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Addressing illegal longlining and ghost fishing in the Galapagos marine reserve: an overview of challenges and potential solutions

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Despite regulations aimed at curbing shark finning and bycatch, shark fishing mortality rates continue to escalate, partly due to unintended consequences of these policies which, along with illegal, unreported, and unregulated fishing and ghost fishing, undermine conservation efforts. The ineffectiveness of current regulations to curb shark mortality highlights the pressing need for reevaluating shark conservation strategies, especially in ecologically sensitive areas. In this context, the debate on enforcing longlining bans in multiple-use marine protected areas, including shark sanctuaries, is intensifying. Some argue for total bans to minimize incidental shark mortalities, while others highlight the socioeconomic importance of longlining, advocating for alternative conservation measures. In 2000, longline fishing was banned in the Galapagos Marine Reserve (GMR) as a precautionary measure to prevent illegal fishing of sharks and bycatch of endangered, threatened, and protected species. After 24 years of enforcement, official and anecdotal evidence indicate that illegal small-scale tuna longlining and ghost fishing are increasing threats across the reserve. This paper provides an overview of the longline fishing controversy within the GMR, incorporating scientific evidence, legal and socioeconomic considerations, and perceptions from the Galapagos small-scale fishing community. We offer novel insights and recommendations for the development of the Galapagos small-scale tuna fishery within an ecosystem approach to fisheries. This approach aims to reconcile conservation goals with the needs of local communities, while also proposing innovative solutions to address the longstanding debate surrounding longlining in the GMR.

KEYWORDS

Galapagos, marine protected areas, illegal fishing, longline, bycatch, small-scale fisheries, ghost fishing, IUU fishing

1 Introduction

Sharks are increasingly threatened by overfishing, driven by the lucrative value of their fins in Asian markets (Dulvy et al., 2014, 2021; Pacoureau et al., 2021). Despite the widespread adoption of numerous regulations to reduce shark finning and bycatch, global shark fishing mortality has continued to rise (Burgess and Becker, 2022; Worm et al., 2024). This surge can be linked to the unintended outcomes of anti-finning policies, some of which have incentivized the complete utilization of sharks, driven by rising markets for shark meat and cartilage (Worm et al., 2024). This trend, in combination with the persistent challenge of illegal, unreported, and unregulated (IUU) fishing, further compromises shark conservation efforts globally (Field et al., 2009; Schiller et al., 2014). Additionally, ghost fishing, a significant yet often overlooked threat, causes indiscriminate loss of marine life through abandoned, lost, or discarded fishing gear (Macfadyen et al., 2009; Gilman, 2015).

The ineffectiveness of existing regulations to curb shark mortality highlights the pressing need for reevaluating shark conservation strategies, especially in ecologically sensitive areas. In this context, there is a growing debate on the feasibility of enforcing longlining bans in multiple-use marine protected areas (MPAs) (Shea et al., 2023), including "shark sanctuaries", i.e., jurisdictions that have prohibited the targeting and retention of sharks and shark parts within entire Economic Exclusive Zones (EEZs) (Ward-Paige, 2017). While some studies advocate for outright longlining bans in shark sanctuaries or multiple-use MPAs to reduce incidental shark mortalities (Chapman et al., 2013; Cerutti-Pereyra et al., 2020), others emphasize the socioeconomic significance of longlining for fishing communities, proposing alternative measures (Davidson, 2012; Simpfendorfer and Dulvy, 2017). Shea et al. (2023) analyzed the impact of longlining on pelagic sharks in eight Western Pacific shark sanctuaries. While they believe an optimal sanctuary should ban longlining, the economic and food security role of longlining, especially in distant island nations, makes strict bans difficult to enforce. Thus, where these bans prove to be unfeasible, Shea et al. (2023) recommended adopting bycatch mitigation strategies, encompassing fishing gear modifications, effort limitations, or temporary or permanent closures of critical habitats, to reduce incidental shark mortalities.

IUU fishing and ghost fishing significantly threaten MPAs in the Eastern Tropical Central Pacific, which embraces the EEZs of Costa Rica, Panama, Colombia, and Ecuador (Castrejón, 2020a), jeopardizing the conservation of endangered, threatened, and protected (ETP) species and the provision of ecosystem services. The Galapagos Marine Reserve (GMR) represents the most iconic MPA of this region (Figure 1). In March 1998, this volcanic archipelago and its surrounding open waters were designated as a multiple-use MPA of 146,599 km^2 (DPNG, 2014). Since then, large-

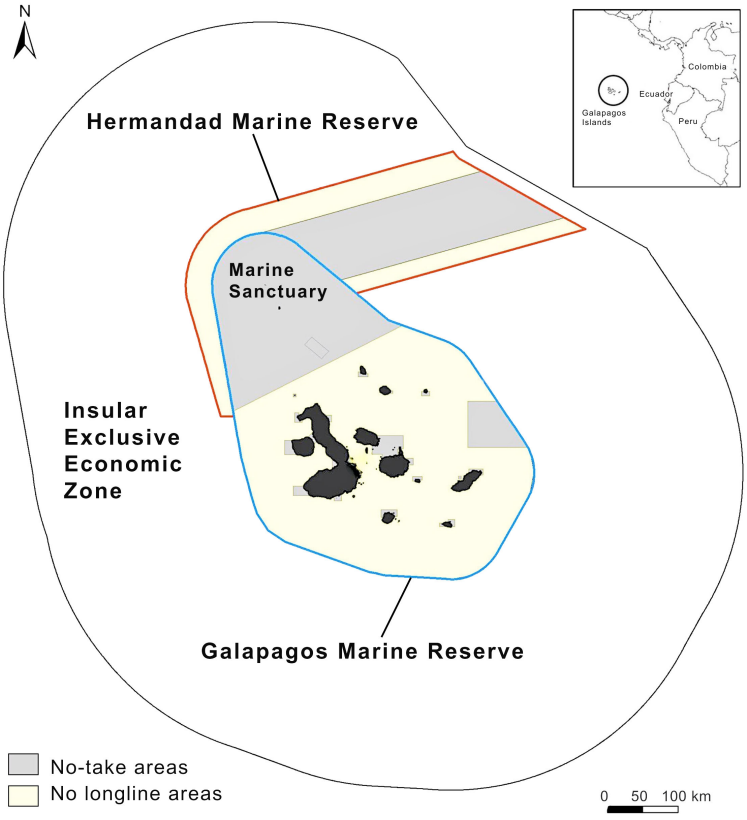

FIGURE 1
Galapagos Marine Reserve (blue line) and Hermandad Marine Reserve (red line) within the Insular Exclusive Economic Zone of Ecuador.

scale fishing inside this reserve has been prohibited, while local small-scale fishers were granted exclusive fishing rights (Castrejón and Charles, 2013).

In 2000, longlining was banned inside the GMR as a precautionary measure to prevent illegal fishing of sharks and bycatch of ETP species. Since then, local small-scale fishers have argued this ban undermines their livelihoods and advocated for longlining as essential for cost-effectively capturing high-quality tuna, representing an alternative source of income that could enhance the local economy and the community's well-being (Castrejón et al., 2021; Castrejón and Defeo, 2023a). They also argue that, by shifting fishing effort from coastal to offshore areas, there is potential to promote the recovery of overfished coastal finfish and shellfish species. Some of them, such as the sailfin grouper (*Mycteroperca olfax*), camotillo (*Paralabrax albomaculatus*), and the sea cucumber (*Isostichopius fuscus*), are listed as endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2024). In contrast, longlining detractors highlight the ecological risks of longlining (Murillo et al., 2004; Cerutti-Pereyra et al., 2020) and the potential damage to the GMR's reputation as a UNESCO World Heritage Site (Izurieta and Green, 2021). As the debate continues without a comprehensive and feasible management strategy to address the Galapagos longlining controversy, IUU fishing and ghost fishing continue across the reserve (Castrejón et al., 2021; Montaño, 2022), highlighting the urgent need to find alternative evidence-based solutions (Castrejón and Defeo, 2023b, a).

This study presents an overview of challenges and novel insights on the contentious issue of longlining in the GMR by 1) describing the Galapagos small-scale tuna fishery and the circumstances that gave rise to the longline controversy, 2) analyzing the legal, institutional, and socioeconomic factors that have made the enforcement of the Galapagos longlining ban unfeasible, 3) evaluating the misconceptions surrounding longlining and their impact on this socio-ecological problem's comprehension and viable solutions, and 4) providing recommendations to address illegal longlining and ghost fishing in the Galapagos small-scale tuna fishery through an ecosystem approach to fisheries.

2 The Galapagos small-scale tuna fishery

During the 1930s, commercial tuna exploitation was initiated by longliners and purse seiners from the United States, Japan, Panama, and Costa Rica (Reck, 1983). By the 1970s, within the boundaries of what is now the GMR, an Ecuadorian large-scale tuna fishing fleet comprising 12 purse-seine vessels and four longliners reported an average total annual landing of 29,710 t (Bustamante, 1999). This catch consisted primarily of skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*) tunas. These catches represented 24% of the total tuna catch registered in Ecuador during that time (Castrejón and Moreno, 2018).

After the establishment of the GMR in 1998 (Figure 1; Table 1), commercial tuna exploitation shifted gradually from an external and large-scale operation toward a local, small-scale economic activity (Castrejón and Defeo, 2023a). Initially, tuna was captured incidentally by a local handline small-scale fishing fleet (Reck, 1983). Because no other preservation method was available at the time, tuna was consumed fresh, used as bait, or salted and dried. This situation changed after 1998, when electricity became accessible 24 hours a day in the Galapagos (Table 1), allowing for the storage and marketing of fresh and frozen fish. This shift, combined with the increasing number of tourists (Supplementary Figure S1), and the growing popularity of sushi as one of the most widely consumed seafood worldwide, gradually boosted tuna consumption in the GMR. Another factor that promoted this change was the total closure of the sea cucumber (*Isostichopus fuscus*) fishery that occurred in 2006 and the overexploitation of Galapagos sailfin grouper, locally known as "bacalao" (cod in English) (Usseglio et al., 2016).

Nowadays, yellowfin tuna is the most consumed seafood in the Galapagos province (Viteri-Mejía et al., 2022; Castrejón et al., 2024), generating an estimated mean gross income of US$ 1.3 million per year (Ramírez-González et al., 2022). As a result, tuna landings have increased to meet the growing domestic demand from restaurants, hotels, tourist cruises, and the local community (Castrejón and Moreno, 2018). However, the amount of tuna caught by the local small-scale fishing fleet is significantly less than the amount caught in the same area by the industrial fishing fleet before the establishment of GMR. Between 1998 and 2018, annual landings by the Galapagos small-scale tuna fishery increased from 41 to 244 t (Supplementary Figure S1), accounting for less than 1% of total tuna landings reported by the industrial fleet inside Galapagos coastal and oceanic waters, before the reserve's establishment. During the same period, the number of visitors increased from 64,791 to 275,817 (Supplementary Figure S1).

In 2020, the total number of fishers and vessels actively participating in the Galapagos tuna and whitefish fisheries was 336 and 139, respectively, representing 30% and 41% of the total number of fishers (n =1117) and vessels (n = 333) registered by the Galapagos National Park Directorate (GNPD) (Ramírez-Gonzáles et al., 2022). Notably, around 97% of these active vessels are less than 12 m in length, constructed from fiberglass or wood, whereas the remaining 3% are larger wooden boats, ranging from 12 to 18 m long and equipped with inboard engines (DPNG, 2021). Handline, pole and line, trolling, and rod are the only fishing gears explicitly authorized to catch tuna in the GMR.

Given the growing importance of the small-scale tuna fishery to the Galapagos province's food security and economy, management authorities, non-governmental organizations (NGOs), and fishers have agreed to promote the sustainable development of this fishery by transferring fishing effort from depleted or overfished coastal fisheries toward healthier oceanic pelagic species, while supporting artisanal fishers' livelihoods by increasing tuna quality and value (Castrejón and Moreno, 2018). However, the primary concern is how to maximize the socioeconomic benefits generated by the Galapagos tuna fishery while minimizing its ecological impact on ETP species, particularly sharks and manta rays (Castrejón et al., 2019). Since 2000, the solution has centered on backing or repealing the GMR's longlining ban (Castrejón and Defeo, 2023b).

TABLE 1 Key historical milestones that shaped the regulation of longline tuna fishing, conservation of endangered, threatened, and protected species, and the development of the small-scale tuna fishery in the Galapagos Marine Reserve from 1989 to 2022.

Year	Historical milestones
1989	• Prohibition of fishing and trade of sharks in the Galapagos Islands.
1998	• Creation of the Galapagos Marine Reserve (GMR). • Prohibition of large-scale fishing inside the reserve. • 24-hour electricity became available.
2000	• Longline ban within the GMR. • Agreement to establish a marine zoning.
2001	• Longline impact assessment by Revelo et al. (2001).
2002	• Expansion phase of the sea cucumber fishery. • Exponential growth of the small-scale fishing sector.
2004	• Longline impact assessment by Murillo et al. (2004). • First sushi restaurant in Galapagos.
2005	• Ratification of longline ban. • Longline impact assessment by Garcia (2005).
2006	• Total closure of the sea cucumber fishery. • Effective implementation of marine zoning. • Longline impact assessment by Tejada (2006).
2007	• Nationwide prohibition of directed shark fishing and finning. • Establishment of regulations to control the marketing of shark bycatch.
2014	• Longline impact assessment by Reyes et al. (2014) and COPROPAG (2014).
2015	• Longline impact assessment by CTI (2015).
2016	• Creation of the Marine Sanctuary. • Authorization of new research on longline fishing impacts.
2018	• Longline impact assessment by CTI (2018), first phase.
2020	• Longline impact assessment by Cerutti-Pereyra et al. (2020).

COPROPAG, Cooperativa de Producción Pesquera Artesanal Galápagos; CTI, Comisión Técnica Interinstitucional.

3 The Galapagos longline controversy

The controversy associated with the longlining ban in the Galapagos stems from the imperative to protect the unique biodiversity of Galapagos, and the need to support local livelihoods (Castrejón and Defeo, 2023a). Therefore, this controversy is correlated with the history of shark conservation efforts in Ecuador and the development of the small-scale tuna fishery in the GMR.

Shark fishing in the Galapagos Islands began in the 1950s, becoming prevalent in the late 1980s due to the growing demand for shark fins in the Asian market (Jacquet et al., 2008; Carr et al., 2013; Schiller et al., 2014). This trend triggered growing public pressure to implement conservation measures for safeguarding the marine biodiversity of the Galapagos. In response to these environmental concerns, the Ministry of Industries and Fisheries prohibited the fishing and trade of sharks in the Galapagos Islands through Ministerial Decree 151, published in the Official Register No. 191 in 1989 (Table 1). However, the wide extension of the Galapagos marine territory made enforcement challenging, while the lucrative nature of the shark fin trade incentivized illegal fishing. Given the limited enforcement capabilities and lenient penalties for infringements, the effective enforcement of the shark fishing ban proved to be unfeasible. Between 1988 and 1991, shark finning was rampant, involving local and international fishing fleets, leading to the deaths of tens of thousands of sharks (Jacquet et al., 2008; Schiller et al., 2014).

The establishment of the GMR in 1998 progressively deterred illegal shark fishing by national and international large-scale longliners (Reyes and Murillo, 2007), although this threat persists nowadays (Castrejón et al., 2021). Despite this achievement, a segment of local small-scale fishers continued to engage in illegal fishing of sharks within the GMR until the mid-2000s (Castrejón et al., 2021). Contrary to common belief, illegal shark catches in the Galapagos were primarily made with gillnets rather than longlines (Castrejón et al., 2021).

To address this threat, GMR authorities implemented a ban on longlining in 2000 (Table 1). This decision was aimed at preventing illegal and bycatch-related shark fishing, choosing to prohibit longlines over gillnets as a precautionary measure (Castrejón and Defeo, 2023b). Additionally, the Interinstitutional Authority for the Management of the Galápagos Marine Reserve, through Resolution No. 011–2000 of November 15, 2000, prohibited the capture, landing, and commercialization of sharks in the Galapagos (Table 1). During the same year, a network of no-take zones was declared through a marine zoning scheme (Heylings and Bravo, 2007). One year later, the Ecuadorian Ministry of the Environment prohibited the landing and trading of sharks caught incidentally at the national level (Table 1). Despite these efforts, illegal fishing of sharks by Galapagos small-scale fishers persisted, encouraged by the high value of sharks' fins in the black market, exacerbated by corruption within regulatory bodies, and a weak monitoring, control, and surveillance system (Castrejón et al., 2021).

In 2007, the Ecuadorian government enacted Decree 486 to manage incidental shark catches and regulate their trade (Table 1). This legislative measure reinforced the nationwide ban on targeted shark fishing, specifically banning harmful practices such as shark finning and the use of longlines for sharks (Castrejón, 2020c). While the decree allowed for the commercialization of incidentally caught sharks, this provision was excluded from application in the Galapagos Islands. The implementation of Decree 486 significantly devalued the black-market price for shark fins in Ecuador, with the price per set plummeting from around US$ 70 to under US$ 10 (Castrejón et al., 2021). This price drop, combined with improvements in surveillance technology, harsher legal repercussions, and increased local demand for tuna, discouraged local fishers from illegal shark fishing and finning activities within the GMR (Castrejón et al., 2021). Thus, many local fishers shifted their fishing effort from illegal shark fishing to illegal tuna longlining, while others ventured into fuel trafficking (Castrejón et al., 2021). The primary fishing gear for targeting tuna among Galapagos fishers consists of pelagic and midwater longlines, which are commonly equipped with approximately 150 hooks (Montaño, 2022).

The shift towards illegal tuna longlining, while reducing direct threats to sharks, introduced new challenges for managing and

conserving Galapagos marine ecosystems. This transition not only intensified the risk of bycatch, potentially harming sharks and other ETP species but also highlighted an often-neglected threat: ghost fishing (Macfadyen et al., 2009). This environmental problem results from fishing gear, like longlines and nets, that have been abandoned, lost, or discarded, continuing to capture and kill marine life indiscriminately (Gilman, 2015). While bycatch refers to the unintended catch of non-target species during active fishing operations, ghost fishing represents an unseen threat that persists beyond fishing activities, causing prolonged and unmonitored environmental damage.

As the Galapagos small-scale tuna fishery's significance for the economy and food security has risen (Viteri-Mejía et al., 2022; Castrejón et al., 2024), so too has the pushback against the longlining ban from local fishers. This opposition is illustrated by a marked rise in the sightings and seizures of abandoned longlines, a trend intensified after the closure of the sea cucumber fishery in 2006 (Jacquet et al., 2008) and during the COVID-19 pandemic (Montaño, 2022). According to a digital magazine article titled "The prohibited fishing gear that everybody uses" by Montaño (2022), the GNPD registered 57 alerts for illegal longlining activities within the GMR from 2018 to 2020. Many of these alerts were for abandoned or lost longlines, often found adrift with various ETP species caught or entangled. The GNPD's statistics reveal a surge in infractions for employing this banned fishing method within the reserve. According to Castrejón et al. (2021), the annual infractions for illegal fishing gear, including longlines, increased from three to 13 between 2017 and 2020. However, without any study examining the long-term trends of illegal longlining since the ban's enforcement in the GMR, determining whether the surge in infractions is due to intensified patrols or an actual increase in illegal longlining activity remains challenging (Castrejón and Defeo, 2023a). Although the total number of reported violations appears relatively small, park rangers, naturalist guides, and fishers contend that illegal longlining is widespread within the GMR, with incidents reportedly rising in recent years (Montaño, 2022; Castrejón and Defeo, 2023a). However, the scarcity of penalties for such violations suggests a notable leniency in law enforcement, indicating significant impunity (Castrejón et al., 2021).

The main threat to ETP species in the GMR primarily comes from illegal fishing of sharks and tuna by national and international longliners, encompassing both large and small-scale operations (Reyes and Murillo, 2007; Carr et al., 2013), rather than illegal tuna longlining by local Galapagos fishers. There was a notable decline in the number of detected and intercepted national and foreign purse-seiners and longliners illegally operating within the GMR, with incidents falling from 42 in 1996 to just 12 in 2004 (Reyes and Murillo, 2007). However, this trend was reversed between November 2015 and August 2020, during which 100 unauthorized entries into the GMR were registered. Most of these unauthorized entries occurred between 2016 and 2018, averaging 30 incidents yearly (Castrejón et al., 2021). While official records did not describe the vessel types or confirm if these ships were actively involved in illegal fishing within the GMR, a considerable share was flagged under Ecuador, followed by 8% under Nicaragua, and 2% under the flags of the United States and Vanuatu (Castrejón et al., 2021). Particularly troubling is the pattern of repeat offenses by some vessels, notably Ecuadorian, which were reported to enter the GMR without authorization on multiple occasions, with instances ranging from five to seven times per vessel (Castrejón et al., 2021). These statistics highlight persistent challenges to enforcing the longline ban and managing the associated risks of ghost fishing and illegal fishing activities within the GMR.

4 Legal, institutional, and socioeconomic factors preventing the enforcement of the Galapagos longline ban

Several legal, institutional, and socioeconomic challenges have prevented the effective enforcement of the longline fishing ban in the GMR, inadvertently encouraging the intensification of IUU fishing across the reserve (Castrejón et al., 2021; Montaño, 2022). Ben-Yami (2001), who conducted the first comprehensive assessment of the Galapagos small-scale fishery system, early warned that "*longlines are and will be operated illicitly, and any enforcement would be extremely difficult*".

Legal loopholes have prevented the effective implementation of the longline ban (Castrejón et al., 2021). The GMR's Fishing Regulation expressly prohibits longlining, but not their transit or ownership. This legal void allows for the unimpeded transport of longlines within fishing ports, enabling their illegal deployment off the coast due to the inability of park rangers to confiscate these gears preventively. Additionally, control and surveillance are undermined by insufficient follow-through on detected violations and the scant prosecution of culprits (Jones, 2013). Institutionally, despite the GNPD employing a Vehicle Monitoring System (VMS) and Automatic Identification System (AIS) to track fishing fleet movements, the absence of a fishery observer program or electronic monitoring leaves unchecked the actual use of fishing gear and catch composition, creating opportunities for poaching.

The credibility and enforcement of longlining regulations are compromised by inconclusive evidence from experimental studies regarding its ecological impact on the GMR. Between 2000 and 2013, five experimental longline fishing projects were undertaken to investigate the effects of various longline configurations on ETP species, using gear selectivity as the primary evaluation metric (Tables 1, 2). However, the variability in experimental designs, inconsistent criteria for catch categorization, and the insufficient evaluation of economic factors in these studies have undermined the applicability and trustworthiness of their findings (Cerutti-Pereyra et al., 2020; Castrejón and Defeo, 2023a). For instance, scientists have employed different criteria to classify catch composition, because of the lack of a proper definition of target, incidental, and discarded species in the Galapagos legal framework (Castrejón and Defeo, 2023a). Consequently, the results have differed significantly between studies, even those using the same dataset (Table 2). Due to the inconclusiveness of prior studies on longlining's social-ecological impact within the GMR, the Governing Council of the Special Regime of Galapagos approved

TABLE 2 Scientific studies addressing the ecological impact of longlining in the Galapagos Marine Reserve.

Reference	Fishing gear	Period	Fishing trips	Sets	Target species (%)	Incidental catch (%)	Discard (%)
Revelo et al. (2001)	PL	Nov 2001	1	NR	7.6	30.4	62.0
Murillo et al. (2004)	PL	Feb-Mar 2003	1	21	14.6	7.9	77.5
		Oct-Dec 2003	7	134	49.2	16.0	34.8
Garcia (2005)	VL (daylight)	Sept-Dec 2005	33	NR	100	0	0
	VL (night)		42	NR	88.1	9.0	3.0
Tejada (2006)	VL	Apr 2005-Feb 2006	100	196	91.0	5.0	4.0
Reyes et al. (2014)	HML	Nov 2012-Dec 2013	107	422	72.3	18.2	9.5
COPROPAG (2014)			107	437	72.2	18.5	9.3
CTI (2015)			111	451	71.4	19.8	8.8
Cerutti-Pereyra et al. (2020)			NR	115	71.5	19.5	9.0
CTI (2018)	VL	May 2017-Apr 2018	24	76	90.5	1.1	8.5
	HML		33	97	92.1	2.0	5.9

The target species, primarily yellowfin tuna (Thunnus albacares), is indicated as a percentage of the total catch. Incidental catch encompasses non-tuna species retained for their commercial value, authorized for extraction, whereas discard includes endangered, threatened and protected (ETP) species and those without commercial value, whether they are returned to the sea alive or dead. Non-tuna and non-ETP species possessing commercial value but discarded due to the absence of local market demand, are categorized as incidental catches (e.g., escolar: Lepidocybium flavobrunneum). PL, pelagic longline; VL, vertical longline; HML, horizontal midwater longline; NR, Not reported.

a new research initiative in 2016 (Table 2), aimed at assessing the effects of vertical and horizontal midwater longlines in the small-scale tuna fishery (CTI, 2018). However, this project's progression has been hindered by the hesitance of management authorities and NGOs to provide necessary financial and political support, largely due to prevailing misconceptions about longline fishing and its potential harm to ETP species (Castrejón and Defeo, 2023a).

The absence of suitable economic incentives is another factor that undermines the enforcement of the longline fishing ban within GMR (Castrejón et al., 2021). There are no premium markets for tuna caught without a longline because the profitability of the Galapagos tuna fishery is based on quantity rather than quality (Berman et al., 2018), discouraging the adoption of more selective fishing gears or bycatch mitigation methods (Berman et al., 2018; Castrejón and Defeo, 2023a). To address this challenge, management authorities, in partnership with NGOs and international cooperation agencies, have provided technical and financial support to local fishing cooperatives to enhance their organizational and business capabilities, as well as their infrastructure (Castrejón and Moreno, 2018). Nonetheless, these initiatives have been unsuccessful for their short-term nature, isolated approach, and lack of sustained institutional and financial support, failing to establish the necessary operational, organizational, and market framework to deter illegal longlining within the GMR (Castrejón et al., 2021).

Galapagos small-scale fishing sector's representatives argue that the measures aimed at promoting the sustainable development of the Galapagos tuna fishery have failed, primarily because they are not aligned with actual fishers' interests and needs (Castrejón et al., 2021). They emphasize the indispensable role of longlining for catching premium large yellowfin and bigeye tunas, which is more lucrative than using permitted fishing methods such as handline or trolling. In their view, any attempt to improve the Galapagos tuna fishery's value chain will be unsuccessful without permitting longlining, likening it to "building a house without foundation" (Castrejón et al., 2021). Therefore, they contest the legitimacy of the longlining ban, claiming it violates their fundamental right to work and hinders their ability to benefit economically from the tuna stocks protected within the GMR (Castrejón and Defeo, 2023a). The absence of suitable market incentives and the perceived illegitimacy of the longing ban probably have discouraged voluntary compliance, undermining conservation initiatives in the GMR.

5 Longlining misconceptions and management implications

Inadequate communication and outreach efforts have contributed to prevalent misconceptions among Galapagos residents regarding longline fishing practices, their environmental impact, and the regulations utilized to govern them (Castrejón and Defeo, 2023a). This misinformation has fueled the promotion of management measures that may be either inadequate or unfeasible, further complicating the controversy surrounding longline fishing in the archipelago. These communication gaps have obstructed the progress of interdisciplinary and transdisciplinary research needed for devising evidence-based solutions to the Galapagos longlining controversy (Castrejón and Defeo, 2023a).

While most residents are aware of the term "longline," there is notable variation in their understanding of its physical configuration. Although 67% of residents correctly identified pelagic and midwater longlines, only 20% can recognize vertical longlines (Castrejón and Defeo, 2023a). Furthermore, 13% incorrectly identified a longline as a handline, and less than 1% cannot recognize a longline at all (Castrejón and Defeo, 2023a). This misconception could stem from the ambiguous terminology used in the Galapagos legal framework, where the term "vertical longline" is inaccurately defined as "handline." As a result, the phrase "longlining ban" carries the potential for confusion and misinterpretation within the context of the Galapagos regulatory environment.

Handline fishing, locally known as "empate," is a traditional method used in the Galapagos whitefish fishery, originally designed in the late 1940s with a single vertical line and two hooks for targeting species like sailfin grouper and scorpionfish (*Pontinus clemensi*) (Reck, 1983). This method has evolved, sometimes featuring over 12 hooks, making it similar to vertical longlining as described by Preston et al (Preston et al., 1998). Recently, FAO has categorized it as a vertical line (He et al., 2021). "Empate" is now also used for catching yellowfin tuna, bigeye tuna, and swordfish (*Xiphias gladius*), with regulations defining it as a single vertical line with hooks no longer than 70 mm, without a limit on hook numbers. Following the ban on pelagic and midwater longlining, fishers introduced the "deep oceanic handline" to target tuna species in deeper waters. This innovation involves multiple vertical lines, each with three to five hooks, totaling up to 50 hooks, all connected along a single horizontal line that keeps them together (Castrejón and Defeo, 2023a). This setup fits FAO's definition of a vertical line, thus remaining permissible under the current GMR Fishing Regulation, under the name "empate", despite the ban on horizontal longlining variants (Castrejón and Defeo, 2023a).

Three prevailing misconceptions about longline fishing practices have together fueled the negative perception of this fishing method: its perceived low selectivity, significant environmental impact, and the misconceived strictness of its regulations. These mistaken beliefs have perpetuated a detrimental image of longlining, and have complicated the development of a balanced, evidence-based management strategy to solve the Galapagos longline controversy.

5.1 Myth 1: longlining is a non-selective fishing gear that catches everything

A common belief among Galapagos residents is that longline is a non-selective fishing gear that impacts sharks and other ETP species (Montaño, 2022). This misconception may stem from park rangers and naturalist guides witnessing the detrimental effects of abandoned or seized longlines on marine life. Such perception is likely amplified by misleading representations about the ecological impact of commercial longlining operations on social media, which may inadvertently overshadow the reality of sustainable, well-managed small- and large-scale longline fisheries (Castrejón and Defeo, 2023a).

Castrejón and Defeo (2023a) examined Galapagos residents' perceptions of longlining's ecological impacts against empirical evidence. An online survey showed participants two images: one used by NGOs and conservation groups to campaign against longlining (Figure 2A), and another based on scientific data from Cerutti-Pereyra et al. (2020) (Figure 2B). These authors found that 75% of catches from horizontal midwater longlining were yellowfin tuna, with 16% being other market-valued species and only 9% discarded species like sharks and manta rays. Despite this evidence, 57% of residents believed the advocacy image accurately depicted longlining's ecological impact, while 36% agreed with the scientific image. This suggests a gap in understanding the difference between the impacts of ghost fishing and commercial longlining (Castrejón and Defeo, 2023a). Additionally, 56% of residents overestimated the bycatch of ETP species, thinking it exceeded 11% of the total catch, contrary to evidence showing it is less than 9% (Garcia, 2005; Tejada, 2006; CTI, 2018) (Table 2).

A global FAO assessment of bycatch in small-scale fisheries (Gillett, 2011) also showed a wide range of non-target species catch rates from 4% to 86% in small-scale longline tuna fisheries. Factors like leader material and length, hook shape, bait type, duration of bait immersion (soak time), depth at which the catch is made, fishing location, and season all play crucial roles in determining the composition, quantity, and size of both target and incidental catches (Clarke et al., 2014). As a result, some studies have rated the bycatch and habitat impacts of pelagic and bottom longlines as moderate (Chuenpagdee et al., 2003). For instance, shark bycatch rates (in individuals) for Chinese tuna longline fleets stand at 7.3% in the Pacific (Wang et al., 2021), comparable to the 8.5% bycatch rate for sharks and rays in Ecuador's EEZ, outside the GMR (Martínez-Ortiz et al., 2015). Nevertheless, social media's portrayal of the Galapagos small-scale longlining impact created a biased narrative that overlooks recent bycatch mitigation research and the wide range of potential solutions to solve the Galapagos longline controversy. This biased coverage may reinforce misconceived notions within the public, contributing to the formation of "echo chambers", or groups of users with similar beliefs, that reinforce a one-sided narrative (Cinelli et al., 2021).

5.2 Myth 2: longlining is an unsustainable fishing modality

Approximately, 80% of Galapagos residents hold the belief that sustainable longline tuna fisheries do not exist (Castrejón and Defeo, 2023a). Contrary to this perception, the Marine Stewardship Council (MSC), a globally recognized certification body for sustainable fishing practices, had certified 25 longline fisheries as sustainable by January 15th, 2024, recognizing their adherence to environmental standards that prevent overfishing and minimize ecosystem impacts (MSC, 2023). An additional 15 longline fisheries are currently undergoing assessment by the MSC, suggesting that this fishing method embodies a model of best practices, aimed at minimizing environmental impacts. Even fishing gears traditionally reported as less selective, such as bottom trawling, can also be managed sustainably, provided they are subject

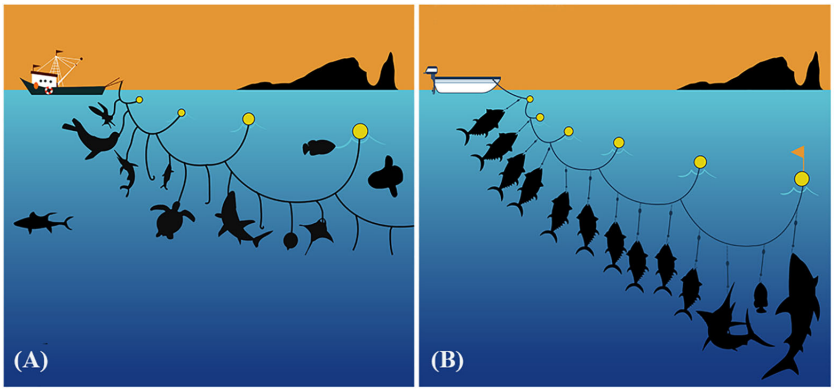

FIGURE 2
Environmental impact of longlining inside the Galapagos Marine Reserve. **(A)** media-based representation of a common image shared on social media by NGO and conservationist groups; **(B)** science-based representation of **(A)**, based on Cerutti-Pereyra et al. (2020). This study found that yellowfin tuna accounted for 75% of the total catch obtained by horizontal midwater longline, with the remaining 16% being incidental catch (i.e., non-targeted species that are retained because they have a commercial value and their extraction is authorized, such as swordfish and wahoo), and 9% being discarded (i.e., species protected or without commercial value or market returned to the sea alive or dead, such as sharks and manta rays). Source: Castrejón and Defeo (2023a).

to effective fisheries management (Hilborn et al., 2023). This highlights that the sustainability of fishing practices is less about the gear used and more about how the fisheries are managed (Hilborn et al., 2023).

5.3 Myth 3: longlining is incompatible with multiple-use MPA or shark sanctuaries

Despite the common assumption among about 80% of Galapagos residents that longlining is unconditionally prohibited in MPAs (Castrejón and Defeo, 2023a), this fishing gear is, in fact, often permitted within many multiple-use MPAs and shark sanctuaries, usually under strict regulations or in specific zones. For instance, a small-scale longline fishery for mahi-mahi is managed within a dedicated area in Coiba National Park, Panama, known as the "Dorado longline fishing subzone" (Maté et al., 2015; Castrejón, 2020b). Furthermore, both pelagic and demersal longline fishing operations are authorized in eleven of the twelve areas within Australia's South-East Commonwealth Marine Reserves Network (Director of National Parks, 2013).

Longlining is also allowed in some shark sanctuaries, which function as specialized Large Marine Protected Areas (LMPA), despite prohibitions on shark fishing and trade (Ward-Paige, 2017; Shea et al., 2023). Mortality rates for specific shark species within these sanctuaries can rise to 5% of sustainable levels for blue sharks (*Prionace glauca*), and 40% for silky sharks (*Carcharhinus falciformis*). Only in two out of eight sanctuaries reviewed silky shark mortality rates have surpassed a sustainability threshold, underscoring the necessity for improved stock assessments and more effective bycatch mitigation measures (Shea et al., 2023). This evidence suggests that, while longline fishing's impact on certain shark species in sanctuaries is concerning, it is inaccurate to label all longline fisheries in shark sanctuaries or multi-use MPAs as unsustainable (Simpfendorfer and Dulvy, 2017).

6 Addressing illegal longlining and ghost fishing through an ecosystem approach to fisheries

Multiple solutions exist to reduce the incidental catch and discard of ETP species in longline tuna fisheries. Operational changes, combined with emerging technologies, spatiotemporal measures, and market incentives, could foster the profitable development of longline tuna fisheries while minimizing the ecological impact of this activity on ETP species (Gjertsen et al., 2010; Hall et al., 2017; Swimmer et al., 2020). Building on Castrejón and Defeo (2023b), we recommend adopting the ecosystem approach to fisheries (EAF) to harmonize societal goals with ecologically meaningful parameters (FAO, 2003). To this end, Castrejón and Defeo (2023b) adapted the decision support tool for integrated fisheries bycatch management developed by Gilman et al. (2022). Following Gilman et al. (2022) and Castrejón and Defeo (2023b), we propose utilizing the participatory process outlined in Figure 3 to adapt the decision support tool for the Galapagos small-scale tuna fishery. The subsequent subsections offer guidance to implement each step of the process.

6.1 Debunk misconceptions

Scientific censorship has limited the understanding of the longlining controversy's origins, extent, and reasons, restricting the exploration of diverse operational, technological, regulatory, and market-based solutions (Castrejón and Defeo, 2023a, b). Environmental groups, being more vocal against longlining (Castrejón and Defeo, 2023a), appear more influential than local small-scale fishers, potentially skewing policymakers' perceptions (Mustafaraj et al., 2011). Additionally, cognitive biases like confirmation bias may cause policymakers to focus on

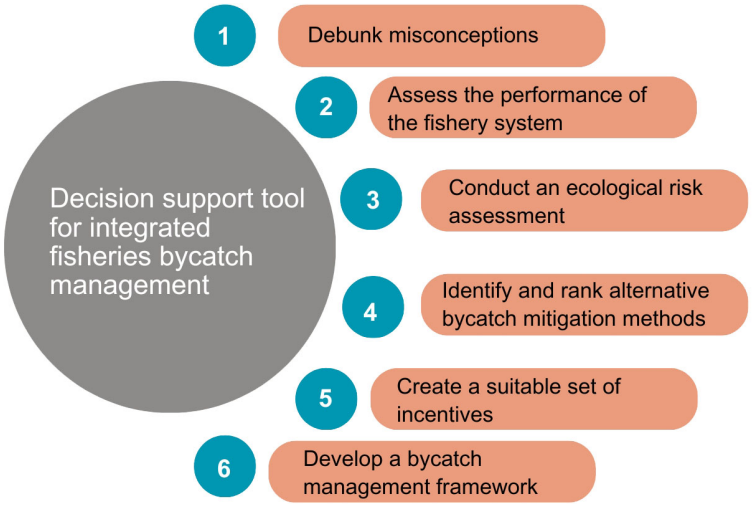

FIGURE 3
Decision support tool designed for the integrated management of bycatch, aiming to promote an ecosystem-based approach to the small-scale tuna fishery of the Galapagos Marine Reserve. Adapted from Gilman et al. (2022) and Castrejón and Defeo (2023b).

information that aligns with their preconceived notions, ignoring opposing evidence (Nickerson, 1998). This bias discourages involvement in the longline controversy among local authorities, NGOs, and scientists, leading to scarce political, technical, and financial support for interdisciplinary and transdisciplinary studies aimed at investigating solutions to this complex social-ecological challenge. This deficiency in support results in the stagnation of innovative solutions that could reconcile ecological sustainability with economic viability.

The dominance of certain voices in the debate has also led to an oversimplification of the Galapagos longline controversy, where a complex socio-ecological problem has been reduced to a false dilemma, i.e., a logical fallacy that occurs when an argument incorrectly presents two opposing options as the only possibilities, when in fact there are more additional options available. This oversimplification fails to acknowledge the multiplicity of stakeholders involved, each with its own sets of values, beliefs, attitudes, and interests, and how these interact with the dynamics of marine ecosystems (Castrejón and Defeo, 2023a). As a result, the longline ban might not only be ineffective but could also inadvertently harm the very ETP species it aims to protect by overlooking critical social-ecological interactions and feedback loops. For instance, this regulation could lead fishers to abandon their longlines to evade detection by tourist cruises or park rangers, potentially exacerbating ghost fishing. This hypothesis requires further investigation to understand the unintended impacts of the longline ban, its management implications, and to develop more effective conservation strategies.

The first recommended step to addressing the Galapagos longline controversy is to debunk existing misconceptions about longline fishing practices, their environmental impacts, and governing regulations (Figure 3). Evidence-based communication and education campaigns should be put in place to make people reflect and question their beliefs based on comprehension of longline fishing practices and their ecological, repercussions, as well as creating awareness about the multiple existing operational, technological, regulatory, and market-based solutions to minimize its impact on ETP species (Castrejón and Defeo, 2023a).

It is essential to communicate to the public the distinction between the ecological effects of ghost fishing and conventional commercial longlining, which diverge considerably (Macfadyen et al., 2009; Clarke et al., 2014). A clear understanding of these differences will enable the design of specific measures aimed at monitoring and implementing actions to prevent the detrimental impacts of ghost fishing and commercial longlining on the marine ecosystems of the Galapagos.

6.2 Assess the performance of the fishery system

The second phase involves a comprehensive examination of the Galapagos small-scale tuna fisheries to improve the monitoring, surveillance, and control systems, and the corresponding legal framework (Figure 3). Such enhancements are necessary to effectively combat illegal longlining practices, mitigate ghost fishing, and reduce bycatch and mortality rates of ETP species within the GMR. This analysis requires a rigorous, all-encompassing, and impartial appraisal of the social-ecological impacts caused by the longlining ban, analyzing the diverse origins and intensities of mortality inflicted by ghost fishing and alternative fishing gear like gillnets, as well as national and international longlining and purse seine fleets.

This performance evaluation should also assess the effectiveness of precautionary management measures enacted by the Ecuadorian government, aimed at curbing the illegal and incidental catches of sharks and other migratory species within and adjacent to the GMR's borders. Firstly, shark fishing is nationally banned, encompassing the GMR. Sharks that are bycaught may be sold on the mainland of Ecuador on the condition that they are landed fully

(with fins naturally attached to the body) (Castrejón, 2020c). Secondly, a new zoning system has established 33% of the GMR's entire area as no-take zones, covering 45,380 km^2 (DPNG, 2016) (Figure 1). Within this, the "Marine Sanctuary"—a substantial no-take zone encompassing approximately 38,546.5 km^2—was decreed in March 2016 to safeguard the areas near Darwin and Wolf Islands and adjacent seamounts known for their high shark densities (DPNG, 2016) (Figure 1). Thirdly, in January 2022, the "Reserva Hermandad," a new large multiple-use MPA, was established (Figure 1). It is designed to protect the migratory paths, foraging grounds, and essential habitats of migratory ETP species. This marine corridor or "*swimway*", situated on the northeastern side of the Insular EEZ of Ecuador, includes a no-take area and a buffer zone, each measuring 30,000 km^2 (Figure 1), where longlining is strictly prohibited.

6.3 Conduct an ecological risk assessment

Decision-making regarding the ratification or derogation of the longlining ban in the GMR should be guided by rigorous scientific criteria. A key metric used for the GNPD to assess the ecological impact of longlining in the GMR is the proportion of incidental catch and discard of ETP species. However, a more critical indicator is the amount of the incidental catch in relation to the population size of the affected ETP species (Shea et al., 2023). Unfortunately, small-scale fisheries in the Eastern Pacific Ocean are mostly data-poor, and the migratory nature of sharks, which are primarily affected by longline fishing (Cerutti-Pereyra et al., 2020), makes estimating the stock status of ETP species relative to reference points a difficult task (Duffy et al., 2019). Considering this challenge, Castrejón and Defeo (2023b) recommended conducting an ecological risk assessment (ERA) to determine whether the regulated use of longline, along with alternative fishing gears like green sticks and harpoons, would pose a significant risk of severe or irreversible harm to ETP species (Figure 3). This approach could provide a valuable tool for analyzing the sustainability of fishing methods, especially when standard biological reference points may be unavailable due to a lack of detailed information on bycatch species (Gilman et al., 2022). The outcomes of ERAs can be leveraged to prioritize fishery- and species-specific research initiatives or delineate mitigation measures to maintain the incidental catch of ETP species within ecologically pertinent margins (Duffy et al., 2019; Gilman et al., 2022).

6.4 Identify and rank alternative bycatch mitigation methods

This stage involves an extensive literature review of bycatch mitigation methods for longline and other fishing gears (Figure 3), assessing their effectiveness, cost-efficiency, practicality, safety, and impact on target, and non-target species, habitats, and ecosystems. This process aims to identify the most promising techniques for experimental validation, focusing on reducing bycatch in sustainable ways.

Even though there is no "one size fits all" solution for bycatch reduction (Swimmer et al., 2020), certain measures have proved to be effective in mitigating the environmental impact produced by tuna longline fisheries. For instance, dynamic spatial management has proven significantly effective, with recent studies showing that dynamic closures can reduce bycatch by 57% without harming target catch rates (Pons et al., 2022). This approach is particularly relevant for the GMR, where evaluating dynamic versus static ocean management could enhance the balance between conservation and fishing interests. By using a spatially explicit approach, managers can identify areas with a high risk of ETP species bycatch and implement appropriate measures, such as seasonal or area closures, to reduce the impact on non-target species while maintaining the viability of the fishery (Pons et al., 2022).

Specific measures like deep and night sets, short soak times, non-wire leaders, and modified hooks and baits have shown effectiveness in reducing significantly shark bycatch (Swimmer et al., 2020), the primary species affected by longlining in the GMR (Cerutti-Pereyra et al., 2020). The effectiveness of some of these bycatch mitigation techniques has been reported by studies conducted in Galapagos. Murillo et al. (2004) reported an incidental catch of ETP species, mostly sharks, ranging from 35 to 78% of the total catch for a study about the impact of pelagic longlining across the GMR, whereas Cerutti-Pereyra et al. (2020) reported a 9% of incidental catch of ETP species by horizontal midwater longlining (Table 2). As these studies evaluated different types of longlines, hooks, and depths of capture, their findings suggest that it is possible to significantly reduce the environmental impact of longlining in the GMR through a combination of bycatch mitigation measures.

Emerging technologies like "SharkGuard" also offer to reduce sharks and rays' bycatch. This shark bycatch mitigation device emits an electrical pulse that keeps sharks away from baited hooks, reducing the likelihood of their interaction with longlines. It has proved to be effective in reducing the mean bycatch of blue sharks and pelagic stingrays by 91.3% and 71.3%, respectively (Doherty et al., 2022). Further trials would be required in the GMR to test the impact of these electrical deterrent devices on target and bycatch species under the specific longline configuration, and environmental and oceanographic conditions, found in the archipelago.

Adopting more selective fishing gear represents another solution to reduce the bycatch of ETP species in the GMR, but it requires balancing bycatch reduction with maintaining target catch rates to ensure effective implementation (Gilman et al., 2019; Swimmer et al., 2020). Experiments in Costa Rica with "greenstick" gear showed high yellowfin tuna catch rates (98.5% of the total catch), whereas the incidental catch of other species was lower than 0.6%, but these trials were unprofitable due to high juvenile catch (Marín et al., 2019). Similarly, in the GMR, trials with vertical longlines caught mostly yellowfin tuna (96% of the total catch) with minimal bycatch (4%), but also resulted in unprofitable juvenile catches (Tejada, 2006) (Table 2). Consequently, both studies suggest targeting adult populations in deeper waters to ensure profitability and sustainability, combined with better post-harvest and marketing practices.

The release of live animals is increasingly recognized as a crucial bycatch mitigation measure in longline fisheries, serving as a straightforward and effective conservation strategy to reduce mortality rates of non-target species (Wosnick et al., 2023). Effective implementation hinges on safe handling and release protocols that are specifically tailored to the physiological stress responses of different species (Zollett and Swimmer, 2019). Additionally, it is crucial to educate and provide incentives to fishers to adopt and prioritize these measures, for example, through financial compensation in a pay-for-release model, to ensure their widespread adoption and effectiveness (Leduc and Hussey, 2019). While this strategy is promising, its success ultimately depends on relies on careful execution and close post-release monitoring afterward to verify the survival and well-being of the released animals (Francis et al., 2023; Wosnick et al., 2023).

To mitigate other components contributing to total fishing mortality, such as ghost fishing, additional management actions are required. For instance, implementing buoys equipped with Global Positioning System (GPS) can be used to track and recover longlines, preventing gear loss and reducing ghost fishing (Macfadyen et al., 2009). Other measures may include introducing biodegradable fishing gear, employing bycatch release devices for higher survival rates of ETP species, and supporting habitat restoration. However, when collateral damage from fishing is unavoidable, compensatory bycatch mitigation strategies are critical. These strategies offset negative impacts on non-target species with positive conservation efforts (Gilman et al., 2022). In the GMR, for example, this could mean allowing regulated midwater longline fishing in exchange for banning gillnets in mangrove areas or permitting longlining exclusively around seamounts to shift effort from overfished coastal areas to healthier pelagic stocks. Such measures aim to reduce juvenile blacktip shark mortality and support the recovery of overexploited species, ensuring the sustainable future of the Galapagos small-scale tuna fishery by balancing economic activities with marine conservation.

6.5 Create a suitable set of incentives

The Galapagos small-scale fishing sector can benefit economically from the gradual and adaptive introduction of fishing practices to reduce bycatch and IUU fishing (Kennelly, 2007; Gjertsen et al., 2010). Market incentives through the development of social enterprises and a voluntary ecolabelling program or certification of origin scheme could encourage fishers to adopt cutting-edge monitoring, control, and traceability technology from the hook to the final consumer (Figure 3). This market incentive would foster access to markets willing to pay a fair price for sustainable, socially responsible, and environmentally friendly seafood products. According to Tanner et al. (2021), tourists are willing to pay a price premium ranging from US$ 2.8 to US$ 7.5 per pound for certified yellowfin tuna from Galapagos that meet four criteria: food safety, freshness, low bycatch levels, and sourced directly from local fishers. Implementing electronic monitoring and traceability systems will reduce the prevalence of IUU fishing. Proper market incentives, combined with a transparent and participatory decision-making process, could promote compliance with regulations and improve the governance of the GMR. To be effective, market-based incentives should involve fishers in their design and implementation from inception to foster a sense of ownership for bycatch mitigation techniques (Gilman, 2011).

Market-based incentives could reward fishers for reducing bycatch through cash or in-kind benefits, such as encouraging the Galapagos tourism sector to pay a premium for longline-free tuna or tuna caught with low percentages of bycatch (Castrejón and Defeo, 2023a). The increased profits from these premiums must be equitably distributed throughout the value chain, ensuring that fishers benefit as much as retailers. Additionally, the acceptance of higher prices should be evaluated among tourists and within the value chain to prevent potential negative impacts on sales. Furthermore, we suggest revitalizing and fully implementing a community-based fishery improvement project (C-FIP), initially agreed upon in 2019 by various institutions, including the GNPD, Santa Cruz fishing cooperatives, and international NGOs (Castrejón et al., 2019). This collaborative effort resulted in an agreed action plan and business plan designed to enhance the management and marketing systems of the Galapagos small-scale tuna fishery (Viteri et al., 2018; Castrejón et al., 2019). Financial constraints and insufficient institutional support have hindered the implementation of this C-FIP. In response, one fishing cooperative from Santa Cruz Island (Pelican Bay Co-op) has proactively sought scientific and technical support to implement the C-FIP action plan using their resources. We recommend supporting this initiative to certify the Galapagos small-scale tuna fishery through the MSC or other fisheries certification programs, leveraging the C-FIP action plan as a guideline for improving this fishery. This initiative could motivate consumers to select fish from the Galapagos small-scale tuna fishery, while also helping fishers access preferential markets, which would enhance their profitability and promote sustainable fishing practices. Penalties for failing to meet performance standards for minimizing bycatch might include bycatch quotas per vessel, with non-compliance resulting in taxes or in-kind sanctions such as reduced fishing days or the withdrawal of fishing licenses (Squires et al., 2021).

6.6 Develop a bycatch management framework

The final step of the decision process includes a participatory decision tool (e.g., multi-criterion decision analysis, conjoint analysis and choice-based survey approaches) to define goals, objectives, and performance standards, based on the information compiled in the previous stages (Gilman et al., 2022). The developed bycatch management framework encompasses management actions and milestones aimed at achieving agreed-upon objectives (Figure 3). This framework may entail amendments to existing legal and regulatory frameworks, improvements in monitoring, control and surveillance, and experimental testing of new fishing gears and methods for bycatch mitigation. The bycatch management framework must also include a workplan for implementing the actions and achieving each milestone, with clear performance indicators (Gilman et al., 2022). The plan must

be monitored and adapted if needed (Figure 3), guided by the findings of performance assessments and ERAs conducted periodically by impartial parties (Gilman et al., 2019). To implement this decision-support tool, substantial investments in science, technology, and innovation are required for promoting gradual and adaptive improvements in fishing practices, aiming to reduce IUU fishing, ghost fishing, and bycatch within and beyond GMR boundaries (Castrejón and Defeo, 2023b).

7 Conclusion

This overview has critically examined the longline fishing controversy in the GMR, revealing the challenges of balancing conservation efforts with local livelihoods amidst illegal longlining and ghost fishing threats. Despite a ban on longline fishing aimed at protecting sharks and other endangered species, these practices persist, highlighting enforcement and compliance gaps due to legal, institutional, and socioeconomic challenges.

Our findings emphasize the need for a better thought-out, innovative, and scientifically grounded approach that aligns conservation objectives with community needs. This comprehensive EAF framework proposes solutions to mitigate illegal longlining and ghost fishing, aiming to reduce the fishing mortality of ETP species, while promoting the sustainable development of the Galapagos small-scale tuna fishery. Key to this approach is debunking misconceptions about longlining, conducting rigorous assessments, identifying alternative bycatch mitigation methods, creating suitable incentives, and developing a bycatch management framework.

Our study also highlights the importance of innovative, community-engaged strategies for sustainable fisheries management in multiple-use MPAs and shark sanctuaries, advocating for adaptive management practices that integrate scientific knowledge and stakeholder participation. It calls for continuous research and collaboration to address the complex challenges of fisheries management in the Galapagos and other ecologically sensitive ecosystems worldwide, striving for a balance between ecological conservation and human well-being.

Author contributions

MC: Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Conceptualization. OD: Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2024.1400737/full#supplementary-material

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