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Mitigating cetacean bycatch in coastal Ecuador: Governance challenges for small-scale fisheries

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ABSTRACT

Bycatch of marine fauna by small-scale (artisanal) fisheries is an important anthropogenic mortality source to several species of cetaceans, including humpback whales and odontocetes, in Ecuador's marine waters. Long-term monitoring actions and varied conservation efforts have been conducted by non-governmental organizations along the Ecuadorian coast, pointing toward the need for a concerted mitigation plan and actions to hamper cetaceans' bycatch. Nevertheless, little has currently been done by the government and regional authorities to address marine mammal interactions with fisheries in eastern Pacific Ocean artisanal fisheries. This study provides a review of Ecuador's current status concerning cetacean bycatch, and explores the strengths and weaknesses of past and current programs aiming to tackle the challenges of bycatch mitigation. To bolster our appraisal of the policies, a synthesis of fishers' perceptions of the bycatch problem is presented in concert with recommendations for fostering fishing community-based conservation practices integrated with policies to mitigate cetacean bycatch. Our appraisal, based upon the existing literature, indicates a situation of increasing urgency. Taking into consideration the fishers' perceptions and attitudes, fisheries governance in Ecuador should draw inspiration from a truly bottom-up, participatory framework based on stakeholder engagement processes; if it is based on a top-down, regulatory approach, it is less likely to succeed. To carry out this process, a community-based conservation programs to provide conditions for empowering fishing communities is recommend. This would serve as an initial governance framework for fishery policy for conserving marine mammals while maximizing the economic benefits from sustainable small-scale fisheries in Ecuador.

1. Introduction

Bycatch is widely known as one of the greatest threats to marine mammals, and it is a marine conservation problem that urgently needs to be addressed in the southeastern tropical Pacific Ocean [1–6]. In that regard, there is a need to improve our understanding of the magnitude and incidence of cetacean bycatch by small-scale fisheries (SSF) on a global scale, a task which is especially crucial for the fishing activities in the southern hemisphere, where bycatch incidence is not mitigated, and in fact is thought to be steadily increasing in the last decades [3,7].

In Ecuador's offshore and nearshore coastal waters, two major fisheries carry out operations: the industrial (i.e., large-scale) tuna fishery, and Small Scale Fisheries (SSF), which is locally also known as artisanal fishing. These two fisheries, which are operated and managed

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in different manners, have already been identified as potential sources of cetacean bycatch at the local and regional scales [1–3,8–10]. In contrast to the SSF, the industrial tuna fishing fleet includes the oversight of regionally-based management instruments, in particular by the Inter-America Tropical Tuna Commission (IATTC), which is a regionally focused governing body that operates in the South Eastern Pacific Ocean. This institution, which includes member states with Pacific coastlines, and also includes Ecuador. Among the management strategies fostered by the IATTC, national fishing quotas are allocated, and a "*Dolphin Safe*" program for tuna fisheries is implemented. This labelling mitigation strategy targets the reduction of the dolphin bycatch incidence in purse seine fishing nets due to interactions between the industrial tuna fisheries and small cetaceans, either in the offshore zones (i.e., within the economic exclusive zone – EEZ, at international waters), or in the coastal fishing grounds where the Ecuadorian tuna fleet operates [8]. The labelling strategy responds to requirements imposed by global tuna trade regulations, and there are sanctions imposed for the violation of these regulations.

In contrast, only scant attention has been allocated to assess and mitigate the incidence of odontocete cetacean and baleen whale bycatch, caused by SSF. In fact, bycatch incidence has been shown to be a deleterious cause of entanglements and stranding of marine mammals, and has become an enduring threat for cetacean conservation during the last three decades [1,9–16].

Marine mammal bycatch events caused by interactions with SSF, however, have become a focus of scientific attention. In 2011, the international workshop about marine mammal bycatch held at the 19th Biennial Conference on the Biology of Marine Mammals (Society for Marine Mammalogy) in Tampa (Florida), brought together scientists, practitioners and researchers from around the world to meet and to recommend appropriate venues with special reference to the SSF for addressing the marine mammal bycatch issue globally. Following this first event, a regional bycatch-related workshop "*Achieving greater reductions in marine mammal bycatch in South American gillnet fisheries*" was celebrated in Buenos Aires, Argentina on 15 September 2012 as a preliminary event to the 9th Latin American Society of Aquatic Mammals' Experts Congress (*Congreso de la Sociedad Latino Americana de Especialistas en Mamíferos Acuáticos*-SOLAMAC by its Spanish acronym) [17].

In support of these initiatives, to fortify the ongoing efforts for addressing fisheries interactions, and to enhance conservation of marine mammals inhabiting Ecuadorian' marine waters, this review paper aims to illustrate the bycatch issue as concerned with the SSF in Ecuador. In doing so, we seek to 1) assess the current status of fisheries and cetacean bycatch; 2) explore the current governance actions which have been taken to deal with marine mammal bycatch events; 3) document the ongoing initiatives intended to mitigate the bycatch events occurring in SSF in Ecuador, particularly those associated with gillnet fisheries; and, 4) exemplify the perceptions of coastal fishers, including their attitudes toward cetacean bycatch and their potential role as active agents in bycatch governance and mitigation efforts. A set of recommendations is provided with the aim of augmenting the fishing communities' willingness to support initiatives to overcome the bycatch problem on a national scale.

2. Characterization of Ecuadorian small-scale fisheries

In Ecuador, small-scale fishing activities are conducted along the mainland coast and other special areas including the Galapagos Islands. From 1980–1990, the Ecuadorian artisanal fleet was estimated at 1900 boats [18], which expanded to approximately 7000 vessels operating in the early 1990s. By the late 1990s, this number had risen to approximately 15,500 artisanal vessels [19], and during 2000–2004 the number increased 8.4 fold, a rate that exceeded the growth rate of the 1980–1990s [18]. In 2008, as many as 15,900 boats were believed to be active [20], which clearly shows a more than 50% increase in the number of small-scale vessels, since the early 1990s to the present. Hence, SSF in Ecuador is characterized by a conspicuous expansion of the number of vessels in the fleet.

Although it is difficult to define artisanal fisheries, classifications usually are made based on vessel size and the types of fishing gears employed. In Ecuador, the most common small-scale fishing vessels are small rafts (2–3 crewmembers) with 20–50 HP outboard motors; long wooden canoes for 3–4 crew members; and 10 m wooden or fiberglass-open boats, propelled by 75-100HP outboard motors [21]. Fishing gear include surface and deep longlines (4–11.5 km in length, each with 100–1500 hooks); surface (3 km in length and 15 m in depth) and deep (300–400 m in length) gillnets, and other gear (e.g. hand line, and *chinchorro*, which is a local term for a seine net) [22–24]. Generally, fishers make between 1 and 4 hauls per fishing trip at 10–120 nautical miles distance from the coast [P. Rosero, unpublished results]. Fifty percent of the artisanal fishing vessels use gillnets [23].

In addition to the expansion of the fleet itself, the SSF in Ecuador has also seen a dramatic increase in the distances traveled from shore for the conduct of fishing, and an increase in the time spent in fishing before returning to shore. Beginning in 1994, the SSF fleet in Ecuador started to utilize a wooden "mother ship" or supply ship coupled with as many as ten fiberglass boats. The intention of this setup was to increase their fishing effort (in terms of area and fishing gear) by extending their fishing range as far as the Galapagos Archipelago and by including more longlines and hand-lines [25,26]. Although the wooden ship initially served only to dispense fuel and supplies to the smaller boats coupled to it, the "mother ships" eventually started to deploy fishing gear as well, further intensifying the fishing effort [26]. The efficiency was also improved by the usage of GPS technology, compasses, and VHF radios. The combination of strategies resulted in an expanded scope of fishing targets and augmented catch, as well as expansion of areas fished, which sometimes brought incursions into marine protected areas [MPAs] [P. Rosero, unpublished results].

Hence, the SSF fleet of Ecuador is characterized by dynamism and change. However, it has remained largely unnoticed, mainly due to its complexity, diversity, and the scale of its activity, as well as due to the negative perceptions of artisanal fishing as an occupation of last resort [27]. In recent years an effort has been made to address the largely delayed consideration of SSF issues by the Ministry of Agriculture, Livestock, Aquaculture and Fisheries of Ecuador (MAGAP) through its subsidiary unit, the Secretariat of Fisheries Resources (Subsecretaría de Recursos Pesqueros, SRP), which undertook a nationwide fisheries census. This initiative aimed to collect up-to-date data on small-scale fisheries in order to characterize the sector and the socioeconomic structure of small-scale fishing communities along Ecuador's mainland coast. During the first phase between late 2009 and early 2010, about 118 of the 173 fishing communities were surveyed, with a total of 43,634 small-scale (artisanal) fishers registered. In 2011, the second phase covered 234 fishing communities, with a total of 19,770 artisanal boats were counted and between 63,970-87,280 small-scale fishers registered as members of the current fishing population in Ecuador; this population is now estimated to be more than 5% of the economically active population nationwide [28–33].

In Ecuador, the small-scale fishing fleet mainly uses longline and surface gillnet (mesh size: 7.5–13 cm) to catch pelagic fin fish species including common dolphinfish or *dorado* (*Coryphaena hippurus*), several tuna species (e.g., Skipjack, *Katsuwonus pelamis;* Yellowfin, *Thunus albacares*; Bigeye, *T. obesus*), billfish species and even sharks [32-38]. Additionally, the artisanal fleet targets several white-meat fish species which are regularly landed in harbors [38]; the most commonly targeted species are snappers (*Lutjanus* spp.), Pacific bearded brotula (*Brotula clarkae*), and several grouper species locally known as *murico*, *mero* or *cherna* (*Epinephelus* spp.).

While the total volume catch or landings from SSF are systematically monitored and recorded by the National Institute of Fisheries (*Instituto Nacional de Pesca*, INP) and by the SRP, statistics and

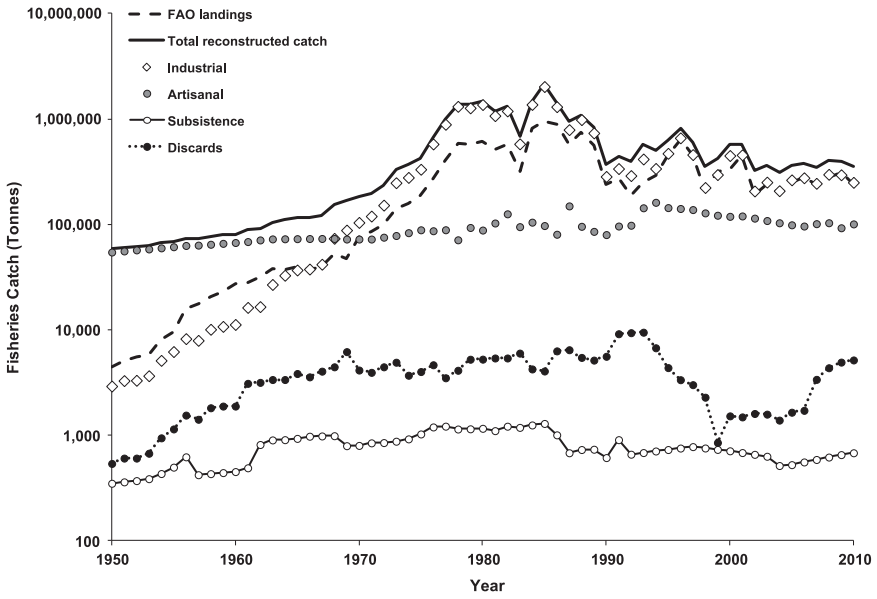

Fig. 1. Total reconstructed catch (black solid line) break down by all fisheries from 1990 to 2010 in Ecuador's mainland compared to the FAO landing data (dashed line) over the same time period. This reconstruction shows the overall trend in Ecuador's fisheries catches (for the mainland EEZ) to be 1.9 times those reported to FAO. The total catch for all sectors from 1950 to 2010 was almost 30.2 million tons, of which small-scale (artisanal) fisheries (grey closed circles) accounted by20%. Data adapted from Alava et al. [33].

processed data are rarely used to inform and support fisheries-related decisions and policy making [33]. According to the marine fisheries catch reconstructions for continental Ecuador, the SSF landings range from 79,900 t in 1990 to 100,900 t by 2010, with a maximum peak of 161,600 t in 1994 [33], as illustrated in Fig. 1. This relative increase in catch may reflect an increase in fishing effort over time, which eventually could produce negative impacts on fisheries stock availability and on marine mammal conservation due to increased risk of exposure to bycatch [1,33].

Hence, the development of SSF in Ecuador has involved a series of changes in target species, vessel types, fishing gear, areas fished, and these strategies vary considerably from community to community along the coastline. In comparison to the industrial fleet, the SSF in Ecuador has been much more flexible and opportunistic in responding to fluctuations in resource species and environmental conditions. The fact that SSF exhibits a high degree of flexibility and heterogeneity means that top-down management policies may not integrate well with local fishing practices in each community. For the design of bycatch mitigation policies, scientists and policymakers will need information provided the local fishing crews, who have intimate knowledge of fishing strategies, and the zones and habitats that are exploited.

3. Marine mammal bycatch

Bycatch of marine mammals has been documented along Ecuador's mainland coasts since the early 1990s [1,9,10,12]. Documented bycatch events of major large cetacean species include the sperm (*Physeter macrocephalus*) and humpback whales (*Megaptera novaeangliae*) [1,9,11,15], while small cetaceans interacting with artisanal fisheries (i.e. gillnets) are mainly represented by dolphins, including the common dolphin (*Delphinus delphis*), spotted dolphin (*Stenella attenuata*), bottlenose dolphin (*Tursiops truncatus*) and Risso's dolphin (*Grampus griseus*) [10,13,14,37]. Other bycatch mortalities include pilot whales (*Globicephala* sp.) and the dwarf sperm whale (*Kogia sima*) [10,13,14,37]. Some cetacean species commonly taken as bycatch in Ecuador's marine waters are shown in Fig. 2.

Few studies have assessed the bycatch rate of cetaceans in Ecuador. Existing literature dealing with incidence of small cetaceans' bycatch in Ecuador suggests that the rate ranged from 0.07 to 0.86 dolphins/day (Fig. 3). For instance, the number of dolphins taken in artisanal boats from two coastal fishing communities (i.e. Santa Rosa and Puerto López) between December 1992 and December 1993 were 217 individuals (i.e. 0.6 dolphins/day), with a bycatch mortality rate of 0.04 dolphins/boats for Puerto Lopez and 0.10 dolphins/boats for Santa Rosa [10]. Recent dolphin bycatch assessments in Machalilla and Salango, as well as new data from Puerto López in 2009 revealed an overall bycatch rate (mean) of 0.07 dolphins/day (July), with a maximum of 0.18 dolphin/day in August [13]. In Santa Rosa, a recent bycatch assessment conducted from July 2009 to December 2010 ($n = 254$ fishing trips) revealed that the most frequently taken species was the common dolphin (*D. delphis*) with an estimate of 98 and 251 dolphins captured from July to October 2009 (i.e. 0.5 dolphins/day) and from February to December 2010 (i.e. 0.76 dolphins/day), respectively [14]. Common dolphins make up of between 70% and 90% of the total composition of bycaught dolphins [10,14]. These estimations are one of the highest bycatch rates for any cetacean species in Ecuador's marine waters.

In the last decades, the bycatch of humpback whales off Ecuador has been of concern because the Southeastern Pacific humpback whale population (or Group G) breeds off Ecuador from June to September each year [1,39,40]. The population has been estimated to number between 2917–6277 individuals [40]. During that period, humpback whale encounters with small-scale fishing operations are a potential source of risk of gear entanglements. The incidence of humpback whale bycatch events due to increased fishing effort has seldom been documented [1,15]. Alava et al. [1] reported that between 0.2% and 1.5% (95% CI) of the humpback population might be potentially bycaught in gillnets annually. In other words, the bycatch mortality in Ecuador is equivalent to 15 or 33 whales per year depending on the total population numbers estimated for this breeding ground [40]. Moreover, a significant correlation was found between the annual bycatch rate and the fishing effort for the period 2000–2009 ($r = 0.68$, $p < 0.05$) in Ecuador [1]. This implies that increasing the SSF effort may cause critical effects on the humpback whales' breeding population, given that humpback whales are *K*-strategists (i.e., low birth and survival rates). Calves have been identified as the most threatened age class of this species to become entangled by small-scale fishing boats setting gillnets in nursing grounds in coastal waters [1,12].

Between 2009 and 2014, Castro and Kaufman [16] reported 15 entangled humpback whales, towing fishing gear and ropes around

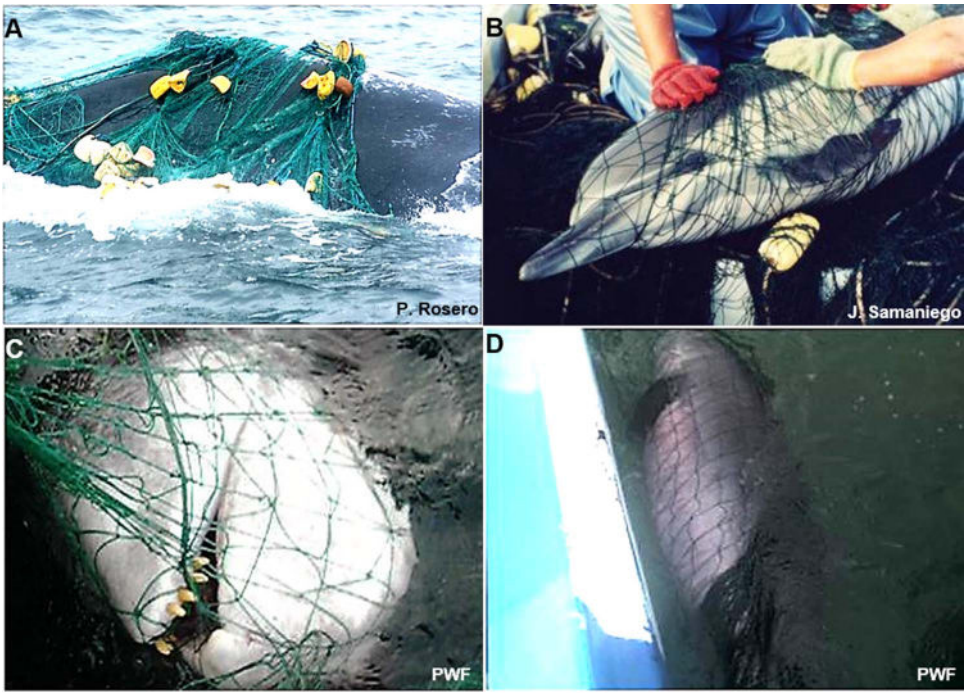

Fig. 2. Several species of cetaceans are victims of entanglements or taken as bycatch in gillnets, observed at sea or at small-scale (artisanal) fisheries landings in fishing villages along the coastline of Ecuador. (A) Humpback whale (*M. novaeangliae*) entangled with a gillnet and ropes with buoys in marine waters of the Machalilla National Park, Manabí Province [37]; (B) Common dolphin (*D. delphis*) bycaught in artisanal gillnets and landed at Puerto Lopez, Manabí Province [10]; (C) Risso's dolphin (*G. griseus*); and, (D) Dwarf sperm whale (*K. sima*) bycaught in gillnets by small-scale vessels operating around the waters of the Machalilla National Park [13,37]. Photo credits: P. Rosero (Fig. A); J. Samaniego (Fig. B); Pacific Whale Foundation (PWF)[13] (Figs. C and D).

their bodies recorded at sea during surveys aboard vessels ($n = 200$) in the waters of Machalilla National Park. Of the total number of entangled humpback whales observed during that period, 60% ($n = 9$) of the whales swam slower, with fishing nets visible around pectoral fins, head or tail, whereas 40% ($n = 6$) of the whales were beached with evidence of fishing gear on the body (Fig. 2a). Based on those observations, an average of 0.075 entangled whales/trip was preliminarily estimated for the period [16].

4. History of bycatch research and bycatch mitigation efforts in Ecuador

The fisheries resource and fishing sector are governed by the MAGAP which is the state-based authority overseeing the entire fishing sector, through its Secretariat of Fisheries Resources (SRP). The SRP has offices in the main ports of Ecuador, where the tasks of inspection, control and monitoring of fishing activities are regularly conducted at landing harbors, known locally as *caletas*. Among other tasks, the SRP regulates fishing activity by allocating fishing permits both, fishers and vessels, by establishing fishing periods and bans, and by regulating fishing gears, tools, and fishing zones. Furthermore, the Ministry of the Environment (MAE) is partially involved with fisheries issues, especially those impacting protected marine biodiversity and threatened species. However, at present it is still unclear if their legal responsibilities include addressing bycatch [41]. To the best of our understanding, the Ecuadorian government has not adopted any management

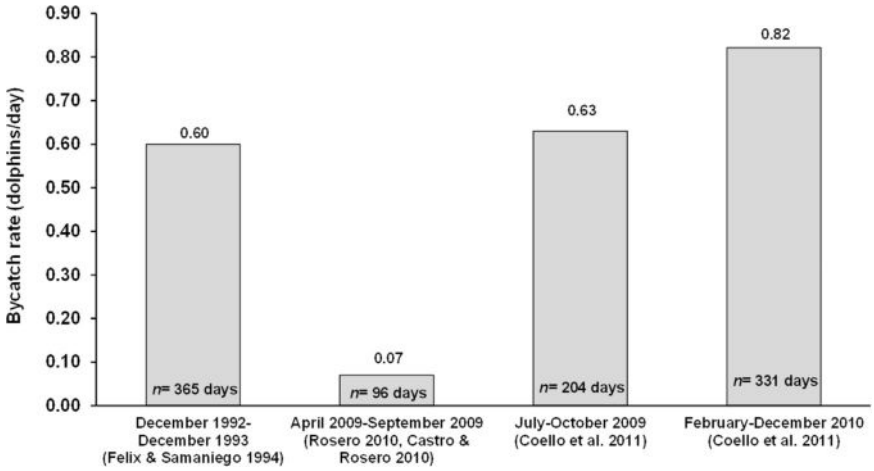

Fig. 3. Rate of small cetacean bycatch on a daily basis (dolphins/day) based on assessments of fisheries interactions involving small-scale (artisanal) fisheries and small cetaceans. These rates were calculated and published in studies ($n = 4$) conducted in fishing harbors and *caletas* of the Ecuadorian coast, including Santa Rosa and Puerto López [10], Puerto López, Machalilla and Salango (Machalilla National Park) [13,37], and Santa Rosa [14]. For this figure the bycatch rate was calculated as the total estimated number of dolphins caught by the entire small-scale (artisanal) fleet from monitored fishing communities and divided by the exact number of surveyed days during operational fishing activities at sea, as reported in each study.

measures aimed to mitigating cetacean bycatch in SSF.

Besides the information generated about fisheries-related activities by the governmental bodies, information about marine mammals' (i.e., humpback whales) distribution, abundance, migration patterns, and bycatch incidence in Ecuador also exist. These studies have been conducted by both private (mostly Non-Governmental Organizations, NGOs) and public organizations (e.g., MAE and INP). However, the incidence of marine mammal bycatch has only been partially assessed by a few monitoring programs of NGOs conducted in four harbors along the coast [10,13,14,37], and scarce and incomplete surveillance programs carried out by the INP, with only cetacean bycatch landings recorded for one harbor (see Coello et al. [14]).

Ecuadorian researchers studying the bycatch problem are aware that socioeconomic attributes need to be addressed in order to successfully implement mitigation measures against bycatch. In their technical reports they have proposed alleviation strategies to be implemented in conjunction with initiatives to address economic needs of the fishing communities. The proposals for bycatch reduction include gear modifications; acoustic reflectors or alarms (i.e. small, low-intensity sound devices called pingers to repel or alert small cetaceans to the presence of fishing gear (see Reeves et al., [42]); as illustrated in Fig. 4, the deployment of pingers in gillnets may well work during small-scale fishing operations, using humpback whales as an example.

Other mitigation measures proposed have included seasonal reduction of fishing effort within breeding grounds and during breeding season of humpback whales; zoning mechanisms (e.g., fishing restricted areas); and training of fishers in first-aid actions and release methods for bycatch-related incidents [1,12,13,43]. Monitoring programs with on-board observers are considered crucial for any successful mitigation program, but in fact very few of them are being carried out by the government agencies [14]. The disentanglement of whales could be an option if special equipment, training and expertise becomes available. In June 2013, the International Whaling Commission (IWC) and the Permanent Commission for the South Pacific (CPPS) conducted the first regional workshop on disentanglements of whales, with the purpose of training marine mammal specialists, biologists, and fisheries officers from Chile, Perú, Ecuador, Colombia and Panamá, in methods of rescue and first-aid for entangled whales at sea [43].

Since the early 1990s, investigations of bycatch events in Ecuador have been conducted by Ecuadorian and foreign NGOs. Thanks to efforts made by five institutions (i.e., Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM), Yaqu-Pacha, Pacific Whale Foundation-PWF, NAZCA-Institute for Marine Research, and Universidad San Francisco de Quito-USFQ), bycatch involving odontocete cetaceans and humpback whales has been widely documented along the Ecuadorian coast (see Figs. 2 and 3). The information produced has been made available for decision and policy makers, who have been informed about the incidence, risks, and potential strategies to mitigate the bycatch problem. In the early 2000s, the Secretariat of Fishery Resources in close collaboration with FEMM, Fundación Natura and INP supported local outreach and environmental education in several ports and fishing communities to raise local awareness of the problem and educate fishers [44]. After those first efforts, few concrete actions have been taken by the fisheries and environmental agencies, which continue to underestimate the problem. Nevertheless, the MAE has recently produced the *Marine Mammal National Report* and has joined the *Regional Marine Mammal Scientific/Technical Committee* for the purpose of promoting the conservation of marine mammals (especially threatened species), in the Southeastern Pacific [45]; nevertheless, the bycatch problem has not been addressed within the current government's environmental agenda.

However, fisheries authorities have made efforts to improve the labor conditions for small-scale fishers, as well as providing better access to assets, and addressing their overall environment. In this regard, harbor infrastructure, social security issues and vocational training have been strategically identified as critical dimensions for the improvement of fishers' wellbeing. On the other hand, very little progress has been made in the field of fisheries-related policy, which remains out of date. Its obsolescence is clearly illustrated by the current fishing legislation that approaches SSF from a pure management

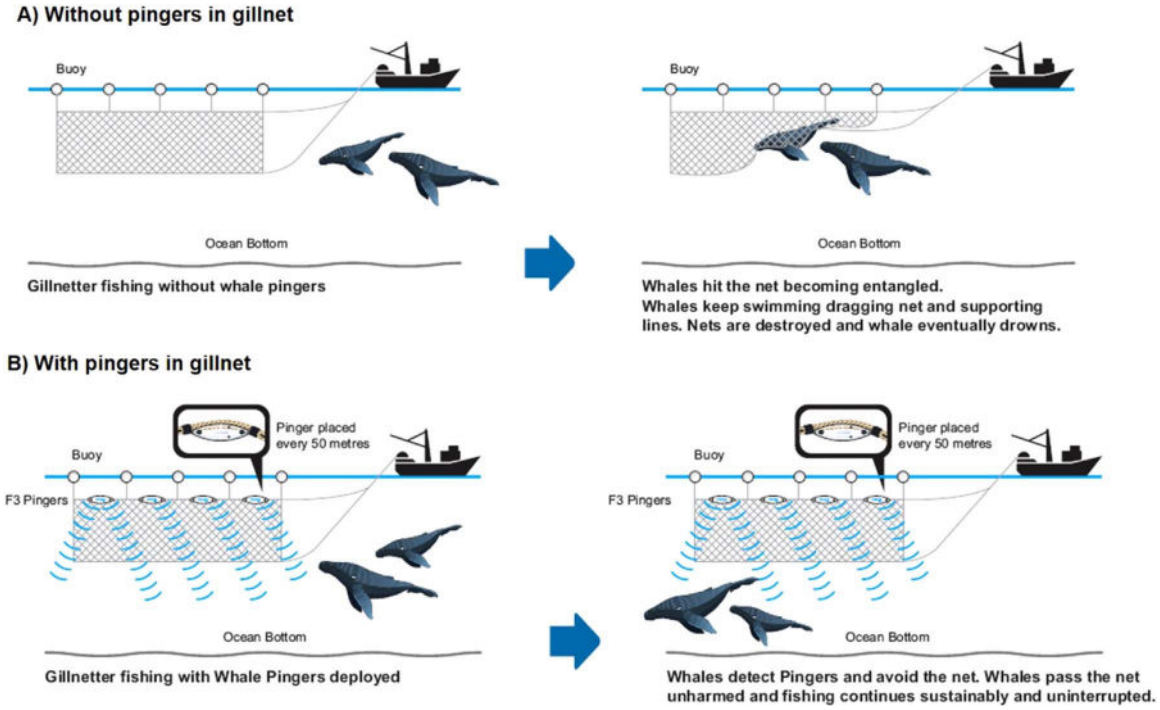

Fig. 4. Illustration showing an example of a gillnet with no pingers (A) versus the deployment of pingers in a gillnet (B). Here, a female humpback whale and her calf are used as an illustrative case to show the susceptibility of whales, mainly calves, to be entangled in gillnets without pingers (A). Whales and other cetaceans generally avoid the net with pingers deployed (e.g., the F3 pinger is used for whales and spaced every 50 m) by passing the net unharmed and fishing continues uninterrupted and the net remains intact (B). Adapted from illustrations gently provided as a courtesy by J. Turner (Future Oceans Society, www.futureoceans.com).

perspective. The command-and-control approach has prompted fishers to be unwilling to take part in a more proactive approach to mitigate bycatch. Since the policy concerning threatened species forbids the landing of endangered bycaught species, the practice of using bycaught marine mammals as bait for fishing activities [46], hides the actual incidence of marine mammal bycatch.

Additionally, due to the economic problems following the earthquake that struck Ecuador on April 16, 2016, financial support from the Government has been allocated to other priorities, not linked to bycatch reduction and/or to long-term mitigation plans.

To date, investigators from NGOs and universities have conducted marine mammal research and monitoring in Ecuador. Therefore, these institutions would be the best candidates to continue research on cetacean bycatch and mitigation. Given their previous experience in this area, it becomes relevant to explore new potential sources of mitigation measures to address bycatch incidents. One potential project is the possible development of the "*Pinger Project*" led by FEMM and sponsored by Future Oceans (www.futureoceans.com) in close conjunction with small-scale fishers in fishing communities of the Ecuadorian mainland coast. This is likely to be one of the most important research and conservation projects to address bycatch regionally.

As a result of the scarcity of on-board assessment by government agencies [14], the NGOs have adopted the practical premise of conducting independent assessments at five fishing harbors' landing sites, on the north, central and southern coast of Ecuador [47]. These complementary activities would serve to encourage the authorities to increase their surveillance and to enhance the problem mitigation.

5. Towards improved governance of fisheries

Current fisheries management practices tend to ignore that managing fisheries is more about governing complex systems than purely managing fish [48,49]. Both environmental and social complexities, diversities, dynamics and scales are normally excluded from the fisheries governance practices. This is true of the management approach which addresses catch, stocks, landings, and yield assessments as the only attributes to take into account when addressing fisheries sustainability [50,51]. In fact, there has been scant evidence of the inclusion of human dimensions, historical and cultural assets, and traditional practices (aspects that largely inform the fishing practices) as features to be taken into account for the governance of fisheries [52,53]. However, the involvement of local fishing communities should be seen as a critical asset in the effort to conserve fish stocks and marine biodiversity [54]. The fisher´s values, attitudes, and perceptions toward the fishing governance practices have not been adequately included in the current fisheries policy.

Data and information gathered under current research initiatives [55] have documented the absence of fishers' active roles as generators and providers of bycatch-related information. Fishers can be key collaborators in bycatch reduction efforts, an idea that derives from the fact that the success of any proposed measure for bycatch mitigation is always limited by the extent to which fishers are willing to collaborate and comply. If artisanal fishers' view of conservation is that it threatens their livelihood, their willingness to commit and cooperate will decrease. Hence, the risk for them to oppose, resist, or evade the mitigation measure will increase [56,57].

Preliminary research indicates a possibility for fishing communities to accept modifications to fishing gear, a recommended measure to be considered for preventing cetacean bycatch. In fact, fishers have shown willingness to modify fishing gear, a feasible means to mitigate marine mammal bycatch in Salango, Puerto Lopez and Machalilla, the fishing villages in the environs of the Machalilla National Park [13,16,55]. They have shown interest in abandoning the usage of surface gillnets and adopting bottom gillnets instead, or in making improvements to surface gillnets to avoid net losses and the hazardous marine pollution caused by floating abandoned nets [13,16].

However, critical questions arise when asking *whether artisanal fishers would be willing to use such modifications.* If so, why, and how, would they cooperate in this? This question was the basis for a preliminary survey carried out by Tatar [55] in the indigenous community of Salango. Although this survey was opportunistic and did not use a sample size of statistical significance, it resonates with observations made elsewhere. First, it confirms the assertion by Castro and Rosero [13] that some artisanal fishers have a positive attitude toward the idea of measures to reduce cetacean bycatch. Secondarily, the exploratory survey also confirms Pauly's [56,57] claim that the competition between small-scale (artisanal) and industrial fleets is relevant in fishers' decisions about where to fish and which gear to use; this competition may also be a major driver of the increase in artisanal fishing effort.

Although there is no current substitute for the pelagic surface gillnet, Castro and Rosero [13] indicate that fishers are interested in measures to prevent cetacean interactions. It is thus encouraging to see the interest among fishers for reducing bycatch, while at the same time, they are cautious to avoid measures that could leave them with economic losses. Interest in bycatch reduction could mean a high level of cooperation in pursuing a common aim. Measures such as gear restrictions, closed seasons on fishing and no-take zones have been proposed as mitigation strategies. However, questions remain unsolved about the moral and ethical aspects of those managerial means, when, for instance, livelihoods access, fishing rights, customary practices, and cultural assets of fishing become compromised when fishing grounds are closed. Researchers propose that the fishers from the Ecuadorian coastal area might be included in the strategic actions to mitigate bycatch events.

6. Challenges in addressing cetacean bycatch

Ecuador's government must advocate the development of a comprehensive and systematic monitoring effort to document bycatch events in temporal and spatial dimensions, and thus reduce the mortality of marine mammals and non-target species in fishery operations [41]. Worldwide, bycatch is often the greatest contributing factor to depredation of marine mammal species, in which marine mammals remove captured fish from nets or lines, leading to a greater risk of entanglement and the potential for retaliatory measures executed by fishers [7,58]. As a first step, "quantitative conservation goals and a transparent reporting system" are a precondition for mitigation measures [59]. The MMPA mandate in the USA illustrates that developing a national mitigation action plan to address bycatch requires quantitative evaluations of fishery impacts on marine mammals, as well as the stakeholders' understandings of the statutory thresholds [60]. However, because bycatch reduction involves both political complexity and issues of trust/distrust between regulators and SSF communities, it has the potential to balloon into a "wicked environmental problem" in which conflicts over maritime resources are driven by differences more profound than simple economic interests [61,62]. For this reasons, we advocate for a collaborative, community-centered program of monitoring and mitigation, instead of a top-down approach that may potentially alienate SSF communities.

Most studies of cetacean bycatch in Ecuadorian fisheries have emphasized the importance of collaborative projects with communities that depend upon SSF [1,13,55]. However, the specific mitigation measures proposed (restrictions on fishing gear, zone restrictions and closed seasons) are precisely those that seem to be the least accepted by fishers. Conversely, it is important to emphasize that some fishers from Esmeraldas (Ecuador's north coast) and Manta (Ecuador's central coast) have proposed restrictions on fishing (*vedas*) during the humpback whale breeding season to avoid entanglements resulting from loss or damage to costly nets (P. Rosero, unpublished results).

Any attempt to resolve the problem of marine mammal bycatch should address the drivers of the intensification of fishing effort.

However, to do so is not a simple task. To convince fishers to change fishing gears, or else to shift to another profitable activity such as tourism does not appear to solve the problem, but may instead contribute to enhance the problem. When fishers allocate a high proportion of their earnings to the improvement of their fishing success, they are likely to perceive diminishing returns in terms of their catch as a reason to switch their fishing gears; doing so would incur economic losses for them, and hence no real advance would be achieved in mitigating cetacean bycatch.

Likewise, government agencies will not make the investment in regulating and enforcing gear prohibitions unless there is a clear gain to be made. Hence, bycatch mitigation measures are more likely to gain support from fishing communities and government-related bodies if there is a widespread commitment of all the parties involved, to promote sustainability of fishing resources and viability of fishing communities. Hence, cetacean bycatch mitigation must be connected to wider issues of the sustainability of fisheries.

From this perspective, there are three reasons which militate for community-based programs for mitigation and monitoring of bycatch. First, the dynamic and changing of SSF in Ecuador, and the heterogeneity of fishing practices in each coastal community indicate a need for information that only local fishing crews can provide to scientists and policymakers. The active and willing collaboration of local fishers in research and monitoring is indispensable for the success of any mitigation program.

A second reason why the rapid evolution of SSF livelihood strategies requires a community-based management approach is to permit the communities to bring their specific concerns (i.e., zones, closed areas, closed seasons, gear restrictions, security) for consideration by the authorities when policies are designed, implemented and enforced. Policies and regulations which ignore local conditions and livelihood strategies are unlikely to muster cooperation, and must be integrated with local communities' values and needs.

Finally, a third issue is that fishing communities do not want increased oversight and monitoring of their activities by the authorities, but they will accept it if they believe it to be in their own interests. For example, fishing crews are reluctant to report an incident of cetacean bycatch to the authorities, but they do want to be protected from piracy and assault on the high seas. If bycatch mitigation programs can be integrally linked to security issues and other concerns of the fishers, their motivation to participate in mitigation programs can be secured.

7. Greatest needs

Bycatch is still a critical anthropogenic threat requiring urgent attention to prevent losses of marine mammal diversity and protect ecosystem health [3]. Environmental awareness campaigns carried out in schools and fishing cooperatives in Ecuador have been proposed as a crucial step prior to the implementation of management measures, in order to increase the receptivity and willingness of the fishers to participate [12,13,44]. The government, coastal fishing communities, NGOs and private groups are key agents in the search for solutions. Within the context of human dimensions, bottom-up strategies, economic incentives coupled with enforcement may generate acceptance and compliance with bycatch reduction technologies, as long as the assessment of technologies and research take into account the fishers' attitudes and need for involvement [63]. Thus, the greatest need is the collaboration and proactive cooperation among stakeholders coupled with the active involvement of the government to recognize the problem. In addition, it is vital to take into consideration the full recognition and integration of political history, social structure and community needs for the formulation of conservation and environmental policy. This requires preparation for open discussions on trade-offs when win-win situations are not possible, especially when top-down enforcement is unfeasible [64]. We echo Pinkerton's [53] recognition of five conditions that must be met for the Ecuadorian coastal communities to be able to commit to the conservation of living natural resources, including fisheries and marine mammals:

1) Communities must have strong access rights to local marine resources (e.g., poor people or fishers will poach or violate fishery regulations if they cannot benefit from it). Access to income from sustainable resource use will decrease the incidence of poaching. In coastal Ecuador, sustainable ways of deriving benefits from resources include ecotourism, nature-based and marine tourism, which provide feasible economic alternatives during the months of the humpback whale breeding season.
2) Communities must have the right to participate in management planning and decision-making processes (i.e., co-management of resources, fish or whales).
3) The nature of the resource must lend itself well to co-management by multiple stakeholders, including communities, entrepreneurs, NGOs and government ministries
4) The resource-using community must provide conditions which support the practices of co-management. For example, governments must provide institutional support to fishing communities in the form of infrastructure, expertise and aid. At the same time, communities should assist the government by assisting in enforcement and reporting any known abuses.
5) The nature of the community's relationship with outside groups and governments must be strong and supportive.

If the government is directly involved and works under these principles together with the fishing communities, then great advances can be made in addressing the problem of marine mammal bycatch. With the inclusion of the human dimension as well as the biological-ecological components, it is possible to improve fisheries systems governability, fisheries sustainability, and to strengthen the viability of fishing communities.

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