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Perceptions and attitudes of residents toward small-scale longline tuna fishing in the Galapagos Marine Reserve: conservation and management implications

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Longlining represents a cost-effective fishing modality for catching tuna, but its use is contentious due to the unintended catch of endangered, threatened, and protected (ETP) species. In 2000, longlining was banned in the Galapagos Marine Reserve, Ecuador. Since then, local small-scale fishers have contested this decision. In contrast, longlining ban supporters argue that this regulation is fundamental for conserving ETP species, despite scientific and anecdotal evidence indicating that its effective implementation is unfeasible. We conducted an online survey to investigate Galapagos residents' perceptions concerning longlining, its ecological impact, and diverse potential management strategies. Our findings revealed misconceptions about longline fishing, which highlight the need for improved public awareness and education regarding longline fishing practices, their impact on ETP species, and possible solutions to this complex social-ecological problem. Our study also highlights Galapagos residents' openness to find a solution that addresses both fishers' livelihoods and the conservation of ETP species. Galapagos residents are receptive to implementing evidence-based solutions, including testing new bycatch mitigation methods and more selective fishing gears, enhancing monitoring and enforcement, and creating market-based incentives that encourage progressive and adaptive improvements in fishing practices. To solve the Galapagos longline controversy, we recommend a holistic, adaptive, and evidence-based approach that encourages stakeholders to engage in open dialogue, fosters cross-sector collaboration, and promotes research, communication, and educational initiatives. By raising awareness through comprehensive, rigorous, and unbiased scientific information, this ecosystem-based management approach aims to ensure the sustainable development of the small-scale tuna fishery, while conserving the Galapagos' invaluable and unique marine biodiversity.

KEYWORDS

Galapagos, marine protected area, longline, bycatch, illegal fishing, small-scale fishery, perceptions, shark sanctuary

1 Introduction

Longlining has proved to be an effective and profitable fishing gear to catch tuna and other targeted fish species (Clarke et al., 2014; IATCC, 2022). However, it has also been criticized for its unintended impact on non-target species, commonly referred to as bycatch (Gillett, 2011). Bycatch include the unintended capture of endangered, threatened, and protected (ETP) species such as sharks, sea turtles, and seabirds, which can become entangled or hooked by longlining (Swimmer et al., 2020).

Longline fishing is a hook-and-line fishing modality characterized by a long horizontal or vertical mainline to which branch lines are connected at regular intervals, each with a baited hook (Preston et al., 1998; He et al., 2021). This fishing technique includes bottom, pelagic, midwater, and vertical longlines, each designed to target different species like tuna, swordfish, mahi-mahi, sharks, and demersal finfish in various oceanographic conditions. Longlines can differ in material types, length and weight of the line, number, spacing and type of hooks, type of bait, and operational practices (Clarke et al., 2014).

The selectivity of longline fishing is influenced by operational, spatiotemporal, environmental, and oceanographic factors, including leader length and material, hook shape, bait type, soak time, catch depth, fishing ground, and season, in fluence catch composition, amount, and size range of target and non-target species (Clarke et al., 2014). Consequently, the selectivity of longline fishing is quite variable. For instance, the percentage of non-tuna species in small-scale longline tuna fisheries can range between 4% and 86% (Gillett, 2011). The impact of longlining on ETP species can be minimized through a wide variety of bycatch mitigation methods, including operational changes, emerging technologies, spatiotemporal measures, and market incentives (Gilman, 2011; Hall et al., 2017; Swimmer et al., 2020; Squires et al., 2021; Gilman et al., 2022).

In the Eastern Pacific Ocean (EPO), longlining is the second most used fishing gear for catching tuna, after purse seining (IATCC, 2022). The EPO is one of the major tuna-producing regions in the world and is also home to a network of fully protected and multiple-use marine protected areas (MPA) listed as natural World Heritage sites by UNESCO. These sites include Cocos Island National Park (Costa Rica), Coiba National Park (Panama), Gorgona National Natural Park (Colombia), Malpelo Fauna and Flora Sanctuary (Colombia), and Galapagos Marine Reserve (Ecuador). Longlining is banned in these MPA, except for Coiba National Park, where longlining is restricted to a designated management area called "Dorado longline fishing subzone", which regulates a small-scale mahi-mahi (*Coryphaena hippurus*) longline fishery (Maté et al., 2015).

The feasibility of implementing longlining bans in MPA is a topic of debate. While some studies advocate for outright longlining bans in "shark sanctuaries" or multiple use MPA (Chapman et al., 2013; Cerutti-Pereyra et al., 2020), others recognize the socioeconomic importance of longlining in these areas, suggesting alternative mitigation strategies (Davidson, 2012; Simpfendorfer and Dulvy, 2017). A recent study examining longline fishing across eight Western Pacific shark sanctuaries and its effects on pelagic shark species acknowledges that an ideal shark sanctuary should prohibit longlining (Shea et al., 2023). However, given the economic and food security roles of longlining in numerous remote island nations, enforcing such bans may not always be feasible. In situations where absolute bans are impractical, Shea et al. (2023) suggest adopting bycatch mitigation strategies, such as gear modifications, effort limitations, or temporary or permanent closures of critical habitats, to reduce incidental shark mortalities. A similar management approach has been suggested by Ben-Yami (2001) and Castrejón and Defeo (2023), who suggest reconsidering the feasibility and efficacy of this regulation in the Galapagos Marine Reserve (GMR) to guarantee the conservation of ETP species. Their proposal is based on scientific and anecdotal evidence suggesting that the longlining ban has been ineffective in deterring illegal, unregulated, and unreported (IUU) fishing in this multiple-use MPA.

The ecological impact of longlining in the Galapagos is especially concerning due to its extraordinary biodiversity, encompassing an array of endemic and threatened marine species. In consequence, longlining was banned in the GMR in 2000 (Castrejón and Defeo, 2023). Since then, the only authorized fishing gears to catch tuna within the reserve include trolling, pole and line, and handline. However, despite the Galapagos National Park Directorate (GNPD) holds one of the most sophisticated control and surveillance systems in the region, illegal longlining continues to be a persistent threat in the GMR, as evidenced by various scientific and anecdotal sources (Ben-Yami, 2001; Reyes and Murillo, 2007; Castrejón et al., 2021; Montaño, 2022). Castrejón et al. (2021) note that infractions due to illegal fishing gears, including longlines, increased from three to 13 between 2017 and 2020. The absence of official annual reports prior to this period makes it challenging to trace the evolution of illegal longlining in the GMR since its inception. Consequently, the cause of the increasing trend in infractions remains uncertain. It could stem from intensified patrols activities or the spread of illegal longlining throughout the reserve. Despite the low number of infractions, park rangers, naturalist guides, and fishers shared the perception that illegal longlining activities are widespread within the GMR and have been on the rise in recent times (Castrejón et al., 2021; Montaño, 2022). Furthermore, the limited penalties for these transgressions suggest a notable level of leniency in law enforcement (Castrejón et al., 2021). The remarkable contrast between the believed widespread nature of illegal longlining and the few infractions and penalties reported highlights a potential enforcement gap.

Several factors hinder the enforcement of the longline ban, including legal loopholes, institutional limitations, and socioeconomic challenges (Ben-Yami, 2001; Castrejón and Defeo, 2023). GMR Fishing Regulation bans longline use but not their transit or ownership, which prevents park rangers from confiscating longlines at ports and paves the way for offshore illegal longlining. While the GNPD can monitor vessel movements through Vehicle Monitoring System (VMS) and AIS, it lacks *in situ* monitoring methods like a fisheries observer program or an electronic monitoring system (Castrejón and Moreno, 2018). In addition, there are no market-based incentives in place, discouraging fishers from adopting more sustainable fishing methods.

The controversy surrounding longlining in the Galapagos small-scale tuna fishery stems from the need to support local livelihoods and the imperative to protect unique and fragile marine ecosystems. Small-scale fishing sector representatives argue that the longlining ban should be derogated because it violates their fundamental right to work (Castrejón et al., 2021). According to them, longlining is the most cost-efficient fishing gear for catching tuna, which could increase catch rates, bolster the economy, and improve the overall welfare of the local community. Opponents of longlining emphasize the risks this fishing gear poses to the Galapagos unique and vulnerable marine ecosystem (Murillo et al., 2004; Grenier, 2007; Izurieta and Green, 2021). They argue that authorizing longlining could exacerbate existing threats to ETP species, such as illegal fishing, overfishing, pollution, and climate change, further jeopardizing the sustainability of the region's marine resources. Additionally, critics highlight the importance of upholding the GMR status as a UNESCO World Heritage Site and a global beacon of marine conservation, which could be undermined by the adoption of potentially harmful fishing practices (Izurieta and Green, 2021). Therefore, opponents of longlining advocate for backing the longlining ban (Cerutti-Pereyra et al., 2020), as they believe it is the most appropriate solution to ensure the conservation of ETP species. The differing views on this issue have made finding a resolution challenging for the last 23 years.

Demographic, socioeconomic, and cultural factors can shape the way individuals interpret information, form opinions, and make decisions about conservation, fishing practices, and natural resource management (Bennett and Dearden, 2014; Jefferson et al., 2021). Therefore, understanding the perceptions and attitudes of Galapagos residents towards longline tuna fishing, and the factors that influence them, is essential for promoting greater understanding and collaboration, as well as developing effective conservation and management strategies (Gelcich and O'Keeffe, 2016). This study evaluates the perceptions of Galapagos residents towards longline tuna fishing and its impact on ETP species, as well as their attitude concerning different management strategies to resolve the longlining controversy. By understanding the views of residents, policymakers can identify potential conflicts and opportunities for cross-sectoral collaboration, build trust and cooperation, and develop policies and strategies that meet the needs and expectations of all stakeholders involved (Bennett, 2016).

2 Materials and methods

2.1 The Galapagos small-scale tuna fishery and the longline controversy

In the 1930s, commercial tuna fishing in the Galapagos Islands began with longliners and purse seiners from the United States, Japan, Panama, and Costa Rica (Reck, 1983). In the 1970s, an Ecuadorian large-scale tuna fishing fleet, consisting of 12 purse seiners and four longliners, joined the commercial exploitation of tuna in the Galapagos (Bustamante, 1999). Between 1995 and 1997, this national large-scale fishing fleet caught on average 29,712 t of yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), and skipjack (*Katsuwonus pelamis*) tuna in the Galapagos Islands (Bustamante, 1999). These catches represented 24% of the total tuna catch registered in Ecuador during that time (Castrejón and Moreno, 2018).

In 1998, the Galapagos Islands and its surrounding open waters, up to 40 nautical miles, were designated as a multiple-use marine protected area of 141,100 km^2 (DPNG, 2014), known as the Galapagos Marine Reserve (GMR) (Figure 1). Since then, large-scale fishing was prohibited within the reserve, and only small-scale fishing by Galapagos residents is authorized. As a result, commercial tuna exploitation in the Galapagos gradually shifted from an external and industrial operation toward a small-scale local economic activity (Castrejón and Defeo, 2023).

Several precautionary measures have been implemented to conserve ETP species, especially sharks (Castrejón and Defeo, 2023). These include the establishment of a network of no-take zones to protect critical habitats, such as shark nursery areas and migratory pathways. The no-take zones collectively cover an area equivalent to 32% of GMR total area (45,380.02 km^2) (Figure 1). The largest no-take zone, known as "Marine Sanctuary," spans 38,546.49 km^2 (27% of the GMR total area). This sanctuary was established to safeguard shark-dense areas (Burbano et al., 2020). Additionally, a national ban on shark fishing and finning was enacted in Ecuador in 2007. Shark bycatch can only be marketed in mainland Ecuador if landed whole. In Galapagos, sharks fishing and trading is forbidden since 1989 (Castrejón et al., 2014), even if they are caught incidentally. Further bolstering these conservation efforts, the "Reserva Hermandad" was established in January 2022 as a new large-scale, multi-use MPA (Figure 1). With a total area of 60,000 km^2, this MPA was designed to safeguard the routes and habitats of migratory ETP species. It is divided into two management zones: a no-take area of 30,000 km^2 and a buffer zone of the same size, in which longlining is prohibited (Figure 1).

The Galapagos' small-scale tuna fishery is crucial for local food security and the economy (Ramírez-Gonzales et al., 2022; Rodríguez-Jácome et al., 2023). Tuna is the most consumed seafood by Galapagos residents (Viteri Mejía et al., 2022), with landings increasing from 41 to 244 tons between 1998 and 2018 due to growing demand (Castrejón and Moreno, 2018; Ramírez-Gonzales et al., 2022). Such figures account for less than 1% of total tuna landings registered before the GMR establishment (Castrejón and Moreno, 2018). The tuna and whitefish fisheries directly employ ca. 336 fishers, which represents 33% of the total number of small-scale fishing licenses (1117) registered by the Galapagos National Park Directorate, generating an estimated annual gross income of $1.3 million (Ramírez-Gonzales et al., 2022). The tuna fishery also provides indirect employment to women who play a key role in post-harvesting activities (Rodríguez-Jácome et al., 2023), and generates income for an increasing number of restaurants, hotels, and tourist cruises, through a multiplier effect (Berman et al., 2018). Information about the bycatch rate in the small-scale tuna fishery is unavailable due to the absence of a fishery observer program or electronic monitoring system (Castrejón and Moreno, 2018). Additionally, the lack of a traceability system makes it impossible to determine whether tuna landings result from authorized fishing gear or illegal longlining.

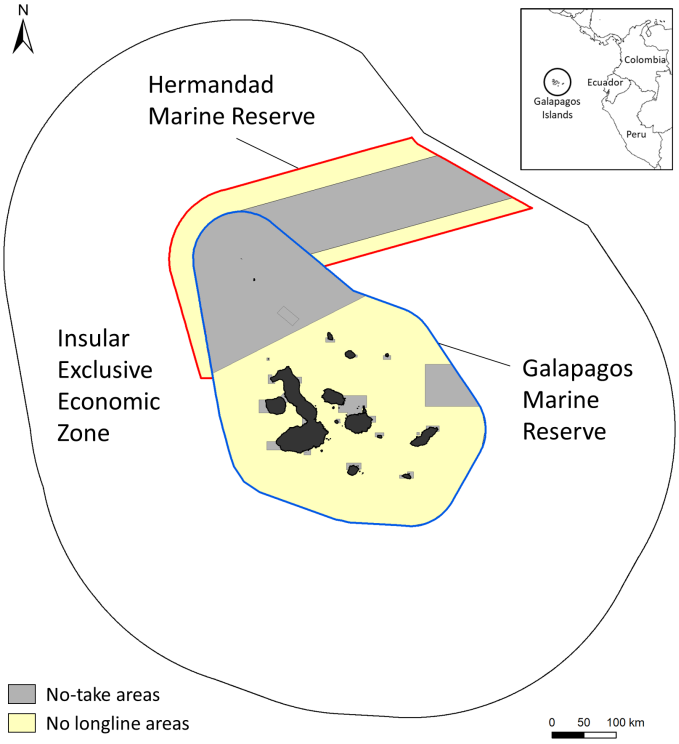

FIGURE 1
Galapagos Marine Reserve (blue line) and Hermandad Marine Reserve (red line) within the Insular Exclusive Economic Zone of Ecuador.

The longline ban was backed in 2005, based on Murillo et al. (2004), who assessed the impact of pelagic longlines in the GMR. According to this study, the bycatch percentage of ETP species ranges between 40% and 70% when using a pelagic longline at depths of 0-30 m. In contrast, Cerutti-Pereyra et al. (2020) evaluated the ecological impact of horizontal midwater longlines at depths greater than 30 m. In this study, yellowfin tuna made up 75% of the total catch, 16% was incidental catch (non-tuna species with commercial value and authorized extraction), and the remaining 9% was discarded (protected or commercially worthless species returned to the sea, alive or dead). Based on these results, Cerutti-Pereyra et al. (2020) indicate that longlining is unlikely to be sustainable in the GMR.

The debate regarding the longlining ban in the GMR remains unresolved, even in the face of global progress in science, technology, and innovative techniques to minimize bycatch. The phrase "longlining ban" can be deceptive as it implies an absolute restriction on all forms of longlining (bottom, pelagic, midwater, and vertical). Contrarily, vertical longlining is implicitly permitted by the GMR Fishing Regulation, under the local name "empate" (handline in English). This fishing method traces its origins in the Galapagos to the late 1940s (Reck, 1983). Initially used to catch groupers, it consists of a single vertical line with two baited hooks, anchored with a weight to maintain its vertical orientation. Over time, the number of hooks increased from two up to 12 or more (Castrejón M, pers. obs.). In consequence, the "empate" evolved into what Preston et al. (1998) describes as vertical longlining, although in most recent years, FAO labeled it as a vertical line (He et al., 2021). Modern fishers usually use "empates" to catch not only demersal finfish species, such as sailfin grouper (*Mycteroperca olfax*) and mottled scorpionfish (*Pontinus clemensi*), but also yellowfin, bigeye tuna and swordfish (*Xiphias gladius*).

The GMR Fishing Regulation defines "empate" as a reel connected to one or multiple short lines with a weight, stipulating that the hook's length should not exceed 70 mm. The regulation does not establish a limit on the number of hooks. This distinction is crucial in differentiating "empate" from vertical longline. Given the prohibition of pelagic and midwater longlining within the reserve, fishers developed a new fishing gear, locally known as "Empate oceánico de profundidad" (roughly translating to "Deep oceanic handline"). This fishing gear is set in oceanic waters at depths greater than 50 m, primarily to catch yellowfin and bigeye tuna. It comprises multiple vertical longlines, each set with three to five baited hooks (totaling 50 hooks), all connected by a single horizontal line (CTI, 2018). This connecting line lacks branch lines and baited hooks. Consequently, the mainline retains its vertical orientation, aligning with the FAO's categorization of a vertical line. Thus, while the GMR Fishing Regulation explicitly bans pelagic, midwater, and bottom longlining, it unintentionally allows vertical variations.

In 2016, the Governing Council of the Galapagos Special Regime (CGREG) approved a new research project to assess the impact of vertical and horizontal midwater longlining in the Galapagos small-scale tuna fishery (CTI, 2018). However, the completion of this study has been delayed for seven years due to a lack of financial and political support. As a result, the decision on

backing or repeal the longline ban has been postponed, making it one of the most contentious issues in the management of small-scale fisheries within the GMR (Castrejón and Defeo, 2023). In the meantime, as the debate continues without a comprehensive and feasible management strategy to tackle this contentious and polarizing fisheries management issue, illegal longlining continues across the reserve (Castrejón et al., 2021; Montaño, 2022).

2.2 Study design

This research utilized an 18-question online multiple-choice survey to evaluate Galapagos residents' perceptions and attitudes towards longline tuna fishing and its impact on ETP species in the GMR (see Supplementary Information). The survey also aimed to collect opinions on potential management strategies to address the Galapagos longline controversy. The order of multiple-choice options for opinion-based questions was randomized for each participant to mitigate potential order bias. This approach aimed to ensure that participants' responses were not influenced by the sequence of options. The survey was conducted in Spanish and aimed at gathering representative samples from Ecuadorian and foreign youth and adults interested or involved in marine conservation and sustainable fishing development in the Galapagos, Ecuador. To obtain a representative sample, we surveyed people working in different economic sectors, including tourism, NGO, public service, commerce, fishing, academy, among others.

We utilized SurveyMonkey, an online survey platform, to collect data for this study. The survey was disseminated within several community groups on Facebook and WhatsApp. These groups encompassed a diverse mix of stakeholders, such as naturalist guides, tourist entrepreneurs, fishers, decision-makers, scientists, and conservationist groups. Prominent among our distribution list were the "Frente Insular de la Reserva Marina de Galápagos" and "Realidades Galapagueñas," with memberships numbering 170 and 2200, respectively, at the time of the survey's implementation.

We also sent the survey to stakeholders from different governmental and non-governmental institutions with influence on public opinion and decision-making regarding the longline controversy, including representatives from the fishing, NGO, tourism, and transport sectors, who were encouraged to participate and share the survey with their contacts. Participants could access and share the survey through a unique link and QR code. To prevent repeated submissions from a single participant, the survey was configured to disallow further responses once it was completed. Before launching the full survey, we conducted a pilot test with a small group of residents to enhance the quality of the survey, reduce interpretation errors, and ensure that the collected data were both valid and reliable. Without this step, researchers run the risk of gathering inaccurate or misleading data, which could lead to incorrect conclusions and misguided recommendations.

The survey was available from April 11th to May 30th, 2022. Participants were informed that their participation was voluntary and anonymous. They were given the liberty to omit any questions they preferred not to answer or to exit the survey at their convenience. The survey consisted of four sections:

1. Demographic information: We gather information about age, migratory status, and economic sector. Participants who did not define their migratory status and who only completed demographic questions without responding to the rest of the survey were removed from our analysis.
2. Understanding of longlining: We assessed participants' familiarity with different types of longlines (Figure 2) and associated regulations. Participants were also asked about their perceptions of vertical longlining within the GMR.
3. Ecological impact of longline tuna fishing on ETP species: Participants were asked to choose the image that best depicted the ecological impact of longlining in the GMR, with options including a media-based image (Figure 3A) and a science-based image (Figure 3B). The media-based image was derived from a commonly shared visual by NGO and conservationist groups on social media. The intent behind using this media-based image was to represent the

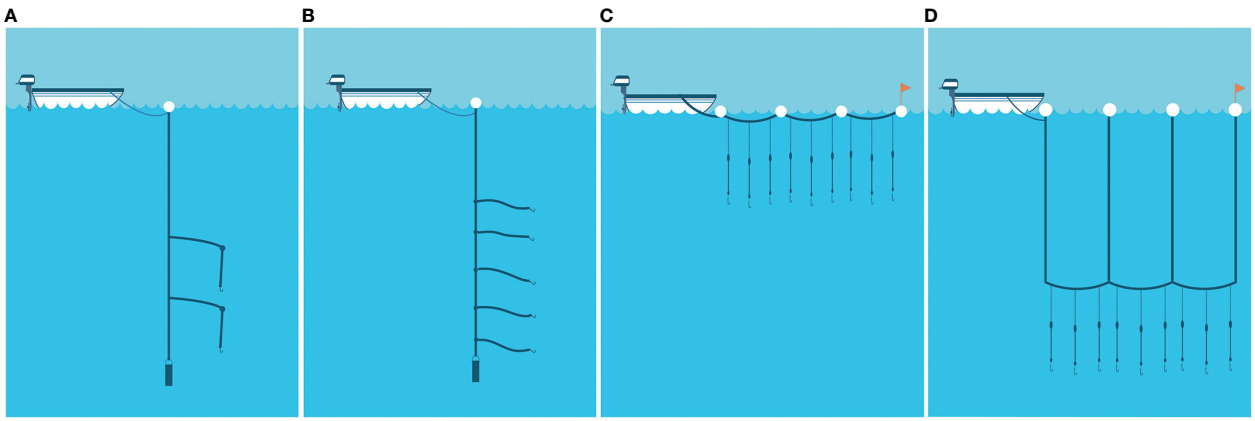

FIGURE 2
Types of longlines: **(A)** handline, locally known as "empate" (Reck, 1983); **(B)** vertical longline; **(C)** pelagic longline; and **(D)** midwater longline.

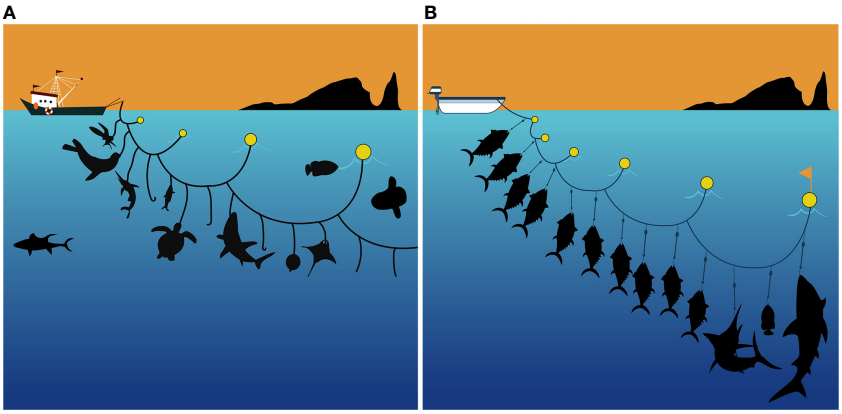

FIGURE 3
Environmental impact of longlining inside the Galapagos Marine Reserve. **(A)** media-based representation of a common image shared on social media by NGO and conservationist groups; **(B)** science-based representation of **(A)**, based on Cerutti-Pereyra et al. (2020). This study found that 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).

prevalent narrative of these organizations regarding the Galapagos longline controversy. The graphics depicted in Figure 3A are not grounded in a specific scientific investigation since the visuals lack any direct references, as seen in Byrne (2020); FIRMG (2021), and Pacífico Libre (2021). Therefore, our assumption is that these visuals were crafted based on individual experiences, beliefs, or institutional positions on the matter of longlining in the GMR. In contrast, the science-based image (Figure 3B) was based on the findings of Cerutti-Pereyra et al. (2020). All figures in the survey were presented simultaneously. This section also investigated participants' perceptions of bycatch of ETP species in longlining. They were then presented with the findings from Murillo et al. (2004) and Cerutti-Pereyra et al. (2020) and asked to rate the impact of bycatch on ETP species as very high, high, adequate, low, or very low. They were also asked their opinion on acceptable bycatch percentages for authorizing regulated midwater longline use in the Galapagos. The survey included the options "Insufficient information to comment," "Other," and "No type of longline should be allowed in the Galapagos, even if the percentage is 0%" The last option aimed to estimate the percentage of participants who may oppose longlining by conviction, even if the impact on ETP species is minimal or negligible.

4. People's attitudes to management approaches: We evaluated participants' attitudes on various management approaches for the Galapagos small-scale tuna fishery. To evaluate the level of trust Galapagos residents have in scientific data as a foundation for decision-making, we asked whether they believed decisions regarding longlining should be based on rigorous, impartial, and comprehensive scientific information. They were also asked about the reasons artisanal fishers advocate for the use of midwater longlining. Lastly, we asked participants what decision they would make regarding the prohibition or regulated use of longlining in the GMR if they were the Minister of the Environment, Water, and Ecological Transition of Ecuador. Eleven management strategies were provided for selection, ranging from a complete ban on all types of longlines to authorizing pelagic and midwater longlines in the reserve. The option "Other" was also provided to allow participants to propose their solutions.

2.3 Data analysis techniques

Pearson's chi-square (χ^2) tests were conducted to assess differences among participants' perceptions and opinions. Contingency tables were created for multiple-choice questions, and the Marascuilo procedure (Marascuilo, 1966) was used for *post hoc* pairwise comparisons. This method adjusts the critical value for multiple comparisons to control for Type I errors. A 95% confidence level was applied for determining statistical significance. Analyses were performed using the chisq.test and MarascuiloTest functions from the base R package version 4.2.3 (R Core Team, 2023) and the DescTools package (Signorell, 2023), respectively.

Monte Carlo simulation-based tests were used to assess the relationship between demographic factors (Migratory status, Age, and Economic Sector) and participants' opinions on longlining regulation in the GMR. We ran 10,000 simulations using the independence_test function from the "coin" package (Hothorn et al., 2008). Due to the low number of observations (<5) in some categories of the Economic sector, we combined them with the "Other" category, ensuring that each category had at least five observations for the analysis. This addressed the issue of data imbalance, increasing the sample size per category and improving the reliability of the analyses.

3 Results

3.1 Demographic profile of participants

A total of 294 participants were recorded in SurveyMonkey. Out of this, we analyzed 156 responses (53% of the total) from permanent and temporary residents of the Galapagos Province. Responses from tourists and individuals under the age of 18 were excluded due to their low representation in the sample. Our sample considers an economically active population of 21 637 people from the Galapagos Province (total population: 33 042 people), based on the most recent projection of the National Institute of Statistics and Census (INEC, 2022). The margin of error for individual questions ranged between 8% and 9% at a 95% confidence level, as some participants opted not to answer specific questions. Most participants (84%) were permanent residents, with 64% aged between 31 and 50 years old (Table 1). Approximately 28% and 13.5% of participants were employed in the tourism and NGO sectors, respectively, while 12% worked across various sectors and 6% were involved in the small-scale fishing sector. Only 4.5% of respondents were jobless at the time of the survey (Table 1).

TABLE 1 Demographic profile of online survey respondents.

Factor	Variable	N = 156	%
Age	19-30	19	12.2
	31-40	55	35.3
	41-50	45	28.8
	51-65	31	19.9
	> 65	6	3.8
Location	Galapagos Province	155	100.0
	Unknown	1	
Migratory status	Permanent resident	131	84.0
	Temporary resident	25	16.0
Economic sector	Student	6	3.8
	Tourism	44	28.2
	NGO	21	13.5
	Commerce	12	7.7
	Public service	12	7.7
	Construction*	2	1.3
	Multisectoral	20	12.8
	Academy	7	4.5
	Agriculture*	2	1.3
	Fishing	9	5.8
	Transport*	1	0.6
	Industry*	1	0.6
	Jobless	7	4.5
	Other	12	7.7

*Indicates categories that were combined with the "Other" category to address data imbalance and conduct a Monte Carlo simulation-based analysis.

3.2 Perceptions of longline tuna fishing

Most participants (94%) were familiar with the term longline (χ^2 = 122.1; p-value < 0.005; df = 1). Participants' understanding of what a longline look like also varied significantly (χ^2 = 222.3; p-value < 0.005; df = 5). While 13% mistakenly confused a longline with a handline (Figure 4A), 67% correctly identified the images of pelagic and midwater longlines. Only 20% recognized vertical longlines, and less than 1% did not know which image represented a longline (Figure 4A). Perceptions significantly differed between most fishing gears, except between handlines and vertical longlines (Table S1).

Participants significantly disagreed on the best way to represent the ecological impact of longlining (χ^2 = 130.3; p-value < 0.005; df = 3). Most participants (57%) selected the media-based image, while 36% selected the science-based image (Figure 4B). The difference in perceptions between both images was statistically significant (Table S2). Additionally, the proportion of respondents who chose the media-based and science-based images was significantly different than those participants who considered that neither image accurately portrayed the impact of longlining on ETP species (Table S2).

Around 35% of participants correctly identified all statements about longlining as true (Table 2). Nevertheless, there were prevalent misconceptions. Over 80% of participants believed there are no sustainable longline tuna fisheries or longlining being prohibited in MPA (Table 2). Furthermore, 12% of participants held the notion that longline fishing cannot accidentally catch ETP species, which could then be discarded, dead or alive. Over 90% were aware that longlines can be set up horizontally or vertically, while 96% correctly recognized the definition of longline (Table 2).

Misconceptions were also revealed regarding handline and vertical longline. In the context of the Galapagos, about 41% of participants thought vertical longlining is banned, 26% mistakenly assumed fishers exclusively use handlines to catch demersal finfish species, and 13% wrongly believed that the Galapagos fishing regulations define a maximum number of hooks for handlines (Table 3). Nevertheless, only 8% and 6% of participants incorrectly disagreed with the given definition of a handline and vertical longline, respectively. Lastly, about 7% of participants thought that fishers did not use up to 12 hooks to capture demersal finfish species (Table 3).

3.3 Perceptions on the impact of tuna longlining on ETP species

Participants displayed significant disagreements on bycatch rates attributed to tuna longlining in the GMR (χ2 = 29.6; p-value < 0.005; df = 6). While 30% estimated bycatch of ETP species at 10% or less, 56% expected it to range between 11% and over 50% (Table 4). Around 15% were unsure about longlining's ecological impact (Table 4). The proportion of respondents who estimated

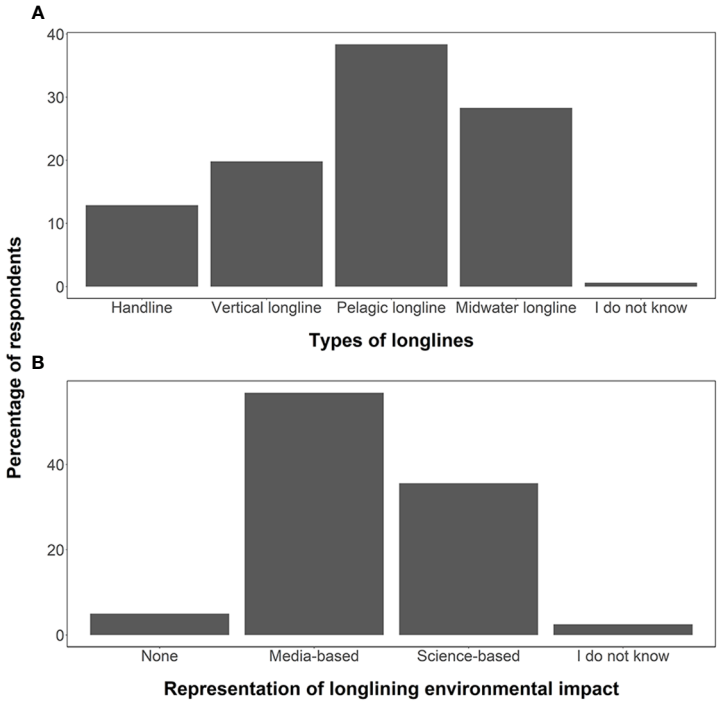

FIGURE 4
Responses to the following questions: **(A)** Which of the following figures depict a longline? (Select all that apply), n = 143; **(B)** Which figure best represents the environmental impact of longlining? n= 142.

that bycatch of ETP species ranged between 0 and 10% was significantly higher than those who estimated it ranged between 21 and 50% (Table S3). No significant differences were found in the other comparisons of ETP species bycatch categories (Table S3).

This divergence in opinions on bycatch estimation was also significant when participants were presented with the bycatch findings from Murillo et al. (2004) ($\chi 2$ = 227.4; p-value < 0.005; df = 5) and Cerutti-Pereyra et al. (2020) ($\chi 2$ = 13.8; p-value < 0.05; df = 5). Most participants (75%) found the 40-70% ETP species bycatch estimation by Murillo et al. (2004) to be Very high or High (Figure 5A), while nearly half (45%) held similar views for the 9% ETP species bycatch estimation by Cerutti-Pereyra et al. (2020) (Figure 5B). The proportion of participants who perceived the bycatch percentage of ETP species estimated by Murillo et al. (2004) as Very high was significantly higher than all other response options (Table S4), while the proportion of respondents who rated the ETP species bycatch estimation by Cerutti-Pereyra et al. (2020) as Low was significantly lower than those who rated it as High (Table S5). There were no other significant differences between the response options (Table S5).

TABLE 2 Responses to the following question: What statement is false?

Statements	N= 132	%	Correct answer
All statements are true.	46	34.8	True
There are longline tuna fisheries that have been certified as sustainable.	26	19.7	True
There are marine protected areas where the use of longlines is authorized.	25	18.9	True
A longline can accidentally capture endangered, threatened, or protected species, such as sharks, manta rays, turtles, birds, and sea lions, among others, which can be released dead or alive.	16	12.1	True
Depending on its orientation, a longline can be horizontal or vertical.	11	8.3	True
A longline is a mainline to which secondary lines are connected, each with a hook and bait distributed at regular intervals.	5	3.8	True
Depending on the depth of capture, a longline can be pelagic or superficial, midwater or bottom.	2	1.5	True
A longline can be used to catch tuna, swordfish, billfish, mahi-mahi, or even sharks.	1	0.8	True

Approximately, 7% of participants considered the ETP species bycatch percentage estimated by Murillo et al. (2004) as adequate (Figure 5A), while 17% shared the same perception for the estimation reported by Cerutti-Pereyra et al. (2020) (Figure 5B). In contrast, only 4% of participants rated the bycatch percentage estimated by Murillo et al. (2004) as very low or low (Figure 5A), while this increased to 20% for the estimation by Cerutti-Pereyra et al. (2020) (Figure 5B). Additionally, the proportion of participants who expressed they were unable to provide a well-informed perspective due to insufficient information varied between 14% and 18% for the bycatch estimations from Murillo et al. (2004) and Cerutti-Pereyra et al. (2020), respectively (Figures 5A, B). Notably, the proportion of participants who selected this opinion was significantly higher than those who opted for Low and Very low when considering the ETP species bycatch estimation reported by Murillo et al. (2004) (Table S4).

Opinions regarding the acceptable percentage of ETP species bycatch for regulated use of midwater longlines in the GMR also varied significantly (χ^2 = 125.5; p-value < 0.005; df = 7). Participants showed strong preference for minimal bycatch of ETP species, with 40% believing that only up to a 2% bycatch rate of ETP species would be acceptable, while 22% believed that bycatch rate should range from 3% to 10% (Table 5). Nevertheless, a significant 26% took a stricter position, asserting that no form of longlining should be permitted in the Galapagos, regardless of the bycatch percentage (Table 5). Only 3% believed that the acceptable percentage of ETP species bycatch should be higher than 10%, while 6% of participants indicated they were unable to provide a well-informed response due to insufficient information (Table 5). Participants who selected the 0-2% and No type of longline should be allowed in the Galapagos, even if the percentage is 0% options were significantly different from most categories (Table S6).

3.4 Attitudes toward the management and regulation of longline tuna fishing

Our findings also indicate that participants are aware of the primary reasons small-scale fishers advocate for midwater longlining in the GMR, with significant differences in their opinions (χ2 = 73.9; p-value < 0.005; df = 6). Most participants (29%) recognized that fisher's primary motivation for supporting midwater longlining is its efficiency in capturing adult tuna (Figure 6A). This proportion was significantly higher than the remaining categories (Table S7), except for the proportion of respondents who believed that midwater longline ban violates fishers' right to work (24%) and those who believed that midwater longline helps fishers to capture tuna of greater size and quality, and to reduce incidental catch of protected species (16%, Figure 6A). In contrast, 11% of respondents think fishers advocate for longlining primarily due to their reluctance to follow regulations, while less than 6% were unaware of the reasons advocated by small-scale fishers. Only 5% believe they support midwater longlining in the reserve with the aim of catching sharks (Figure 6A).

After being informed that scientific and anecdotic evidence (Reyes and Murillo, 2007; Castrejón et al., 2021; Montaño, 2022) indicates that illegal longlining persists in the GMR, despite the sophisticated control and surveillance system of the GNPD, participants' opinions varied significantly (χ^2 = 38.9; p-value < 0.005; df = 5). About 25% of participants considered that the Ecuadorian government should improve control and surveillance of the GMR, while a similar percentage suggested evaluating the selectivity and profitability of new fishing gears and methods (Figure 6B). Approximately 19% of participants believed that even if the longline ban cannot be enforced, it should not be authorized in the reserve. Similarly, around 16% believed in testing various operational, regulatory, technological, and market-based solutions to mitigate the bycatch of ETP species, while about 14% believed in regulating the use of longlining with strict management measures (Figure 6B). Less than 3% of participants proposed alternative solutions (Figure 6B), which was the only opinion that was significantly lower than the other categories (Table S8).

A significant majority of participants (84%) agreed that the decision to ban regulated longline use in the GMR should be based on rigorous, impartial, and comprehensive scientific data (χ^2 = 216.5; p-value < 0.005; df = 3). This response differed significantly from other categories (Table S9). The chi-square test also revealed significant differences in participants' opinions on management strategies they would implement to address the Galapagos longline controversy if they were the Minister of the Environment, Water, and Ecological Transition of Ecuador (χ^2 = 132.6; p-value < 0.005; df = 10). Participants showed a significantly higher preference for exploring new bycatch mitigation methods, selective fishing gear, and electronic monitoring and traceability systems (19%), supporting fishers to obtain access to fair markets (18%), and

TABLE 3 Responses to the following question: What statement is false?

Statements	N= 120	%	Correct answer
The Galapagos fishing regulations implicitly authorize the use of vertical longlining in the Galapagos.	49	40.8	True
Galapagos fishers use only the handline to catch grouper and scorpionfish.	31	25.8	False
The Galapagos fishing regulations do not define the maximum number of hooks that a handline can have.	15	12.5	True
The handline is a fishing gear consisting of a vertical line and two baited hooks.	10	8.3	True
Galapagos fishers use one to twelve hooks to catch grouper or cod, scorpionfish, and other fish.	8	6.7	True
Vertical longline is a vertical line with three or more baited hooks.	7	5.8	True

TABLE 4 Responses to the following question: Suppose a fisher using a longline to catch tuna within the Galapagos Marine Reserve accidentally catch other species.

Number of individuals	N= 122	%
0-10	36	29.5
11-20	20	16.4
21-30	13	10.7
31-40	8	6.6
41-50	10	8.2
> 50	17	13.9
I do not know	18	14.8

If the total catch were 100 individuals, including tunas and other species, what would be the estimated number of protected species, such as sharks, mantas, turtles, and seabirds, that might be among bycatch?.

relying on scientific data for decision-making (14%) (Figure 7 and Table S10). A comparable proportion of participants (12%) either advocated for prohibiting all forms of longlines in the GMR, inclusive of vertical ones, or proposed that the tourism sector should pay a higher price for longline-free tuna —i.e., tuna harvested exclusively with authorized fishing methods like trolling, handline, or reel (Figure 7). In contrast, the three least popular options among the respondents included the ratification of the pelagic longline ban coupled with the authorization of midwater longlining under stringent management measures (3%), alternative solutions (2%), and the prohibition of all types of longlines in the GMR, except for vertical longlines (2%) (Figure 7).

3.5 Influence of demographic factors on perceptions and attitudes

The perspectives on how the Ecuadorian government should address the longline controversy varied among participants (Figure 8). Even though certain perspectives were more prevalent within demographic groups, our findings indicate that there is no widespread agreement among participants on the most effective strategy to address this complex socioecological issue. Furthermore, participants' perspectives were not systematically influenced by the demographic factors examined in this study (age, migratory status, and economic sector). Monte Carlo simulation-based tests did not detect a significant association between Age ($p = 0.7$) or Migratory Status ($p = 0.4$) and the opinions expressed by the participants. Only a marginally non-significant association was observed between Economic Sector and participants' opinions ($p = 0.07$). These results indicate that variation in perspectives among participants can arise due to a wide range of factors other than the demographic variables considered in the study.

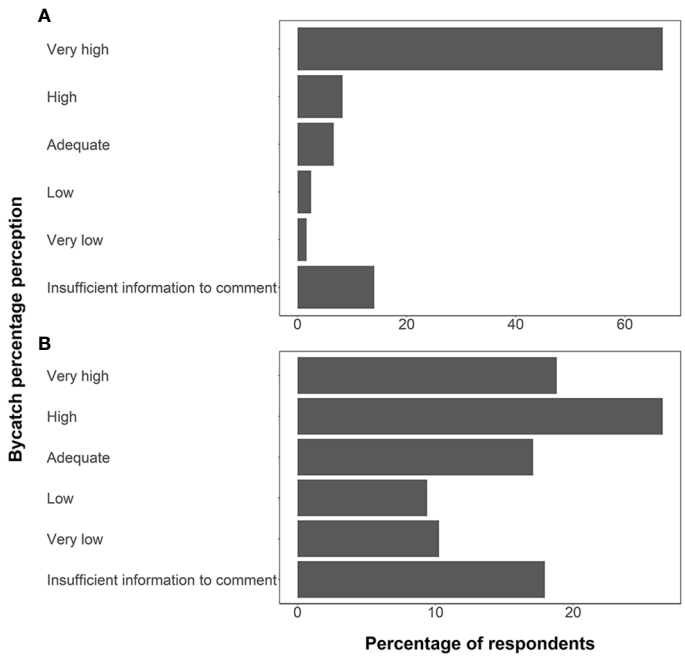

FIGURE 5
Percentage of responses to the following questions: **(A)** A study published by the Charles Darwin Foundation in 2004 found that when a pelagic longline is used in the Galapagos Marine Reserve at a depth of 0-30 meters, the percentage of bycatch of protected species varies between 40% and 70%. This means that out of 100 individuals of various species caught, an estimated 40 to 70 individuals would be protected species, such as sharks, mantas, or turtles. What do you think of this percentage? n = 121; **(B)** According to a study published in the journal Ocean and Coastal Management in 2020, conducted by the Charles Darwin Foundation, National Geographic's Pristine Seas, and the Galapagos National Park Directorate, the use of midwater longlines within the reserve at a depth of 50 meters or greater reduced the percentage of incidental capture of protected species to 9%. This means that out of 100 individuals of various species caught, an estimated nine individuals would be protected species such as sharks, mantas, or marine turtles. What do you think of this percentage? n = 117.

TABLE 5 Responses to the following question: According to scientific research, the percentage of bycatch of protected species generated by midwater longlines can be reduced to less than 9% through a combination of operational changes, technology, market incentives, and regulations.

Number of individuals	N= 117	%
0-2%	47	40.2
3-5%	18	15.4
6-8%	6	5.1
8-10%	2	1.7
10-12%	4	3.4
No type of longline should be allowed in the Galapagos, even if the percentage is 0%	30	25.6
I do not have enough information to judge whether this percentage is high or low	7	6.0
Other	3	2.6

If such a reduction was achieved, what percentage of catches of protected species do you believe would be adequate to authorize the regulated use of midwater longlines in the Galapagos?

Most permanent (18%) and temporary (24%) residents supported investigating new bycatch mitigation methods, selective fishing gears, and electronic monitoring and traceability systems (Figure 8A). Both groups also favored assisting fishers in accessing fair markets (17% for permanent residents and 22% for temporary residents). Additionally, 13% of permanent and 15.5% of temporary residents agreed that decisions should be based on existing scientific research. Conversely, 13% of permanent residents believed all types of longlines should be banned in Galapagos, while only 4% of temporary residents held this opinion (Figure 8A).

Age groups exhibited both similar and divergent perspectives (Figure 8B). The 30-40 and 51-65 age groups showed the highest percentage of respondents (25% and 18%, respectively) in favor of investigating new bycatch mitigation methods, selective fishing gears, and electronic monitoring and traceability systems. However, 18% of those participants between 51 and 65 years old also advocated for banning all types of longlines in Galapagos (Figure 8B). In contrast, most respondents in the 30-40 (18%) and >65 (22%) age groups supported assisting fishers in gaining fair market access, while most in the 19-30 age group (22%) advocated for decision-making based on existing scientific studies (Figure 8B).

Within each economic sector, the survey revealed a variety of perspectives on management strategies (Figure 8C). Jobless and Academic sectors were represented by 31% and 26% of participants, respectively, who supported investigating new bycatch mitigation methods, selective fishing gears, and electronic monitoring and traceability systems. This perspective was shared by most respondents in the Other category (26%), which included participants from agriculture, construction, transportation, industry, and other economic sectors (Figure 8C).

A second group of Academic participants (26%) also supported assisting fishers in accessing fair markets, as did most participants from the Multisectoral (20%) and NGO sectors (18%). In contrast, the Commerce sector had the highest proportion of respondents (29%) who believed that purchasing fishing licenses or offering experiential fishing permits were the most viable alternatives (Figure 8C).

In the Fishing sector, most respondents (27%) supported authorizing pelagic and midwater longlining in the GMR (Figure 8C). In contrast, most Tourism sector participants (23%) advocated for banning all types of longlines in the Galapagos. Most participants from the Public Service sector (29%) took a moderate position, favoring the pelagic longline ban and continued research on midwater longlining to assess new bycatch mitigation measures before making a decision. This perspective was also supported by most participants in the Students category (20%), who similarly favored basing decisions on existing scientific research (Figure 8C).

4 Discussion

4.1 Perceptions and attitudes toward longline fishing

This study provides insights into the broader debate on the management of longline fishing and the conservation of ETP species in multiple-use MPA, including shark sanctuaries. Our findings reveal notable misconceptions among Galapagos residents concerning longlining. Some participants confused longlines with handlines, and some struggled to differentiate between horizontal and vertical longlines. This technical knowledge gap suggests inadequate communication and outreach efforts, highlighting the need to better educate Galapagos residents about the differences among different longlining modalities. Without this understanding, there is a risk of forming misguided perceptions about the ecological impact of different fishing gears and potentially advocating for inadequate policy measures.

We found that 80% of participants expressed that no longline tuna fisheries are certified as sustainable, while a similar proportion believed that longlining is universally banned in MPA. Contrary to these beliefs, as of May 18th, 2023, 27 longline fisheries have been certified as sustainable by the Marine Stewardship Council, with another 15 under assessment (MSC, 2023). Furthermore, although the 17 global shark sanctuaries, serving as specialized Large Marine Protected Areas (LMPA), prohibit shark fishing and trading, many still allow longline tuna and billfish fisheries (Ward-Paige, 2017; Shea et al., 2023). According to Shea et al. (2023), who evaluated eight out of 17 existing sanctuaries, shark mortality produced by longline fisheries varied drastically, from 600 in Samoa to 36,256 in the Federated States of Micronesia. Mortality rates in these sanctuaries reached up to 5% of sustainable levels for blue sharks (*Prionace glauca*), and 40% for silky sharks (*Carcharhinus falciformis*). Only two of the eight shark sanctuaries examined exceeded sustainable mortality rates for silky sharks, pointing to an urgent need for enhanced stock assessments and bycatch mitigation. Thus, while concerns about longlining impact on certain shark species are valid, it is incorrect to label all longline fisheries in shark sanctuaries, or multiple use MPA, as

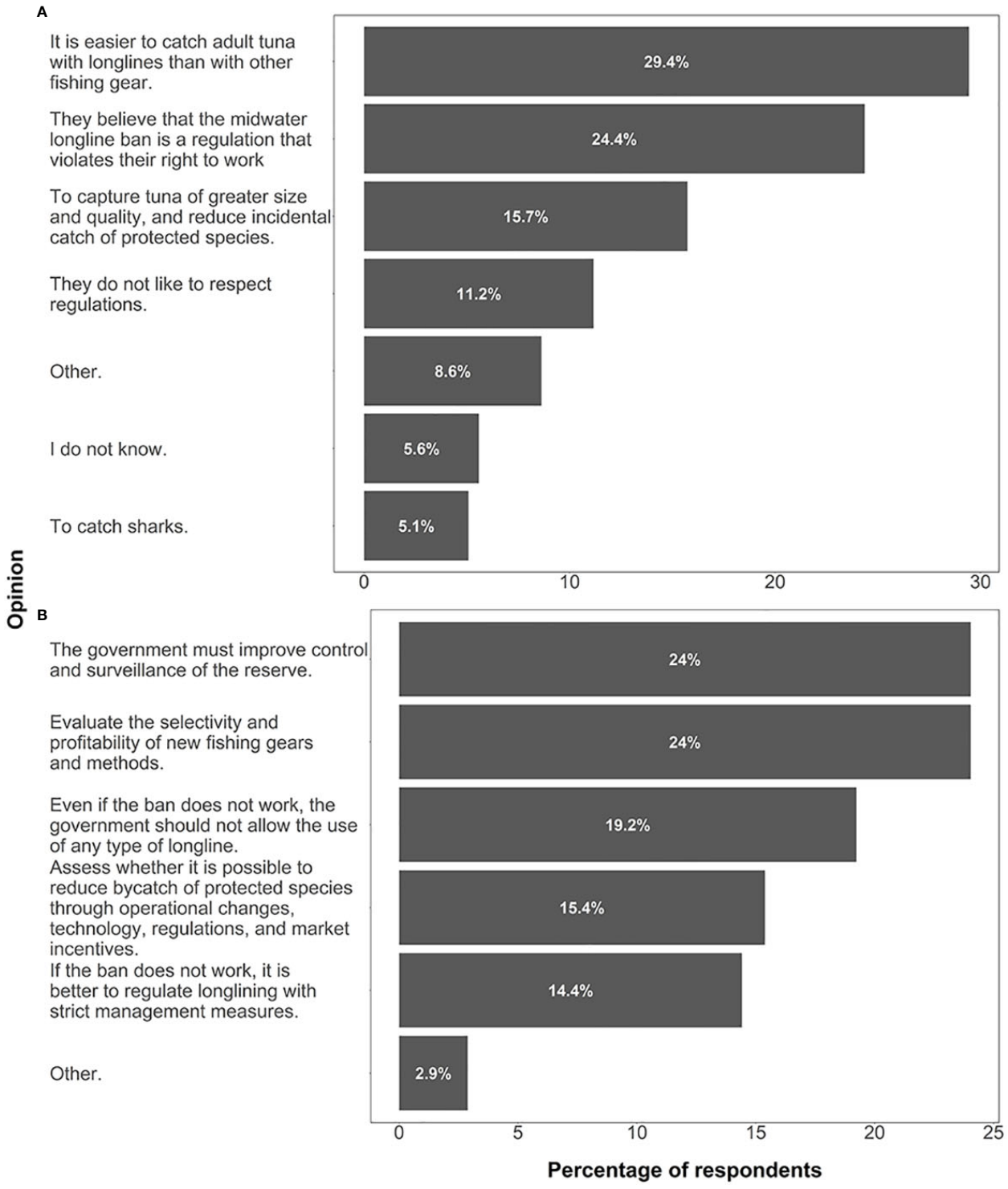

FIGURE 6
Percentage of responses to the following questions: **(A)** What do you think are the reasons why artisanal fishers in the Galapagos are advocating for the use of midwater longlining within the reserve? (Select all that apply), n = 116; **(B)** Despite the prohibition of pelagic and mid-water longlines in the Galapagos Marine Reserve since 2000, scientific and anecdotal evidence suggests that this fishing gear continues to be used illegally. This is concerning, given that the Galapagos National Park Directorate has one of the most sophisticated control and surveillance systems in the Eastern Tropical Pacific. What is your opinion on this issue? (Select the options that reflect your opinion), n = 116.

unsustainable (Simpfendorfer and Dulvy, 2017). The takeaway from this discussion is that most fishing gears have the potential to be environmentally sustainable, even those scrutinized by advocacy groups, as long as they are well-managed (Hilborn et al., 2023). Thus, our findings emphasize the need to rectify common misconceptions about longline fisheries' sustainability. This can be achieved through communication and education campaigns, facilitating an informed debate on longlining in Galapagos.

Significant disparities also exist among participants' perceptions regarding bycatch rates attributed to tuna longlining in the GMR. Participants' perceptions about acceptable levels of bycatch of ETP species are not necessarily indicative of education or knowledge gaps. Instead, they might be rooted in participants' value judgment. Differing views on bycatch rates could stem from personal experiences, scientific or anecdotal information, or media coverage that might not accurately represent available scientific information regarding the ecological impact of different types of longlines. These findings reiterate the need of putting in place effective communication and education campaigns to transmit the most recent scientific findings to Galapagos residents, so they are aware that the ecological impact of small-scale longlining on ETP species can be significantly reduced through modification of fishing gears and other types of bycatch mitigation methods, as suggested by local (CTI, 2018; Cerutti-Pereyra et al., 2020) and international studies (Gjertsen et al., 2010; Clarke et al., 2014; Hall et al., 2017; Swimmer et al., 2020).

The debate surrounding the acceptable bycatch of ETP species to authorize longlining in the GMR has persisted for over two decades. A significant gap in the legal framework is the absence of scientific benchmarks to guide the regulation of fishing gears in the GMR. This inconsistency is evident when comparing the legal status of certain fishing gears. While gillnets, internationally renowned for their relatively lower selectivity (Chuenpagdee et al., 2003; Alfaro-Shigueto et al., 2010), are authorized by the GMR Fishing

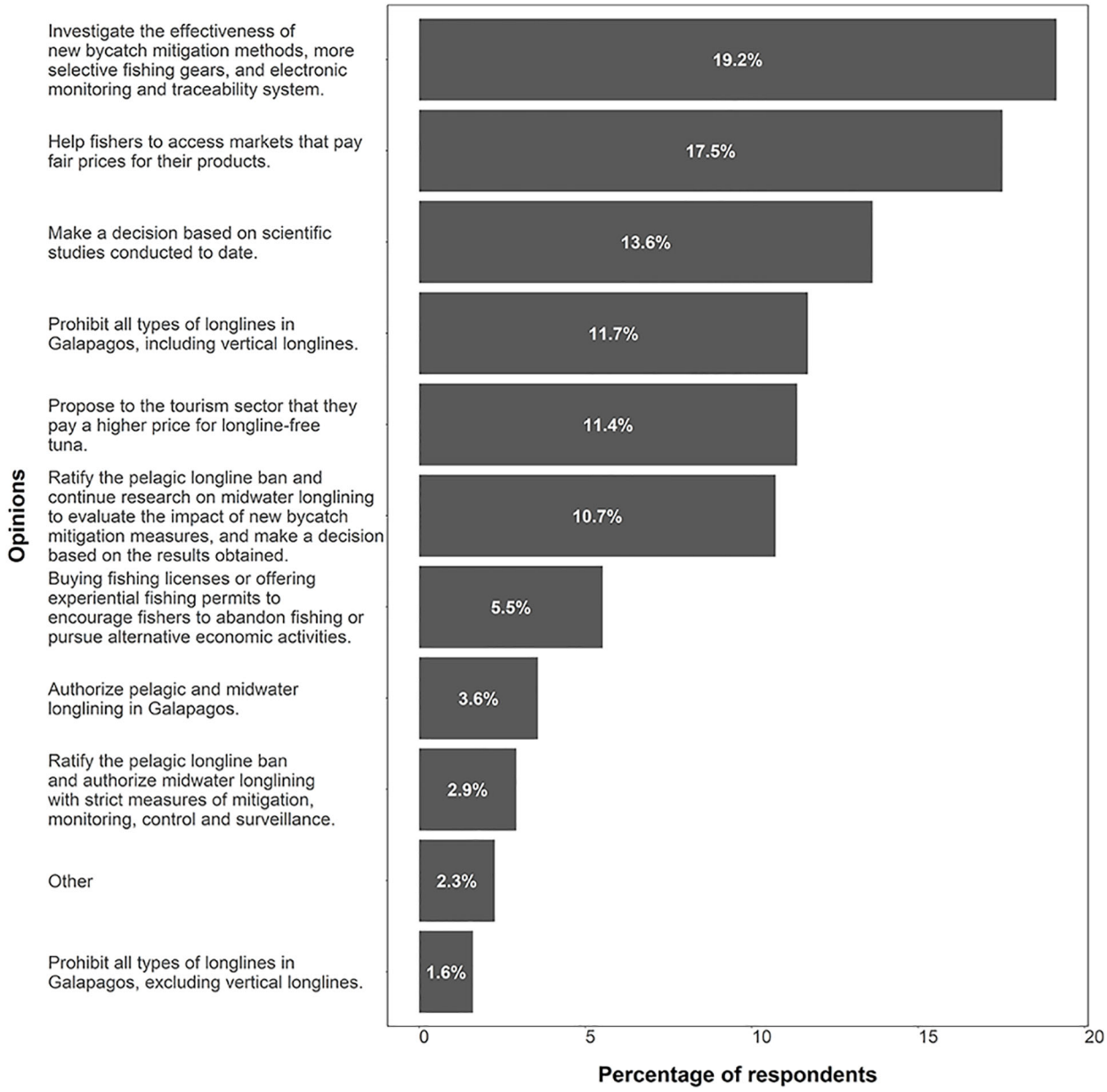

FIGURE 7
Percentage of responses to the question: If you were the Minister of the Environment, Water, and Ecological Transition of Ecuador, what would be your decision regarding the prohibition or regulated use of longlining in the Galapagos Marine Reserve? (Select all that apply.), n = 114.

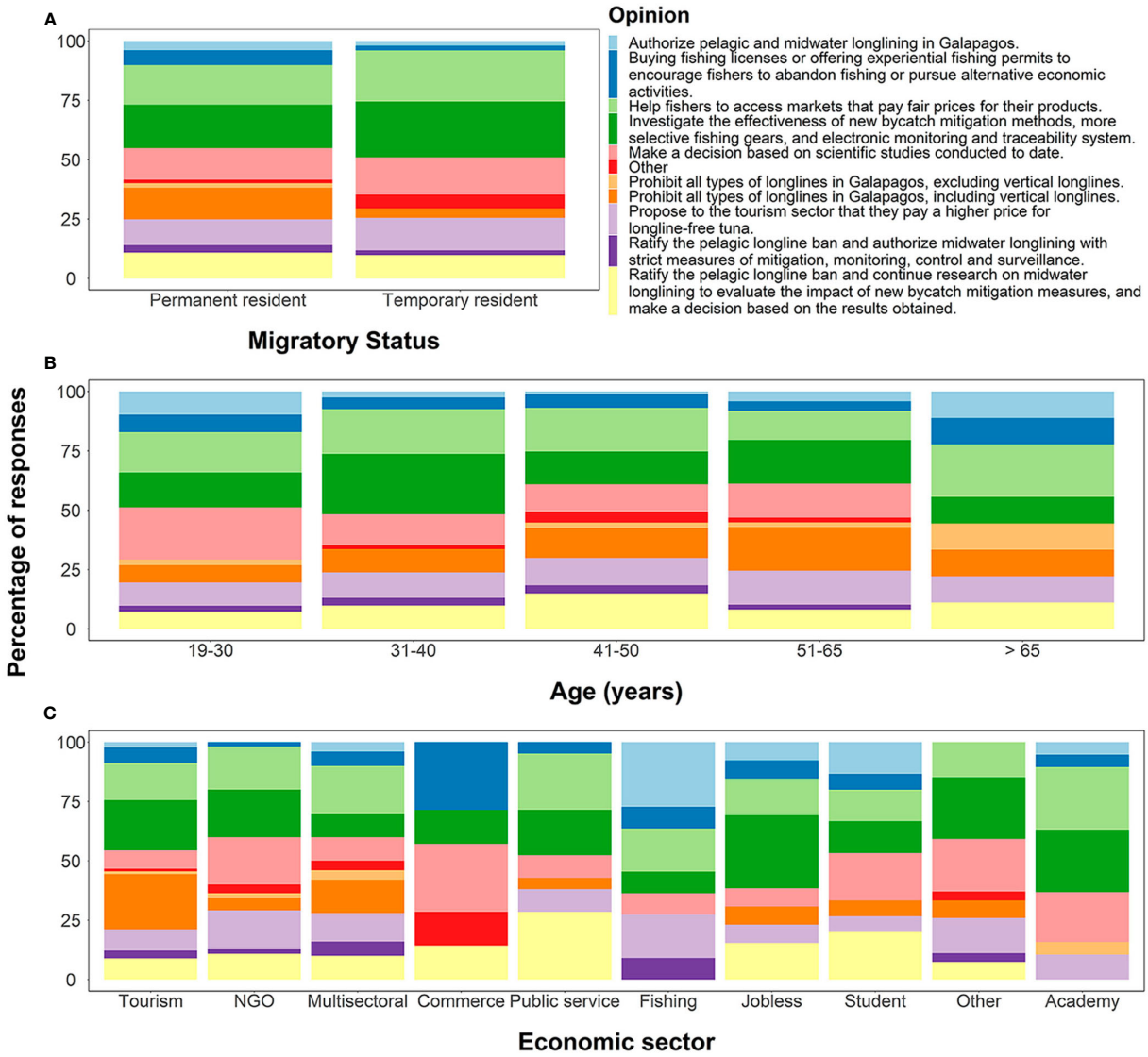

FIGURE 8
Percentage of responses to the question: If you were the Minister of the Environment, Water, and Ecological Transition of Ecuador, what would be your decision regarding the prohibition or regulated use of longlining in the Galapagos Marine Reserve? (Select all that apply.). Responses are shown by: **(A)** migratory status; **(B)** age; and **(C)** economic sector, n = 114.

Regulation, other more selective methods like harpoons are forbidden. Gillnets, for instance, have been found to incidentally catch juvenile blacktip sharks up to 25% of the total catch (Llerena et al., 2015). In contrast, Cerutti-Pereyra et al. (2020) found that the bycatch of blacktip sharks, the main ETP species impacted by horizontal midwater longlining, is below 2%. Based on these results, Llerena et al. (2015) recommended declaring sharks' nursery grounds as no-take zones, while Cerutti-Pereyra et al. (2020) advocated for continuing prohibiting midwater longline across the GMR to prevent the incidental catch of ETP species. The comparison of the different recommendations derived from both studies highlights the inconsistency in management recommendations regarding fishing gears regulations in the GMR, based on their ecological impact. This example highlights the imperative need for a comprehensive evaluation of the ecological impact of the diverse fishing gears used in the Galapagos' small-scale fisheries to inform and harmonize management decisions.

The percentage of incidental catch and discard of ETP species is a valuable performance indicator to determine the ecological impact of longlining. Yet, even more relevant is the magnitude of incidental catch and its relationship with biological reference points, associated to the biomass or population size of the most vulnerable ETP species affected by longlining (Alfaro-Shigueto et al., 2010; Shea et al., 2023). This is particularly relevant in the context of the Galapagos, where the main species affected by longlining are sharks (Murillo et al., 2004; Cerutti-Pereyra et al., 2020), as occurs in the rest of Ecuador (Martínez-Ortiz et al., 2015) and the world (Clarke et al., 2014). Unfortunately, the data-poor nature of small-scale fisheries and the migratory nature of sharks make it a difficult task to assess their stock status through

conventional assessment methodologies (IATCC, 2022; Shea et al., 2023).

In consequence, Galapagos management authorities lack biological reference points to set a bycatch threshold for ETP species. To address this challenge, the GNPD and fishing sector agreed upon to set a 10% bycatch threshold (in individuals) (Cerutti-Pereyra et al., 2020). While this threshold emerged from negotiation rather than science, it aligns closely with the shark bycatch rates reported by Wang et al. (2021) for longline operations in the Pacific Ocean. In this region, shark bycatch comprises 7.3% of the total individual catch, a figure slightly lower than the 8.5% of sharks and rays' bycatch (in individuals) reported by Martínez-Ortiz et al. (2015) for the pelagic longline and surface gillnet operations within the Exclusive Economic Zone of Ecuador (excluding the GMR). The intention of the GNPD was to use the 10% bycatch threshold to decide if midwater longlining would be authorized in the GMR, based on the research project's results described by Cerutti-Pereyra et al. (2020). However, data generated by this project were analyzed and interpreted through different scientific criteria, resulting in bycatch percentages ranging from 9% to 11% (COPROPAG, 2014; Reyes et al., 2014; CTI, 2015). This variability arises from the Galapagos legal framework's inadequate definition of bycatch, leading scientists to apply different criteria to classify catch composition. Consequently, bycatch percentages fluctuated around the agreed threshold, causing further contention. Recognizing these inconsistences, the Governing Council of the Galapagos Special Regime (CGREG) approved a new research project in 2016 to assess the impact of vertical and horizontal midwater longlining in the GMR (CTI, 2018). However, this research initiative has been hindered by funding constraints and political hesitations, leaving the controversial debate on Galapagos longlining unresolved.

Our research indicates that 62% of Galapagos residents might support a bycatch threshold for ETP species under 10%. We assume that this will occur as long as there is rigorous scientific evidence ensuring that controlled use of midwater longlining in the GMR will not hinder the recovery of sharks and other ETP species. Conversely, we anticipate resistance from about 29% of Galapagos residents. This opposition comprises individuals determinedly against any type of longlining in the Galapagos, and a smaller faction (3%) who believe a bycatch threshold over 10% for ETP species is tolerable. The position of another 6% of residents remains unclear, as they felt uninformed to decide on the acceptability of a bycatch threshold for ETP species below 10%. Therefore, while most Galapagos residents may support a carefully regulated bycatch threshold for ETP species, policymakers should not overlook the concerns of a significant minority.

Understanding the perceptions of Galapagos residents regarding the motivations of small-scale fishers for advocating longlining is crucial to identify misconceptions, concerns, and shared views. Our data shows that most participants believe fishers advocate longlining mainly for its efficiency in catching adult tuna and the belief that the midwater longlining ban impacts their fundamental right to work. Notably, only 5% of participants associated fishers' motivations with targeting sharks. This suggests that the majority recognize that fishers' advocacy for longlining revolves around economic interests rather than the desire to be involved in illegal shark fishing and finning, as occurred in the Galapagos from the 1980s until mid-2000s (Castrejón et al., 2021). Leveraging this understanding can bridge trust between conservationist and fishing sector, facilitating the collaborative formulation of a comprehensive management strategy that address both fishers' economic challenges and minimize the ecological impact of longlining on sharks and other ETP species.

Our survey results also elucidate the opinions of participants concerning the illegal longlining activities in the GMR. A quarter of participants called for augmented governmental oversight, indicating a perceived inefficacy in the current surveillance system. There is an equivalent preference towards exploring new fishing techniques and methods, suggesting openness to testing alternative operational and technological solutions. While 19% advocated for upholding the longline ban, highlighting its ecological significance, there was a proportion of participants emphasizing bycatch mitigation strategies (15%) and advocating for longlining with strict regulations (14%). Similar results were obtained regarding the specific management measures that could be supported by Galapagos residents to solve the longline controversy. In this case, most participants (19%) also showed a significant preference towards investigating novel bycatch mitigation techniques, in combination with electronic monitoring and traceability systems. This implies a recognition of the role of innovation and technology in addressing this persistent social-ecological problem. Additionally, the significant support (18%) for assisting fishers in accessing fair markets reflects Galapagos residents' openness to implement market-based solutions. For example, supporting fishers in accessing markets that offer fair prices for their products could help alleviate their economic needs, enabling a more collaborative approach to fisheries management (Hall et al., 2017).

The acknowledgment by 14% of participants on the importance of relying on scientific data for decision-making stresses the emphasis that participants place on objective, empirical evidence as a foundation for policy decisions. The fact that 84% of participants recognize the importance of scientific data in informing decisions amplifies this perception further, indicating that a significant majority of the survey participants value evidence-based policymaking. This suggests that policies or actions rooted in scientific evidence are more likely to gain public trust and acceptance. This perception also provides policymakers with a directive on how to approach decision-making processes to ensure maximum stakeholder alignment and support.

There is a dichotomous perception among participants, with some advocating for a complete ban on all longline types (12%), while a similar proportion (11%) support the idea of encouraging the tourism sector to pay a higher price for longline-free tuna, i.e., tuna caught only with trolling, handline, or pole and line. The openness of participants for cross-sector collaboration highlights the potential for the payment of ecosystem services as a solution. The opportunity costs associated with the conservation of sharks, in this case by maintaining the longline fishing ban, could be offset by those profiting from a healthier ecosystem, like the tourism sector. Therefore, the possibility that this sector pays a higher price for longline-free tuna represents an opportunity to create market incentives that encourage fishers to use

more selective fishing gears, or adopt bycatch mitigation methods, as suggested by Gjertsen et al. (2010) and Squires et al. (2021). This market-based approach is feasible. 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 Galapagos yellowfin tuna that meet four criteria: food safety, freshness, low bycatch levels, and sourced directly from local fishers.

4.2 The role of demographic, social, and cultural factors in shaping perceptions and attitudes

Our study highlights the complex nature of the Galapagos longline controversy, revealing diverse perspectives regarding longline fishing practices, their environmental impacts, and the potential solutions to solve the Galapagos longline controversy. Perceptions are mediated and influenced by diverse cultural, political, socioeconomic, and demographic factors (Bennett, 2016; Gelcich and O'Keeffe, 2016; Casola et al., 2022). Consequently, diverse groups may perceive the same situation differently, based on their unique personal experiences, values, beliefs, preferences, knowledge, and motivations (Bennett, 2016). For example, fishers advocate for longlining authorization in the GMR due to its economic benefits and concerns that a ban on this activity may violate their right to work (Castrejón et al., 2021; Castrejón and Defeo, 2023). The importance of fishing as a livelihood and cultural practice may have influenced their perspectives that supported the authorization of pelagic and midwater longlining in the GMR. In contrast, the tourism sector shared more restrictive views, advocating for the prohibition of all types of longlines in the reserve, prioritizing conservation of ETP species over socioeconomic considerations. Other economic sectors such as NGO, academia, and commerce, tend to favor strengthening fisheries research and development of market-based incentives. These results contradict the anti-longlining sentiments expressed on social media (FCD, 2022), and in open letters (Izurieta and Green, 2021), by some NGO and conservationist organizations. These opinions likely represent the institutional viewpoints of these organizations, as opposed to the perceptions of most members of this group. Therefore, although 26% of participants showed opposition to any kind of longlining in the reserve (Table 5), the results of our study suggest that most participants are open to exploring alternative and less restrictive evidence-based solutions. A similar situation occurred in a Spanish longline fishery operating in the Atlantic Ocean, where most stakeholders proposed to reduce the bycatch of shortfin mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*) through minimum size and quotas and a spatial-temporal closure to protect blue shark juveniles (Dinkel and Sánchez-Lizaso, 2020). This case demonstrates that research aimed at understanding stakeholders' perceptions provides in-depth understanding of preferences and priorities of those people directly affected by management decisions. This knowledge facilitates identifying a common ground between fishers, scientists, and NGO to find pragmatic and innovative solutions that can improve the legitimacy, attractiveness, and probability of effective implementation of conservation measures (Gelcich and O'Keeffe, 2016).

Our study revealed that age, migratory status, and economic sectors did not significantly influence the perceptions of Galapagos stakeholders. Hence, the variations in perceptions are likely shaped by other demographic, social, or cultural factors. For instance, information shared through social media and traditional communication channels significantly affects individuals' beliefs, actions, and attitudes, including in conservation and environmental management areas (Fuentes and Peterson, 2021; Casola et al., 2022). Local perceptions can shape the public understanding and interpretation of the social-ecological impacts of conservation efforts, affecting the perceived legitimacy, social acceptability, and effectiveness of management measures (Bennett, 2016; Gelcich and O'Keeffe, 2016; Johansson and Waldo, 2021). In this context, Galapagos stakeholders' perceptions regarding the ecological impact of longlining may have been formed after some participants (e.g., a naturalist guide or park ranger) witnessed the retrieval of drifting large or small-scale longlines that have entangled or hooked sharks, marine turtles, or seabirds (Castrejón, pers. obs.). Our results suggest that this perception could also be significantly influenced by the inaccurate images that circulate in Facebook, Twitter, WhatsApp, and other social media platforms to advocate against longlining. These images, similar to Figure 3A, are not based on the latest scientific findings reported by Cerutti-Pereyra et al. (2020) and other authors (CTI, 2018) for the GMR, but reflects personal experiences, opinions, or institutional positions against longlining. Such images could also reflect the impact of "Ghost fishing"(Macfadyen et al., 2009) rather than the impact of a commercial small-scale longlining operation within the GMR. Additionally, longline images typically shared on social media are often juxtaposed with images of large-scale operations with miles of lines and hundreds of hooks, thereby potentially overshadowing the prospect of sustainable, small-scale longline operations that are responsibly regulated. This could distort public perception about small-scale longlining in the Galapagos.

Further, print and broadcast media tend to highlight the viewpoints of individuals and organizations opposing small-scale tuna longlining in the GMR. This bias is evident in a quote from a prominent Ecuadorian newspaper and a headline from a popular digital magazine, both raising concerns about the perceived threat of longlining in the Galapagos (Medina, 2018; Ponce, 2018). This skewed media coverage often presents an unbalanced and inaccurate portrayal of Galapagos small-scale longlining, emphasizing extreme viewpoints and ignoring the diverse perspectives of Galapagos residents and recent scientific advances in bycatch mitigation. This leads to the creation of "echo chambers", or groups of users with similar beliefs that reinforce a shared narrative (Cinelli et al., 2021). These findings highlight the importance of fostering public engagement and conveying accurate scientific information to portray the nuanced context and complexities of longline fishing.

4.3 Limitations and recommendations for future research

Our research provides valuable insights into Galapagos residents' perceptions and attitudes regarding the longline

controversy. However, our findings should be interpreted with caution. Potential population demographics shifts in the Galapagos since the 2015 census (INEC, 2015) may have significantly altered the age distribution and composition of economic sectors. The COVID-19 pandemic may have further amplified these shifts. The pandemic's profound impact on the Galapagos economy led to job losses due to the collapse of the tourism industry (Díaz-Sánchez and Obaco, 2020; Viteri Mejía et al., 2022), which employs approximately 60% of the residents (Pizzitutti et al., 2017). Consequently, the economically active population migrated from the Galapagos to mainland Ecuador in search for job opportunities (Rizzo-Correa and Prieto-López, 2021). Although a recent census was conducted in November 2022, the results were not public at the time of writing this paper. Therefore, accurately assessing the representativeness of our survey data might be challenging. We recommend undertaking further research with a more extensive and representative sample size across specific demographic groups (e.g., youths, tourists, fishers, farmers, etc.) to corroborate our findings.

Surveying social media platforms may not accurately capture the views and behaviors of the entire Galapagos population. For instance, older adults might be underrepresented on these platforms, which could partially explain the underrepresentation of the >65 age group in our survey. On the other hand, despite the generally higher presence and activity of younger individuals (19-30 age group) on social media (Laor, 2022), they are probably also underrepresented in our survey due to several factors, such as the social media platforms used for the survey or the survey's topic, which might not have been as appealing to this age group. This may have reduced their probability, willingness, or interest in participating. In contrast, the 31-40 and 41-50 age groups are better presented in our survey. The COVID-19 pandemic, with its accompanying lockdowns and social distancing measures, led to an increased reliance on digital platforms for work, education, socialization, and entertainment (Severo et al., 2023). This likely increased social media usage across all age groups, particularly among those who may have been less likely to use these platforms before the pandemic, such as the 31-50 age group. Therefore, the representation of different age groups in our survey data appears to be influenced by a combination of the factors highlighted previously.

Given the misconceptions this study has uncovered concerning longlining in the GMR, and the lack of a clear consensus among participants in crafting a solution for the Galapagos longline controversy, we recommend fostering inclusive, multi-stakeholder dialogues and developing evidence-based policies to address this complex social-ecological issue. We propose investments in research, science communication, and education to increase public understanding and awareness of longline fishing practices, their environmental impacts, and governing regulations. Effective science communication and open dialogue with local communities, dissemination of scientific information and advice, and advancement of educational initiatives are essential for increasing public awareness, fostering communication and collaboration among stakeholders and policymakers, and facilitating informed discussions on conservation and management measures (Liao et al., 2019; Dinkel and Sánchez-Lizaso, 2020).

The demographic factors considered in this study were not critical determinants of stakeholders' preferences. We recommend complementing this study with interviews and focus groups, to generate a more comprehensive understanding of stakeholders' perceptions and the factors influencing their attitudes to longlining. These research methods can help to uncover additional demographic, social, and cultural factors that may not be captured through survey data alone. Longitudinal studies can also provide valuable insights into how perceptions and attitudes of Galapagos residents change over time in response to new information, regulations, or communication and educational initiatives. Conducting follow-up surveys or interviews over an extended period can help scientists and policymakers to understand the dynamics of stakeholder perspectives and the effectiveness of management strategies implemented to resolve the Galapagos longline controversy.

As Galapagos policymakers lack stock assessments and biological reference points to set an explicit bycatch threshold for ETP species (Castrejón and Moreno, 2018), there is a pressing need for further investigation and the implementation of consistent, cost-effective, participatory and innovative fishery monitoring methods. These actions are essential for evaluating the ecological and socioeconomic consequences associated with different fishing modalities, including longlining, trolling, handlines, pole and lines, and gillnets. This knowledge will aid in the determination of a suitable bycatch threshold for the Galapagos small-scale tuna fishery, which must prompt the implementation of management measures if the threshold is exceeded (Gilman et al., 2022). To achieve this objective, Castrejón and Defeo (2023) suggest conducting an Ecological Risk Assessment (ERA) to identifying those ETP species that are most susceptible to irreversible harm by longlining and use the results to prioritize research or mitigation strategies, based on the participatory development and implementation of a bycatch management framework (Gilman et al., 2022). However, understanding the post-catch mortality rates, influenced by factors such as handling practices and entanglement duration, is also imperative (Schaefer et al., 2021). The GNPD's fishery monitoring systems should track both bycatch and post-catch mortality rates. Then, the resulting data should be used to develop training programs for fishers, with the aim of reducing harm to ETP species during the release process, enhancing their survival rates.

5 Conclusion

The longstanding controversy surrounding longlining in the Galapagos presents a multifaceted challenge at the intersection of conservation, fisheries management, and socio-economic development. Our study has revealed a multitude of perceptions and misconceptions among Galapagos residents about this issue, stemming from a mix of scientific knowledge, personal experiences, and societal values. Significant differences in views on bycatch rates and what constitutes acceptable bycatch levels exist, reflecting differing value judgments and possibly inaccurate information sources. The legal framework currently lacks clear guidelines on permissible fishing gear based on their ecological impact, which exacerbates inconsistencies in Galapagos fisheries management. Despite these differences, participants indicated a significant belief in evidence-

based policymaking, with many supporting innovative bycatch mitigation techniques, the use of technology, and market-based solutions that balance economic and conservation needs. While fishers advocate for longlining, emphasizing their economic sustenance and cultural ties, the tourism sector predominantly leans towards conservation, apprehensive about its ecological repercussions. In contrast, other sectors like academia and NGO highlight alternative management strategies. The discrepancy between these views and the dominant anti-longlining sentiment in popular media suggests a possible disconnect between institutional positions and ground realities. Additionally, the digital age has magnified the potential for misinformation, as seen with the dissemination of misleading images on social platforms, which might not accurately reflect the nuances of small-scale longlining in the Galapagos. Traditional and social media tend to sensationalize extreme viewpoints, overshadowing the diverse opinions of Galapagos residents and advancements in sustainable innovations.

Navigating this complex social-ecological problem demands a comprehensive, adaptive, and evidence-based approach that considers the perspectives and needs of all stakeholders involved. By promoting open dialogue, fostering cross-sectorial collaboration, supporting comprehensive, rigorous and unbiased scientific research, and strengthening collaborative governance, the Galapagos residents can collaboratively design a pragmatic and impactful conservation and management strategy. This ecosystem-based management approach to fisheries can create the enabling conditions to pave the way for more effective and inclusive conservation strategies that ensure the sustainable progression of the small-scale tuna fishery with the conservation of the Galapagos' invaluable and unique marine biodiversity.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because no ethical concerns or risks to human subjects were present in the course of this research, and thus ethical approval was not deemed necessary. Participation was anonymous and voluntary. The studies were conducted in accordance with the local legislation and institutional requirements.

Author contributions

MC conceived the study, designed, and distributed the online survey, and analyzed data. MC and OD interpreted the data and wrote the manuscript. Both authors revised and approved the submitted version of the manuscript.

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Conflict of interest

MC is a co-founder and general manager of INNOVAPESCA CIA. LTDA. MC declares that no funding, salaries, or grants from INNOVAPESCA were involved in the research or publication of the article in question.

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

Correction note

A correction has been made to this article. Details can be found at: 10.3389/fmars.2025.1692743.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1235926/full#supplementary-material

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