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Fishers' solutions for hammerhead shark conservation in Peru

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ABSTRACT

Filling ecological and social data gaps for small-scale fisheries is crucial for global conservation of shark species. In 2016, international protection of vulnerable smooth hammerhead sharks (*Sphyrna zygaena*) resulted in a seasonal fishing ban to protect juvenile sharks in Peru's small-scale fisheries. Richer data on the fisheries' social-ecological dynamics are necessary to understand fishery impacts and the ban's efficacy. Semi-structured interviews with 88 Peruvian gillnetters revealed that fishers are cognizant of their impacts on the hammerhead population and further, that historical fishery impacts on the species are more severe than reflected in official records. On balance, respondents welcome conservation measures: 76% of respondents were in favor of the ban. However, most respondents also voiced objections to the ban, with unfairness emerging as a central theme including with regards to impracticality, economic severity, ecological necessity, and the burden of compliance. These objections may directly and indirectly stem from a lack of transparency and fisher participation in the ban development-and-implementation process. Fishers suggested alternative or additional options for hammerhead management, such as minimum sizes or dynamic "move-on" spatial closures. These results point to the benefits of a participatory process that engages fishers in practical and more equitable conservation solutions.

1. Introduction

Precipitous population declines have put elasmobranch species in the international conservation spotlight (Dulvy et al., 2014; Worm et al., 2013). The loss of sharks is concerning not only for the loss of biodiversity, but also for potential top-down effects structuring marine ecosystems (Baum and Worm, 2009; Ferretti et al., 2010). International and national regulations for fishery exploitation, the principal threat to shark populations (Dulvy et al., 2014; Worm et al., 2013), have increased over the past few decades, thus far with limited effectiveness (Davidson et al., 2016; Lack and Sant, 2011; Techera and Klein, 2011).

A major challenge to understanding and managing fishery threats to sharks is the lack of data for small-scale fisheries, which in some countries contribute the majority of elasmobranch catch (Cartamil et al., 2011; Walker, 1998; Worm et al., 2013). In Peru, elasmobranch species are primarily caught in small-scale fisheries, where sharks are targeted for direct human consumption rather than strictly for fins (Alfaro-Shigueto et al., 2010; Doherty et al., 2014). Small-scale fisheries in Peru collectively exert effort and impact comparable to large industrial fisheries (Alfaro-Shigueto et al., 2010). Consequently, Peru's shark landings rank within the top 20 globally (18th in mean annual catch from 2007 to 2017; Okes and Sant, 2019) and represent the highest cumulative historical landings in the Pacific (372,075 tons from 1950 to 2010; Gonzalez-Pestana et al., 2014). Lack of fishing effort data, population assessments, and directed study of the sizable (estimated > 100,000 km nets set annually, Alfaro-Shigueto et al., 2010) small-scale drift gillnet elasmobranch fishery have been identified as major research gaps hindering Peruvian shark fishery management (Doherty et al., 2014; Gonzalez-Pestana et al., 2014).

In 2016, following the 2013 listing of three species of hammerhead sharks under the Convention on International Trade in Endangered Species (CITES) Appendix II, Peru implemented a seasonal ban on hammerhead fishing from January 1 through March 10 (PRODUCE, 2016). This coincided with the highest landings in San José and

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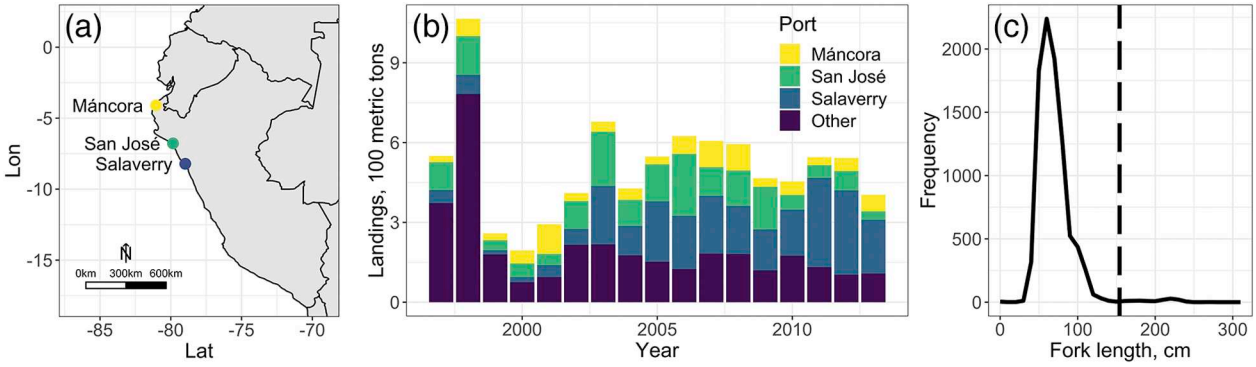


Fig. 1. (a) Study area and locations of interviews. (b) Total smooth hammerhead landings (metric tons) in Máncora (yellow), San José (green), Salaverry (blue), and other Peruvian landing sites from January 1997, when IMARPE started recording disaggregated shark species landings, and September 2013 (adapted from de la Puente Jeri, 2013). No significant trends in landings were detected ($y = -1.22x + 2962.44$, *CI -22.57, 20.12, Adj.* $R^2 = -0.07$, $p = 0.9$). (c) Distribution of fork length of 9086 observed smooth hammerheads in gillnet sets between 2004 and 2016 ([self-citation]); dotted line indicates estimated fork length at maturity (Mas et al., 2014; Nava and Márquez-Farías, 2014). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Salaverry, the two ports with the highest volume of smooth hammerhead (*Sphyrna zygaena*) landings (IMARPE, 2014) (Fig. 1a, b). Prior to the ban, the smooth hammerhead was the most commonly caught shark species in drift gillnets and the third most-caught shark species in Peru behind blue shark (*Prionace glauca*) and shortfin mako shark (*Isurus oxyrinchus*) (Gonzalez-Pestana et al., 2014). Mean annual landings have been around 500 tons since species-level landings records began in 1997 (de la Puente Jeri, 2013) (Fig. 1b). These landings far exceed formal global catch evaluations of this species: from 2002 to 2011, the sum of landings reported from all countries in the FAO FishStat database was < 1800 total tons, while in that same period Peru landed > 5300 tons (de la Puente Jeri, 2013; Gonzalez-Pestana et al., 2014; Mundy-Taylor and Crook, 2013).

The International Union for the Conservation of Nature (IUCN) has evaluated smooth hammerheads, highly sought after for the fin trade (Cardeñosa et al., 2018), as "vulnerable" (Rigby et al., 2019). Data on the species are limited, including for the Eastern Pacific, but they are thought be the slowest-growing of the large hammerheads and highly susceptible to catch and bycatch owing to aggregative behavior and high rates of post-capture mortality (Gallagher and Klimley, 2018; Simpfendorfer, 2005). Movement studies are limited, but suggest that juveniles aggregate in coastal waters whereas adults are more pelagic (Compagno, 1984; Gallagher and Klimley, 2018).

In Peru's small-scale fisheries, landings of smooth hammerheads, as well as other shark species, are comprised largely of juveniles (Castañeda, 2001; Doherty et al., 2014; Gonzalez-Pestana, 2014) (Fig. 1c); researchers have also documented this phenomenon elsewhere for smooth hammerheads in inshore fisheries (Marina and Campos, 2014; Mundy-Taylor and Crook, 2013). Adult sharks, including breeding females, are most commonly caught in the austral spring and summer months (peaking in December) albeit in low numbers (Castañeda, 2001; IMARPE, 2014). Neonates are also caught during these months, while increasingly larger juveniles are landed through the summer and fall (Castañeda, 2001, IMARPE, 2014). This seasonal size distribution is consistent with coastal Peru acting as a juvenile aggregation area for smooth hammerheads (Gonzalez-Pestana, 2014). Landings volumes also peak later in the year for northern ports, suggesting seasonal movement that may follow currents, temperature, and/or productivity patterns (IMARPE, 2014; Mason et al., 2019).

Based on landings reports, it is unclear whether fishers specifically target juveniles or whether catch of juveniles is a circumstance of geography, market demand, population status, gear type, or other factors. "Gauntlet" fishing targeting juvenile sharks may be a sustainable strategy given elasmobranch life history: for many species, neonatal and juvenile age classes contribute less to population growth than adults or subadults (Kinney and Simpfendorfer, 2009; Prince, 2005). However, landings of juveniles, if part of a trend of declining sizes, may indicate overfishing. Without long-term landings data, length data, or life-history models for this species, it is difficult to assess the fishery's sustainability. The lack of these data also makes it difficult to predict whether this ban, which is timed to coincide with catch of juveniles and neonates as opposed to other age classes (Castañeda, 2001; IMARPE, 2014), will be effective at improving hammerhead population health.

Interviewing fishers is a valuable way to fill data gaps for this poorly understood fishery. Fishers' insights may extend scientific time series, contribute to population assessments, and provide richer social and cultural context crucial to evaluating and implementing effective conservation measures (Aswani et al., 2018; Bennett et al., 2017; Neis et al., 1999; Poe et al., 2014; Sáenz-Arroyo et al., 2005). In particular, understanding the local social and ecological context may avert unintended consequences such as those demonstrated by a shark-fishing ban in Baja, Mexico, where an abruptly announced moratorium on directed shark fishing resulted in high levels of elasmobranch bycatch and a 600% increase in sea turtle strandings as fishers scrambled to enter other fisheries, as well as erosion of trust in management and conservation science initiatives (Finkbeiner, 2014). In this study, we interview hammerhead fishers to gain insight into the history and sustainability of the hammerhead fishery in Peru as well as fishers' perceptions of and reactions to the hammerhead ban. We discuss how fishers' attitudes and knowledge, in addition to their social learning processes, might contribute to more effective conservation measures as Peru and other countries work to manage their small-scale elasmobranch fisheries.

2. Methods

In 2018, we conducted 88 semi-structured interviews with drift-gillnet captains or boat owners between February 8 and March 11 in three major Peruvian ports: Salaverry, San José, and Máncora (Fig. 1a, Table 1). We selected those ports as they have the largest drift-gillnet fleets, comprising approximately 30%, 20% and 10% (respectively) of hammerhead catch in Peru from 1997 to 2013 (Alfaro-Shigueto, 2014; IMARPE, 2014). We used a purposeful sampling strategy to select interview respondents (Gentles et al., 2015; Patton, 2015), focusing on drift-gillnet captains and/or boat owners as "information-rich cases" because these individuals make the decisions about when, where, and how to fish. Local government officials acted as initial key informants to identify and select respondents (Ritchie and Lewis, 2003).

The interview protocol included items eliciting short, closed-ended responses that resulted in quantitative data, such as demographics of

Table 1
Respondent demographics, fishing-gear, and targeted-species data in each of the three ports. Total number of boats from Alfaro-Shigueto (2014). Asterisk in column heading indicates significant difference among ports according to one-way ANOVA ($p < 0.05$); asterisk within column indicates significant difference indicated by TukeyHSD test ($p < 0.05$).

Port	Total drift gillnet boats	Number interviews	Mean age*	Mean years of experience with gillnets	Mean number of gears used* -most common alternate gears	Mean number of species targeted per gear type -most common species targeted in gillnets
San José	109	33	50 (sd = 15, range = 20–76)	25 (sd = 15, range = 5–60)	2.8 (sd = 1, range = 1–5)* - Squid jig - Small-mesh coastal net - Large-mesh bottom-set net	2.8 (sd = 1.8, range = 1–9) - hammerhead - ray - thresher shark - blue shark - silky shark
Máncora	55	29	51 (sd = 12, range = 30–76)	24 (sd = 12, range = 2–44)	1.6 (sd = 0.9, range = 1–4) - Squid jig - Small-mesh coastal net - Large-mesh bottom-set net	3.7 (sd = 1.9, range = 1–8) - thresher - hammerhead - tuna - blue shark - mahi mahi
Salaverry	70	26	43 (sd = 11, range = 18–68)	21 (sd = 12, range = 6–51)	1.9 (sd = 0.8, range = 1–3) - Squid jig - Longline - Large-mesh bottom-set net	3.3 (sd = 2.5, range = 1–11) - hammerhead - mahi mahi - thresher - blue shark - mako shark

the fishers themselves, shark sizes, and months fished. We derived a quantification of hammerhead size by asking fishers to use their hands to demonstrate an estimation of spans, which researchers measured to the nearest centimeter. The protocol also included items that elicited more lengthy, open-ended responses that resulted in more qualitative data related to the overall ecological, social, political, and cultural context of the fishery as well as fishers' reactions to the ban. We conducted interviews in Spanish and recorded handwritten notes, which the interviewer transcribed and then translated into English prior to analysis. We facilitated further dialogue through sharing initial findings with fishers via a written report in Máncora and Salaverry and a presentation in San José in March 2018; we integrated some of that early-stage feedback into our thematic analysis of the qualitative data. We conducted this research in accordance with our university's Institutional Research Board, which governs interactions with human subjects (protocol #44763 approved January 11, 2018).

For the more quantitative data, we tested differences using paired student's *t*-tests or one-way ANOVA and Tukey's HSD post-hoc tests. To test the relationship between fisher age and observed size differences in hammerheads while capturing variability among ports, we used a linear mixed-effects model with port as a random effect and restricted maximum likelihood estimation (REML) with the package nlme (version 3.1.131) in R (version 3.4.2) (Pinheiro et al., 2017; Zuur et al., 2009). We assumed a normal distribution and checked the model residuals for goodness of fit, and selected models with a likelihood ratio test (Zuur et al., 2009).

Where interview items tended to yield more closed-ended and categorical responses, we present the proportion of respondents whose responses fell within those themes, with some respondents covering multiple themes. For the more open-ended, more highly qualitative and discursive interview data, we used a thematic analysis process (Braun et al., 2018) to seek emergent themes. Using an inductive orientation, initiated with the interview data, we iteratively categorized and coded the data to derive themes and meanings (Braun and Clarke, 2006; Braun et al., 2018). In those instances, we did not seek to present the data in quantitative ways but, rather, we describe the thematic categories that emerged during the analytic process, and we share representative quotations to illustrate common themes.

3. Results

3.1. Hammerhead fishery demographics

Respondents averaged 48 years old (sd = 13), with mean 24 years of experience fishing with gillnets (sd = 13). Respondents in San José had significantly more flexible fishing strategies than respondents in Máncora or Salaverry (ANOVA $p < 0.001$; TukeyHSD SJ > S, SJ > M, $p < 0.001$; S ≥ M, $p = 0.622$), using nearly three types of fishing gear on average. They were also slightly more likely to report having alternative income sources, such as driving a motorcycle taxi or carpentry (21% versus 17% and 8% in Máncora and Salaverry, respectively, ANOVA ns) and to report having at least one additional household member with a source of income (39%, vs. 28% in Máncora and 31% in Salaverry, ANOVA ns) (See Table 1 for respondent demographics and fishing behavior data and supplemental material for full results from statistical tests). Respondents in San José and Salaverry reported primarily fishing for hammerheads in the austral summer months, December through March, while the fishing season in Máncora peaks later, in April and May (Fig. 2).

3.2. Hammerhead fishery declines

A majority of respondents (87%) said that the quantity of hammerheads they catch per trip has decreased since the start of their fishing careers. The most common explanations the fishers gave for this decrease related to an overall increase in fishing effort. Respondents described direct exploitation by Peruvian and foreign fleets as well as indirect effects of industrial forage-fish fisheries through comments such as the following:

> Much overfishing, by ourselves, the fishers. We fish the small ones. We don't let them grow.
>
> (Máncora, age 41)

> Before, in 1955 or 1960, there were so many hammerheads. Plenty in these parts, 10–20 miles from the coast. Today, we don't see them. There are people who capture them out at sea, 100 miles out. Our government has given materials to foreign boats. Trawls, purse seines. The trawls, those catch everything. The smallest to the

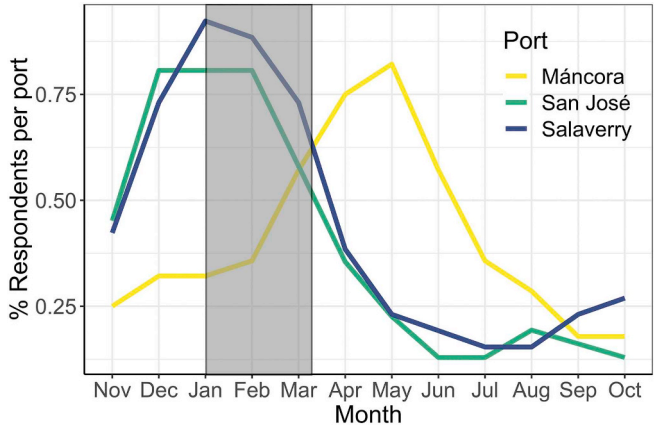


Fig. 2. The proportion of respondents in Máncora (yellow), San José (green), and Salaverry (blue), who fish for hammerheads in each month. Rectangle indicates duration of the hammerhead fishing ban. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

> biggest. What a damage that our government has done us. A great loss. Before, there was abundance around the islands. After the trawls, everything is dead. There were hammerheads around the islands, 2 miles around. Now we don't see them. They've disappeared.
>
> (San José, 76)

> What happened was that Ecuadorean purse seiners fished out all the sardine and mackerel, the food, they killed everything. The hammerheads now don't have anything to eat, so they don't come in to the coast.
>
> (Máncora, 64)

3.3. Hammerhead size declines

The mean reported hammerhead size significantly decreased from 145 cm (sd = 60) when respondents started their hammerhead fishing careers to 85 cm (sd = 33 cm) at present (t = 8.20, p < 0.001, CI 144.6, 85.0) (Fig. 3a). Older fishers reported significantly larger losses in size (random intercept model with $\beta = -1.24$, CI -2.19, −0.30; port intercepts vary with standard deviation = 16.79 and 53.84 residual standard deviation. Adding a random slope did not improve the model, L = 0.63, df = 2, p = 0.58) (Fig. 3b). Eighty percent of respondents believed the sharks they catch now are juveniles. Of the 13 respondents (15%) who stated they catch adult hammerheads, only one demonstrated a size consistent with estimated smooth hammerhead size at maturity (Mas et al., 2014; Nava and Márquez-Farías, 2014). The majority of respondents (90%) stated that they would prefer to catch larger sharks.

When asked what prevents them from catching larger sharks, approximately one-third (34%) of respondents emphasized that they can no longer find them. “There are no big ones. They're gone,” said a 48-year-old fisher from Máncora. Respondents discussed overfishing, echoing previously described themes, and some posited that the larger sharks have moved further offshore than in the past, making them less feasible to catch. Respondents also explained that coastal aggregations of juveniles are easier to catch than solitary pelagic adults, descriptions consistent with published accounts of hammerhead life history (Compagno, 1984; Gonzalez-Pestana, 2014; Simpfendorfer, 2005). When asked about the effects of catching juveniles, 68% of respondents discussed the negative impacts of declining future populations or decreased opportunities for reproduction (see Table 2).

3.4. Perceptions and reactions to the ban

Over 90% of interviewees were aware of the hammerhead ban, although fewer than half correctly stated its seasonal duration. In terms of support, 76% said they were in favor of the ban while 17% were against the ban, 6% neither for nor against, and 1% didn't know (for those unaware of the ban, the interviewer asked in hypothetical terms), although most respondents articulated arguments on both sides. Common reasons in support of the ban were to protect the species, particularly juveniles, and allow for larger, more abundant, and/or higher-priced sharks when the ban lifted. “It suits me,” explained a 42-year-old fisher from Salaverry. “It's our undoing, fishing too fast. When the closure lifts, there are more. The species won't go scarce as fast.” A 62-year-old fisher from Máncora said, “Our reality as fishers is that we have to reserve the fish, take care of the fish.”

Respondents provided more diverse reasons for opposing the ban (see Table 3). The most common objection related to impracticality: gillnets are indiscriminate, making it difficult to avoid any particular species. These respondents expressed indignation over facing a steep fine for a rule with which it was challenging to realistically comply. Other emergent themes in respondents' objections included the ban's ecological necessity, economic severity, distribution of burden of compliance, and lack of transparency in the implementation process. Respondents provided alternative solutions, including more flexible or lenient iterations of the ban, gear modifications, individual quotas, direct monetary support, and integrated international policies. We categorized these solutions and, where appropriate, paired them with fishers' objections to the ban in Table 3.

Respondents cited the fine associated with the ban (reports of 4000 to 5000 Peruvian soles, equivalent to more than USD $1000, per ton landed) as a motivator for changing their fishing behaviors, although

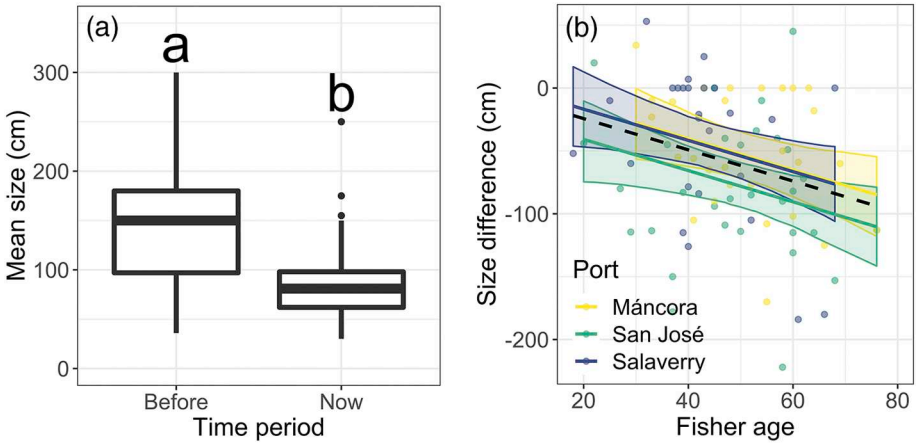


Fig. 3. (a) Distribution of reported average hammerhead sizes in cm when respondents first started fishing (Before) and presently (Now) t = 8.20, p > 0.001, CI 45.17, 73.90. (b) Relationship between respondent age and the reported hammerhead size difference, with port as a random effect. Dashed line shows fitted values for the whole sample, while solid lines show fitted values for each port. Shading represents 95% confidence intervals based on bootstrapping model predictions with 1000 iterations. $y = -1.24x + 0.51$; slope CI -2.19, -0.30; intercept CI -49.83, 50.86; intercepts vary with sd = 16.79, CI 4.47, 63.07.

Table 2
Fishers' perceptions of the effects of catching juveniles on the hammerhead shark population. Proportions are incomplete because some fishers misinterpreted the question. Sample size is smaller because we did not ask this question to fishers who believe they catch adult sharks.

Theme	Sample quote(s)	Proportion of n (84)
Catching juveniles will reduce the population	-"If we fish too many juveniles, if they kill the newborns, afterward you won't see the fish. We fishers realize." (Máncora, 76) - "They're babies, they don't reproduce. They have to grow, just like the anchovy." (Salaverry, 43) - "Of course it affects the population. It doesn't let them reproduce, grow. Killing the babies, the population will diminish." (San José, 47) -"IMARPE says if we fish young ones, small ones, they decrease." (Máncora, 37) -"The population will keep decreasing" (San José, 36)	0.67
Catching juveniles prevents them from growing to adulthood [no specific reference to reproduction/population]	-"It's a damage. Very young, they won't grow." (San José, 53)	0.02
Catching juveniles is fine, but catching pregnant females will reduce the population	-"It affects the population more to catch the adult pregnant females, who are the reproducers." (Máncora, 45)	0.06
Catching juveniles does not affect the population	-"Catching juveniles doesn't affect the population much. The mom has 50 babies. There are plenty. But they need time to grow." (Salaverry, 58) -"It won't affect [the population] much because I only go out in November and December, and only catch a few." (San José, 37) -"It doesn't affect it. It's normal." (San José, 53)	0.12
We do not catch juveniles	-"We don't catch juveniles. The mesh is too big." (San José, 29)	0.04
I do not know	-"I don't know what to say. We don't conduct studies." (Máncora, 62)	0.02

they noted that inconsistent enforcement enables continued hammerhead landings. Respondents indicated that they have responded to the ban by targeting different species, fishing in different areas, or fishing more intensively before and after the ban. In San José, respondents most often reported switching to squid jigging, while in Máncora and Salaverry, respondents reported fishing further from the coast or targeting other large pelagics. Some in San José and Salaverry also discussed traveling northward after the ban lifted to continue fishing for hammerheads.

Because gillnet fishing is conspicuous, particularly to other fishers, decisions to switch gear are a means of spreading awareness about the ban, thus supporting discussion and enhancing social learning opportunities among the fishing community. A fisher described that process as follows:

> The first year of the ban, almost no one complied. The second year, some. The third, many comply. They've taken their nets down. You can see which boats are full. You can tell who's fishing if they have their nets up. My friends would ask, 'Why aren't you fishing?' I would say, 'There's a ban. They're going to fine you.'
>
> (San José, 47)

During the interviews, 21% of respondents indicated without prompting that, even without the hammerhead ban, they do not specifically target hammerheads or juvenile hammerheads; 18% reported that they focus more on thresher sharks (*Alopias* spp.). A few respondents explained that large threshers, which fetch a good price for their fins, are still abundant, while hammerheads have become too small and scarce to cost-effectively fish. One fisher suggested that this switch occurred about four years prior to the interviews (in approximately 2014), while several others reported peak hammerhead catches in the early- to mid-1990s.

4. Discussion

Respondents report that hammerheads have become fewer, smaller, and further out to sea in northern Peru during their fishing careers, likely as a consequence of overfishing. The trend of older fishers remembering catches of significantly larger sharks and reports of peak hammerhead catches prior to earliest-available official landings data both indicate a shifting baseline (Sáenz-Arroyo et al., 2005): available data likely underestimate this fishery's impact on the hammerhead population. Respondents' descriptions of their fishing strategies and history suggest that landings of juveniles are less a gauntlet strategy and more a symptom of declining numbers of adults; indeed, some respondents have switched to target other species for which they can still find larger adults.

This study confirms that hammerhead conservation measures, such as Peru's seasonal ban, are urgently needed. However, such measures are unlikely to be sufficient. Fishers' responses point to the importance of expanding such measures to broader regional or international efforts, particular age classes of hammerheads, and/or other species of sharks that may experience sequential depletion. In particular, fishers' responses suggest that concentrated exploitation of thresher sharks, which currently lack national protection, may pose an emerging conservation concern. Peru has an opportunity to implement effective conservation measures because fishers are amenable: The majority of fishers interviewed were cognizant of their and other fishers' roles in hammerhead declines, conscious of the risks of catching juvenile or pregnant sharks, and in favor of regulation to protect these important species (see Table 2).

Nevertheless, it is clear that the ban is not as effective as it could be. From an ecological perspective, it leaves sharks vulnerable by neither capturing variability in fishing seasons among ports and mobility in fishing grounds, nor adequately protecting breeding female sharks caught in November and December (Castañeda, 2001), which may be more important for population recovery (Kinney and Simpfendorfer, 2009). From the fishers' perspective, the ban is impractical and inequitable, and thus untenable. Unfairness emerged as a central underlying theme in respondents' objections, from the burden of a seemingly arbitrary fine to the indignity of fishers who identify as environmental stewards feeling criminalized while they watch international and industrial actors fish with impunity.

Objections to impracticality and unfair allocation of benefits and costs, which are common reactions to regulations both in fisheries as well as in broader contexts, often may be traced to lack of transparent and participatory processes during development and implementation of those regulations (Aswani et al., 2018). Some respondents explicitly referenced procedure in their complaints ("[the authorities] don't explain it;" "ignorance about what the ban is like out at sea"), but most of the stated objections could stem from a perceived or real disconnect between how fishing authorities developed and implemented the ban and fishers' lived reality. In the respondents' accounts, the ban does not reflect understanding of how their gear works, the realities of their economic constraints, their observations of hammerhead population dynamics, and/or their beliefs regarding who or what powers are responsible for the larger-scale fishery decline. Stated both directly and implicitly were feelings that fisheries authorities do not acknowledge or

Table 3
Common objections to the hammerhead ban paired with suggested alternative solutions, attributed by respondent port and age.

Objection	Themes and representative quotes	Solution(s) and representative quotes
Impractical/ unfeasible	*Unable to avoid catching hammerheads with unselective nets:* -"Fish fall in the net accidentally, what can we do?" (San José, 68)	*Spatial closures or move-on rules* -"Don't fish them. Don't look for their waters. If you know that they're in a certain place, leave." (Salaverry, 44)
	Wasteful to throw away dead sharks: -"They're already dead, we shouldn't have to throw them back. It's a loss." (Salaverry, 43)	-"Fish along the bottom when the small hammerheads appear." (San José, 60)
		Gear modifications -"Use bigger mesh, 8" would be better." (San José, 33)
Procedural issues	*Out of touch with fishers' experiences:* -"The fisheries authorities governing from above, there's a lot of ignorance about what the ban is like out at sea." (Salaverry, 39)	*Fisher organization* -"The union. The president [of artisanal fishing association] needs to have a meeting, so we all unite." (Salaverry, 42)
	Insufficient awareness or outreach: - "Sometimes we don't know. The authorities don't explain it. They fine you, and it surprised me." (San José, 59)	
	Insufficient explanation: -"They don't explain it. They only say that hammerheads are banned, no more. They have to explain [why.]" (Salaverry, 45)	
Economic severity	*Direct cost of fine:* -"It's such a big fine. We're not going to fish." (Máncora, 58)	*Direct support* -"Other jobs like cleaning schools, parks, the beaches." (Máncora, 60)
	Indirect costs of reduced fishing: -"People live by fishing. We can't just stop working for two months." (Máncora, 61) -"Where is the money going to come from? My kids are in college, how are we going to do it?" (Salaverry, 42)	-"If [the government] gave us a pension, that would be great." (Máncora, 37)
	Indirect costs of switching gear: -"They shouldn't leave us without any facilities to fish other species." (San José, 60)	*Shorter or shifted ban duration* -"With a ban of only 1-2 months, we could keep working. It's more feasible." (Salaverry, 68)
	Costs in the context of additional bans: -"There's also a ban for swordfish, sailfish, marlin. Lots of costs." (Máncora, 76) -"Swordfish is also banned. What are we going to fish?" (Salaverry, 56)	-"Put the closure in winter [when we don't fish]." (San José, 68)
	Reduced security: -"In winter, there's no fish. It sustains us through the winter, to fish more in the summer." (Salaverry, 48)	
Ecological necessity	*Still catch big sharks* "If I see that they're small, then it's right to ban them. But there still are big ones. We should be able to continue fishing." (San José, 29)	*Minimum size* -"They should implement a minimum size." (Máncora, 47)
	Still catch plenty of sharks "We're catching plenty of them. There are a ton January – March but we have to land them in secret so the authorities don't see. We're catching just as much as usual." (Salaverry, 42)	*Shorter or shifted ban duration* -"Move the closure to protect the pregnant females, December through February. Don't go fishing then." (Máncora, 60)
	The ban doesn't protect the pregnant females (See "Shorter or shifted ban duration")	*Quotas* -"A quota per boat trip" (San José, 59)
Burden of compliance	*Distribution of resources between artisanal and industrial fisheries in Peru* -"The State has abandoned artisanal fisheries. They don't give us technological equipment. In the industrial fishery, if they catch a small anchovy, there's automatically a ban. Why not in artisanal?" (San José, 48)	*More technical and scientific capacity* -"We should follow the ways of the industrial fishery… implement technology to conserve all the resources." (San José, 48)
	Distribution of responsibility among foreign, industrial, and small-scale fleets -"If we conserve our coast, other people from other places are going to fish it. Chile fishes it." (San José, 76)	*Integrated national and international management* -"It must be whole. Who controls the foreign fleets?" (San José, 72)
	-"Why can they [still fish] and we can't?" (Máncora, 54)	-"There must be regulations for purse seiners. Responsible fishing should be for everyone." (Máncora, 62)
	-"I've seen on *Discover* and *National Geographic* programs that [in other countries] they're fishing just for the fins. If they kill mother sharks in other countries, how can we conserve them? We're being stewards, but China and Japan fish year-round." (Salaverry, 52)	

respect fishers' experiences.

Perhaps tellingly, fishers rarely proposed solutions that would increase their participation in the management process. This may indicate a need for capacity building among fishers to facilitate more effective engagement in local-scale marine-resource management. Furthermore, additional study of the political history of the ban and the attitudes of managers and other stakeholders could clarify the extent of fisher input in the management process and the root causes of fishers' perceived disconnect.

Moving forward, attention to process is a promising path for bringing together fishers' and managers' shared commitment to protecting juvenile and breeding female hammerheads. As Aswani et al. (2018) describe, a more participatory process that allows fishers and managers to express their perceptions, concerns, values, and needs can

facilitate more acceptable and effective conservation outcomes. In previous studies of small-scale fishing communities in Peru, researchers identified an equitable and participatory decision-making process as key to increasing perceptions of fairness and thus legitimacy of self-imposed fisheries control rules, suggesting that participation is important at multiple scales of governance (Nakandakari et al., 2017).

Some of the alternative solutions fishers provided suggest how engaging fishers in managing their resources might operate. Not all are feasible—integrated international management and sustained alternate livelihood security, for example, are likely beyond the power and jurisdiction of Peru's fishery managers. Some alternatives may be effective if combined or adapted. While researchers have previously found low enforcement of and compliance with minimum capture lengths for the few other species of sharks managed thus (Doherty et al., 2014; Gonzalez-Pestana et al., 2014), combining size limits with mesh size regulations or quotas—and developing these regulations with fisher input—may be more effective. Respondents in this study demonstrated awareness of each other's gear usage, including mesh size, so the social learning opportunities documented and described above could improve compliance. Fisher participation in developing these regulations could help both with the research needed to determine the appropriate age class(es) of hammerheads to protect, and in setting a meaningful size limit (currently, the majority of size-regulated shark landings are below minimum sizes, potentially reflecting additional disconnect between management actions and fishers' realities; Gonzalez-Pestana et al., 2014).

Another avenue could be an informal dynamic approach, which has been recommended for reducing bycatch in fisheries elsewhere (Dunn et al., 2016; Hazen et al., 2018; Lewison et al., 2015). In these same fisheries in Peru, researchers have already demonstrated the potential of the spatial and temporal "move-on" approaches respondents suggested in this study for mitigating sea turtle bycatch (Alfaro-Shigueto et al., 2012). In separate aspects of the interviews used in this study, respondents demonstrated their skill in identifying juvenile hammerhead habitat based on dynamic environmental predictors including temperature and water color, and further, reported sharing this information in networks spanning multiple ports ([self-citation]). In addition to the social-learning process that occurs as fishers interact with and influence one another to comply with regulations, this suggests that fishers might readily engage in developing and participating in "move-on" rules that require cooperation and coordination, as well as potentially some elements of self-governance, among fishers. Similarly, efforts to build capacity and create learning communities related to hammerhead biology, fishery regulations, and policy participation mechanisms might complement ongoing conservation initiatives in the region to increase understanding and efficacy among fishers with a shared goal of protecting hammerheads (Steyaert et al., 2007).

We recognize that fisher participation is no panacea. Further study is needed on the appropriate and efficacious legal frameworks for fisher input in Peruvian fisheries policy. Additionally, it would be important to explore in deeper, more nuanced ways the attributes of these particular fishing communities to better understand the dimensions that may or may not facilitate self-governance and/or co-management before making further recommendations on those fronts. Moreover, the dispersed, mobile work of these fishers, who may spend weeks at a time at sea, can make sustained participation in policy processes challenging. Nonetheless, we are confident that increased fisher engagement in the management process is one potentially effective, and certainly more equitable, path toward improving future iterations of this ban as well as other shark conservation policies.

5. Conclusions

Allison and Ellis (2001) note that fisheries development research often emphasizes what small-scale fishing communities lack in terms of economics and equipment, rather than how their existing abilities and assets—in the form of networks, place-based knowledge, and experience—may be perceived as strengths. This fishery already exhibits strong social capital and local environmental knowledge, with the promise of great motivation for seeking longer-term conservation solutions. Enhancing arenas for sharing knowledge, supporting opportunities for building capacity, and/or making available strategies that more effectively engage the fishers' community could lead to more equitable, practical, and sustainable options for shark fishery management as Peru and other countries work to comply with emerging national and international elasmobranch conservation measures. Meanwhile, the international shark conservation community should be conscious of policies that pressure national governments to implement approaches that are ineffective on the ground, or, more accurately, the water.

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Data statement

Stanford University's IRB approved this study on January 11, 2018, protocol #44763. Interview protocols and transcripts available at https://purl.stanford.edu/wv848yd6100.

CRediT authorship contribution statement

Julia G. Mason: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing - original draft, Visualization, Funding acquisition. **Joanna Alfaro-Shigueto**: Conceptualization, Investigation, Resources, Data curation, Writing - review & editing. **Jeffrey C. Mangel**: Conceptualization, Investigation, Resources, Data curation, Writing - review & editing. **Larry B. Crowder**: Conceptualization, Writing - original draft. **Nicole M. Ardoin**: Conceptualization, Methodology, Writing - original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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