle captures were prepared using MAPTOOL (Seaturtle.org, V. 2002, available at www.seaturtle.org/maptool).

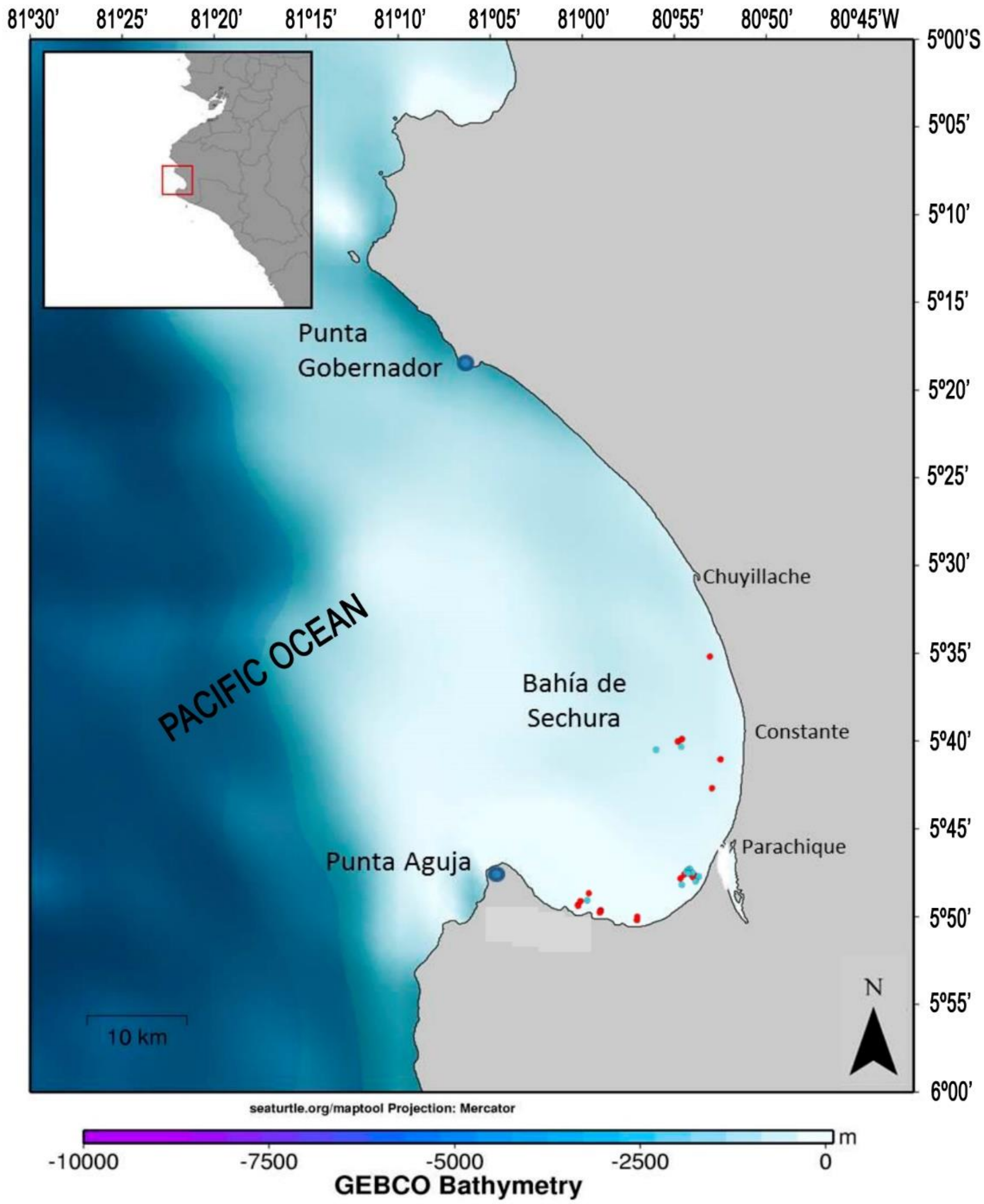

Figure 1. Location of gillnet sets in Sechura Bay, Peru. Sets without bycatch of sea turtles (●); sets with bycatch (●) (Seaturtle.org Maptool, V. 2016).

RESULTS

Fifty-three fishing sets were monitored (Fig. 1), 15 on winter (April to June), 10 on spring (October to December), 14 on summer (January to March) and 14 on autumn (July to September). Nets averaged 1.12 ± 0.02 km in length (range = 0.88-1.45 km) and 19.09 ± 0.45 h of soak time (range = 10.22-28.52 h).

Sea turtle bycatch totaled 104 individuals. One-hundred individuals were *C. mydas* (96.2%), three individuals were *E. imbricata* (2.9%) and one individual was a *L. olivacea* (0.9%) (Table 1). Bycatch occurred in 62.3% of monitored sets (Fig. 1) with an overall bycatch rate of 1.96 ± 0.44 turtles set^{-1} (range = 0-16 turtles set^{-1}).

The number of turtles caught varied by season. The largest number of captures occurred during winter (n = 39), followed for autumn (n = 29), spring (n = 21), and summer (n = 15) (Fig. 2). The month with the highest number of caught turtles was July (n = 34) while the months with the lowest number of captures were December and June (n = 1, each month) (Table 2). Logistical constraints and poor weather conditions precluded the gathering of observer data of the fishing trips for the months of November 2013 and January 2014 at Constante port.

Table 1. Number of sea turtles incidentally caught with gillnets in Sechura Bay in 53 fishing sets, morphometric measures and animal fate, July 2013 to June 2014. CCL: curved carapace length.

Species	Bycatch	CCL (cm)		Fate	
		Mean ± SD	Range	Alive	Dead
Chelonia mydas	100	57.3 ± 0.9	40.5 - 79.6	72	28
Eretmochelys imbricata	3	40.2 ± 2.4	36.5 - 44.6	1	2
Lepidochelys olivacea	1	64.1	na	1	-

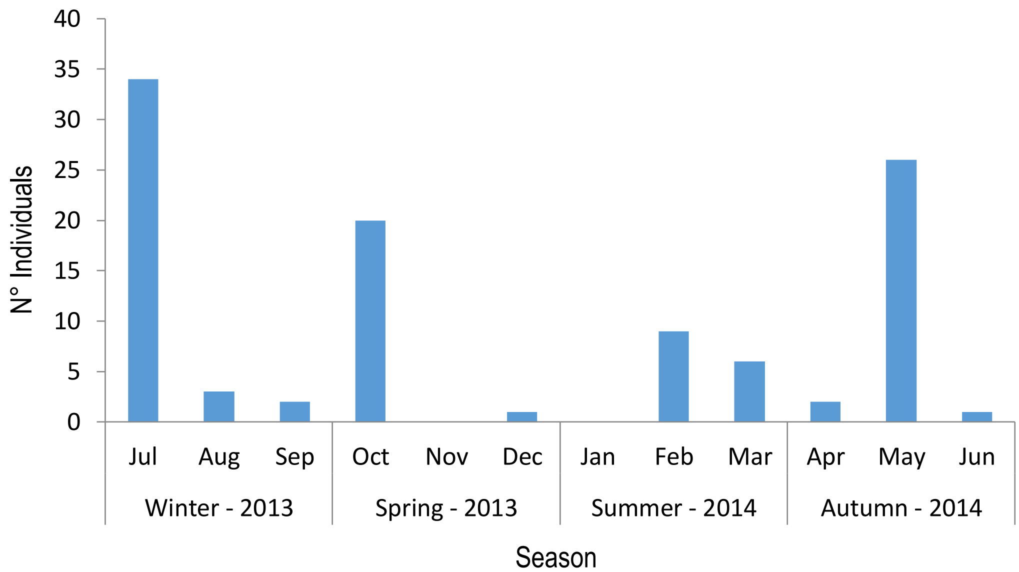

Figure 2. Numbers of incidentally captured sea turtles by season and by month in the Sechura Bay, 2013-2014. *Notice that November and January do not have fishing sets.

Of the 104 turtles caught, we obtained complete morphometric data from 99 individuals (Fig. 3). The remaining five animals for which data collection was not possible were all *C. mydas*. The observed CCL by species was 57.3 ± 0.9 cm (range: 40.5 cm to 79.6 cm) for *C. mydas*; 40.2 ± 2.4 cm (range: 36.5 to 44.6 cm) for *E. imbricata*, while the only olive ridley *L. olivacea* measured 64.1 cm CCL. Of all turtles captured, 28.8% (30 individuals) were recovered dead (28 *C. mydas* and 2 *E. imbricata*). The remaining 71.2% (74 individuals) were captured alive, tagged and released. These consisted of 72 *C. mydas*, one *E. imbricata*, and one *L. olivacea*.

The overall CPUE observed was 1.11 ± 0.31 turtles km^{-1} 12 h^{-1} or 0.11 ± 0.03 turtles km^{-1} 12 h^{-1}. Sets during the winter had the highest observed CPUE with a mean of 1.94 ± 1.58 turtles km^{-1} 12 h^{-1} or 0.19 ± 0.10 turtles km^{-1} 12 h^{-1}. Similarly, the CPUE varied among months. July recorded the highest CPUE with 5.11 ± 2.65 turtles km^{-1} 12 h^{-1} or 0.43 ± 0.22 turtles km^{-1} 12 h^{-1}, while December had the lowest CPUE with 0.16 ± 0.1 turtles km^{-1} 12 h^{-1} or 0.01 ± 0.01 turtles km^{-1} 12 h^{-1} (Table 2). The annual bycatch for the Constante Port was 183 sea turtles.

DISCUSSION

Sea turtle catch rates

Recent declines of large marine vertebrates, such as sea turtles, seabirds and marine mammals, have focused attention on the ecological impacts of incidental take, or bycatch, in global fisheries (Oravetz, 2000; Wallace *et al*., 2010; Lewison *et al*., 2014). Sea turtles are incidentally captured in almost all fishing gear, including trawl nets, gillnets, pelagic and bottom longlines (Lewison *et al*., 2004; Rosales *et al*., 2010). Among these, gillnet fisheries may be the single largest threat to sea turtle populations (Gilman *et al*., 2010; Wallace *et al*., 2010). In Peru, gillnets were reported as the main source of turtle mortalities in artisanal fisheries from 1986 to 1999 (Estrella & Guevara-Carrasco, 1998a, 1998b; Estrella *et al*., 1999a, 1999b) and have been the focus of attention in recent years (Mangel *et al*., 2010; Wang *et al*., 2013; Ortiz *et al*.,

Table 2. Monthly and seasonal capture per unit effort (CPUE; turtles km^{-1} 12 h^{-1} and turtles km^{-1} 12 h^{-1}), July 2013 to June 2014.

Season	Month	Bycatch (n)	Fishing set	CPUE (turtles km^{-1} 12 h^{-1})		CPUE (turtles km^{-1} 12 h^{-1})	
				Month	Season	Month	Season
Winter	July	34	6	5.11± 2.65	1.94 ± 1.59	0.43 ± 0.22	0.19 ± 0.10
	August	3	5	0.40 ± 0.23		0.03 ± 0.02	
	September	2	4	0.34 ± 0.20		0.03 ± 0.02	
Spring	October	20	6	1.62 ± 0.50	0.90 ± 0.72	0.14 ± 0.04	0.09 ± 0.03
	December	1	4	0.20 ± 0.16		0.01 ± 0.01	
Summer	February	9	7	0.51 ± 0.24	0.50 ± 0.10	0.04 ± 0.02	0.04 ± 0.01
	March	6	7	0.40 ± 0.10		0.03 ± 0.01	
Autumn	April	2	4	0.30 ± 0.20	1.14 ± 0.51	0.02 ± 0.01	0.12 ± 0.06
	May	26	9	2.10 ± 1.10		0.17 ± 0.09	
	June	1	1	1.10 ± 0.00		0.09 ± 0.00	

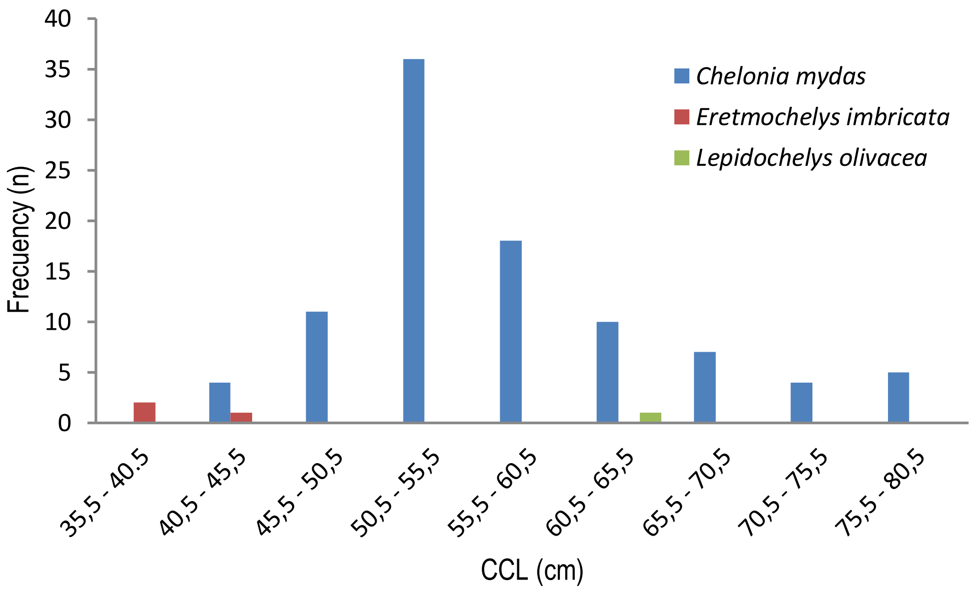

Figure 3. Size-classes of sea turtles captured, by species, in the Sechura Bay, July 2013 to June 2014.

2016). Our results suggest that gillnets are an important source of bycatch and mortality of sea turtles in Sechura Bay, being a threat to the sea turtles populations in this important foraging and developmental habitat (de Paz & Alfaro-Shigueto, 2008; Santillán, 2008).

Studies of the sea turtle bycatch suggested that bycatch rates reported for gillnets in Sechura Bay are among the highest in the world (Wallace *et al.*, 2010; Alfaro-Shigueto *et al.*, 2011). Alfaro-Shigueto *et al.* (2011) reported that is notable the high proportion of bycatch-positive sets and high CPUE for green turtles in the bottom set nets at Constante port (56%; 2.78 turtle per set). Caceres *et al.* (2013) observed that all monitored trips with sea turtle interactions were by bottom set net boats. These bycatch rates are similar to the present study, reporting that 62.3% of observed sets had bycatch. The mean CPUE was approaching two turtles per set and the mortality rate was 28.8%. These values are of concern and we anticipate that would be higher in the absence of onboard observers.

Our bycatch results are in agreement with other studies investigating sea turtle bycatch by net fisheries in Peru. A study in Pisco-Paracas, De Paz *et al*. (2002) reported a total of 204 sea turtles caught in gillnets during 276 monitored days, with the bycatch consisting of *C. mydas* (67.8%), *L. olivacea* (27.7%) and *D. coriacea* (2.9%). Castro *et al.* (2012) monitored 265 fishing operations from Lambayeque, from which a total of 383 sea turtles were captured: being 80.4% olive ridleys, 19.3% green turtles and 0.2% hawksbill turtles. Cáceres *et al.* (2013), collected data from the Constante Port and recorded that 43 green turtles were captured during 14 monitored trips. Rosales *et al.* (2010) in Tumbes registered 95 specimens belonging to four sea turtles species (*Chelonia mydas*, *Lepidochelys olivacea*, *Dermochelys coriacea* and *Eretmochelys imbricata*); the most registered species were *C. mydas* (64.2%) and *L. olivacea* (30.5%). In each of these studies, *C. mydas* was one the most frequently caught species of sea turtle. Our results reinforce these findings, we observed the capture of 104 sea turtles, of which the vast majority were *C. mydas* (96.2%), followed by *E. imbricata* (2.9%), and one individual *L. olivacea* (0.9%).

The results reported in this research suggest that the bycatch in gillnets is one of the main cause of mortality of sea turtles in this area. We reported a mortality percentage of 28.8, being higher than the reported in industrial shrimp trawlers vessels of eastern Venezuela (17.5%) (Alio *et al.*, 2010). The CPUE of 0.61 ± 0.22 turtles set^{-1} reported by Rosales *et al.* (2010) in Tumbes for a research of three years was lower than the reported in this study (1.96 ± 0.44 turtles set^{-1}). However the annual bycatch rate was lower than the report in the same area by Alfaro-Shigueto *et al.* (2011), reporting a high proportion of bycatch-positive sets and obtained an annual bycatch rate by this fishery of 368 sea turtles. This study also reported a high bycatch per unit effort (BPUE) for green turtle (2.78 turtles per set), and a mortality rate of 41%, being it higher than the results obtained in this study. As part of experimental research carried out from 2011 to 2013, also in the Sechura Bay demersal gillnet fishery, Ortiz *et al.* (2016) obtained a CPUE of 1.40 ± 0.16 green turtles km^{-1} 24 h^{-1} in control nets, this bycatch rate is similar to our observed CPUE of 1.11 ± 0.31 turtles km^{-1} 12 h^{-1}.

Given these high rates of observed bycatch, in order to secure long-term population viability and to conform with international guidelines for responsible fisheries (FAO, 2009), sea turtle bycatch mitigation solutions for these fishery need to be identified to minimize the number of bycatch mortalities (Nguyen *et al.*, 2013). While net modifications have, in some cases, resulted in megafauna bycatch mitigation in certain fisheries without substantial reductions in target catch, mitigating net bycatch has proven challenging because nets are inherently nonselective (Peckham *et al*., 2015 & Gilman *et al*., 2010). However, recent research, conducted in-part in the Constante demersal set-net fishery, suggests that sea turtle bycatch in gillnets could be reduced through illuminating nets (Wang *et al*., 2013 & Ortiz *et al*., 2016).

Sea turtle size classes

The sizes of *C. mydas* captured in Sechura Bay in this study corresponded to a population consisting of juveniles (89.5%) and sub-adults (10.5%). The mean CCL = 57.3 ± 0.9 cm (range = 40.5 to 79.6). In this same area, Santillán (2008), analyzed the fishery bycatch from Constante Port and found a mean CCL for green turtles of 63.6 ± 1.6 CCL (range: 47.5 to 88 cm; n = 45), indicating a concentration of juvenile and sub-adult turtles. Cáceres *et al*. (2013), obtained a mean CCL of 60.2 ± 6.8 cm (range: 52 to 92 cm), and thus considered all as juvenile turtles. Paredes *et al*. (2015) in Virrilá estuary reported a mean CCL of 59.2 ± 10.2 cm (range = 30.9-89.7 cm) indicating a population represented by juveniles (62.6%) Our results suggest that this bay harbor an immature population.

In the Eastern Pacific Ocean (EP), the hawksbill turtle has been reported as once “common” from Mexico to Ecuador (Alfaro-Shigueto *et al*., 2010a; Gaos *et al*., 2010) recruited to neritic habitats (Scales *et al*., 2011). Studies in Máncora, Constante and Parachique, from 2000 to 2005, found a mean CCL of 38.9 ± 5.9 cm (range 28.3-49.0 cm, n = 11), indicating a population of mostly immature individuals (Alfaro *et al*., 2010a). Quiñones *et al*. (2011) in the San Andrés area, reported a mean CCL size of 45.2 ± 3.2 cm, and they concluded that juveniles and sub-adults used this area as a foraging ground. We reported the incidental capture of three *E. imbricata*, with a mean CCL of 40.2 ± 2.4 cm (range: 36.5-44.6 cm). This size corresponded to juvenile individuals and is similar to other reports for the northern coast of Peru.

Kelez *et al*. (2003) measured 16 carapaces of *L. olivacea* from Tumbes to Ancash (Peru) from 2001 to 2002 and reported a mean CCL of 66.6 cm. For the year 2008, in Tumbes, measurements of 47 *L. olivacea* carapaces yielded a mean CCL of 63.3 ± 4.5 (range: 51-70 cm; n = 47) indicating the presence of juveniles, sub-adults and adults (Forsberg, 2012). Our observed bycatch of one *L. olivacea* with a CCL of 64.1 cm is consistent with a sub-adult sized individual.

CONCLUSION AND RECOMMENDATIONS

Gillnets are a significant source of sea turtle bycatch in Sechura Bay. Our results indicate that Sechura Bay is an important foraging area and developmental habitat for green turtles and also possibly for critically endangered hawksbill turtles. This research found that a majority of sets having bycatch, given these catch rates; we recommend the identification and implementation of mitigation measures to reduce sea turtle bycatch, like illuminating nets with LED lights, shark silhouettes and use float lines without buoys (Gilman *et al*., 2010; Wang *et al*., 2010, 2013; Ortiz *et al*. 2016). To help maximize their uptake and effectiveness, such efforts to identify solutions should involve small-scale fishermen as well as scientists and other stakeholders and decision-makers.

Enhanced management and protection of this bay that acknowledges its importance as a developmental habitat and foraging ground is recommended. To decrease sea turtle captures and commerce, efforts are needed to offer fishermen new economic alternatives. Additional efforts should include an education and research program targeting the Sechura Bay community.

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