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Illegal artisanal longline use in the Galapagos Marine Reserve characterized through monitoring and control data

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Illegal longline fishing in the Galapagos Marine Reserve (GMR) represents a socioecological issue with significant impact on protected marine species. This study characterizes the use of illegal longlines in the GMR by combining and analyzing datasets generated from monitoring and control operations by the Galapagos National Park Directorate. We explored temporal and spatial patterns of longline detections, identified impacted species, and estimated compliance of vessels associated with longlines. The number of longlines detected varied across years but no clear seasonal pattern was evident. The most frequently captured species taxa were sharks and rays, including critically endangered scalloped hammerheads (*Sphyrna lewini*) and endangered manta rays (*Mobula birostris*). The critically endangered waved albatrosses (*Phoebastria irrorata*), as well as green turtles (*Chelonia mydas*), were also captured. Longline fishing occurred frequently in the submarine canyon south of Isabela Island, the seamount east of Santa Cruz Island, and waters between Pinzon, Isabela, and Santiago Islands, which are areas of high primary productivity and popular fishing grounds. Longlines were also frequently recorded near Darwin and Wolf Islands, a regionally-important hotspot for shark conservation. Offending vessels associated with longlines represented 17% of the artisanal fleet targeting pelagic fish species and were responsible for approximately 30% of pelagic fish landings. Notably, 80% of the fishing trips by the offending vessels when longlines were recorded had no associated fisheries landing recorded. Offending vessels had their Automatic Identification Systems (AIS) deactivated, in 69% of the fishing trips when illegal longlines were recorded, despite their use being mandatory by law. These findings provide baseline data to assist managers of the GMR to improve enforcement effort allocation and underscore the importance of strengthening surveillance and enforcement efforts to mitigate illegal fishing activities.

KEYWORDS

bycatch, protected species, IUU fishing, surveillance, enforcement

1 Introduction

The Galapagos Marine Reserve (GMR) is a large multiple-use marine protected area with a management zoning scheme that only allows artisanal fishing (i.e., small vessels up to 18 meters using regulated fishing gears) by permanent resident certified fishers. The management plan of the GMRs aims to reduce conflict between stakeholders (e.g., conservation, local community and tourism) by defining areas for tourism, recreation, extraction, mixed areas with rotating closures as well as no-take areas (Edgar et al., 2004). Longlines are often criticized for the incidental capture of threatened and protected species - contributing to population declines (Gallagher et al., 2014; Gray and Kennelly, 2018). Thus the use of longlines has been prohibited in the GMR since 2000 through the Special Regulations for Fishing Activity in the Galapagos Marine Reserve, as a precautionary measure to prevent illegal and incidental fishing of protected species (AIM, 2005). Despite control efforts by the Galapagos National Park Directorate (GNPD), the illegal use of longlines by artisanal fishers in Galapagos is known to occur, with some fishers of large pelagics openly stating its regular use (Castrejón and Defeo, 2023b). This group argues that the prohibition threatens their livelihoods as it decreases their chances of capturing high-value commercial fish to export. Therefore, they demand the development of a small-scale longline fishery targeting tuna, also suggesting this would support the recovery of overexploited coastal species (Castrejón and Defeo, 2024, 2023a, 2023b). The debate around the longline ban and the proposed development of a longline fishery in Galapagos has recently gained attention in the scientific literature; however, this topic has been a point of contention for over two decades (Castrejón and Defeo, 2024; Hearn and Bucaram, 2025).

Longline selectivity experiments have been conducted in the GMR in coordination with local environmental authorities at the request of fishers (Cerutti-Pereyra et al., 2020). These experiments found consistent incidental capture of threatened and protected marine species, including notable percentages of sharks, rays, turtles and seabirds (Cerutti-Pereyra et al., 2020). The low selectivity and high bycatch rates observed in these experiments contrasts with the development of a potentially sustainable longline fishery, which has been suggested by the local fishers, and conflicts with the conservation objectives of the GMR (Hearn and Bucaram, 2025). While scientific information about selectivity of longlines is available (Cerutti-Pereyra et al., 2020; Murillo et al., 2004), investigations into patterns of illegal longline use, enforcement and rates of compliance with regulation are still necessary for a better understanding of the dynamics and scale of illegal unreported and Unregulated (IUU) fishing in the GMR.

The GNPD is responsible for managing and enforcing regulations to conserve marine ecosystems and biodiversity in the GMR. To achieve this, the GNPD has a marine monitoring and control program aimed at ensuring compliance, including of fishing regulations (DPNG, 2014). To conduct the program, the GNPD has 15 marine vessels and a crew of park rangers trained in vessel boarding, legal regulations, and other key aspects for the management of the GMR such as monitoring, control and enforcement (DPNG, 2024). The GNPD also has a control center equipped for remote and real-time remote monitoring of maritime traffic, and fisheries observers and video surveillance systems at the main fishing ports. This report presents the analysis and interpretation of datasets collected by GNPD park rangers during surveillance and control operations under the marine monitoring and control program. It describes patterns of longline fishing and its interactions with protected species in the GMR. Improved understanding of these illegal fishing patterns provides crucial information for evidence-based reserve management and policy decisions regarding IUU fishing, which is currently the major threat to protected species in the GMR.

2 Methods

2.1 Databases

Enforcement effort and illegal longline use in the GMR were described between 2018 and 2024 by analyzing four databases generated by the GNPD through the SIAG system (Galapagos Environmental Information System, in English). The databases contained records of GNPD enforcement control operations (including offenses documented by park rangers and prohibited fishing gear encountered at artisanal vessels), vessel movement data from Automatic Identification Systems (AIS) transmissions (2019-2024), and fisheries landings by artisanal vessels at Galapagos ports. Although not originally designed for scientific research—which limits the scope of inferences and statistical analyses—these datasets contain valuable information for informing management strategies within the GMR. The use of the datasets is described below. All data analyses described were performed in R (R version 4.3.1).

2.1.1 Enforcement and illegal longlining patterns

The enforcement database contains the number and type of enforcement operations conducted by the GNPD. These data were used to assess enforcement effort and longline detection rates for subsequent analyses of compliance.

The prohibited fishing gear database recorded infractions, including illegal longlines, and was used to describe spatial and temporal patterns of longline use, identify offending vessels (i.e., those associated with an illegal longline offense during enforcement operations) and the marine animals captured by longlines. For analysis, longlines were classified as per the state in which they were found during enforcement operations: in the water (drifting unattended or in use) or, onboard a vessel. Marine species captured by longlines were recorded and identified into a taxonomic group of sharks, Manta rays (*Mobula* spp.), sea turtles, albatross, other rays (e.g., golden cownose ray and spotted eagle ray) and other marine species (unspecified in the database). Identifications to a lower taxonomic level were also made but only for events where photo evidence was recorded (see photos in S1).

The annual longline detection rate was calculated as Infractions per Unit of Patrol Effort (IPUE) by dividing the number of longlines found by the number of enforcement operations each year. The number and percentage of captured individuals in each taxonomic

group were also calculated. The georeferenced points of the longlines were plotted on a Google type map using the "ggmap" package (Kahle and Wickham, 2013). This map was selected because it displays ocean floor topography, serving as a familiar reference to visually relate longline locations to underwater features.

2.1.2 Vessel movements patterns

The AIS database contained continuous satellite transmissions from vessels within the GMR, including vessel identity, speed, direction and position. These data were used to describe the space use of offending vessels between 2019–2024 by quantifying transmission density, incorporating both vessel abundance and residence time, within 0.1-degree quadrants using the package "sf" (Pebesma, 2018).

It is mandatory for artisanal fishers in the GMR to have their AIS device on while performing fishing activities within the reserve (Ecuador, 2015). Therefore, the percentage of infraction events where AIS devices were inactive was calculated for three categories: all offenders, repeat offenders (vessels with two or more infractions) and one-time offenders. This was calculated by analyzing offending vessel transmission data (transmission presence or absence) on the days when the GNPD detected the offences.

2.1.3 Vessel landings patterns

The Fish Monitoring Certificates database records the fisheries landing data landed at the main Galapagos fishing ports. The dataset included vessel name, trip dates, landed species and quantity (kg). Ten pelagic fish species frequently landed in the GMR and by longline fisheries elsewhere in Ecuador were selected for the analysis (See Table 1 in Martínez-Ortiz et al., 2015). These data were used to quantify the proportion of pelagic fish landed by offending and non-offending vessels. The presence or absence of landing records by offending vessels in the period surrounding their infraction dates was also analyzed to calculate the percentage of infraction events in which potential longline catches were reported in official fisheries data.

3 Results

3.1 Description of illegal longline use and enforcement effort

In general, the number of enforcement operations increased from 2018 (620) to 2022 (1014), followed by a slight decline in 2023 and 2024 (Figure 1). An average of 18 longlines were detected per year in enforcement operations across the study period, with the lowest number recorded in 2018 (5 longlines) and the highest in 2020 (30 longlines; see also S2). More longlines were recorded in the water (i.e., drifting unattended or in use, 58%) than onboard vessels (42%). Longline use was recorded throughout the years; however, no clear seasonal pattern was evident.

The IPUE varied across years with no clear relationship between the number of longline infractions and enforcement operations. This suggests that the number of infractions recorded is not directly determined by the number of enforcement operations conducted by the GNPD, and other variables likely contribute to longline use and detections by enforcement operations (e.g., spatial and, seasonal variables, species abundances, social factors). The IPUE increased from 2018 to 2020 followed by a decline in 2021 (Figure 1). From 2021 to 2024, IPUE progressively increased, suggesting an increase in use of longlines in Galapagos in this period.

3.2 Species impacted by illegal artisanal longlines

Approximately a third (34%) of longlines found in the water had caught at least one protected species. The taxa most often captured by longlines were sharks, manta rays, turtles, and albatrosses (Table 1). Sharks were the most commonly caught taxa, representing 50% or more of the individuals captured in 2020, 2021 and 2023. Both pelagic and coastal shark species were captured, including the IUCN Critically Endangered scalloped hammerhead sharks (*Sphyrna lewini*), blue sharks (*Prionace glauca*), and thresher sharks (*Alopias* sp.) (see photos in S1). In 2024, manta rays (*Mobula* spp.) were the most commonly captured taxa, accounting for 52% of the records. Albatrosses were recorded in longlines in 2020 and 2024, including the IUCN Critically Endangered waved albatross (*Phoebastria irrorata*, see photos in S1).

3.3 Spatial distribution of illegal longlines and offending vessels

Longlines were recorded throughout the GMR (Figure 2A). Densities were highest near productive underwater features - such as submarine canyons, seamounts, and areas close to ports. These included the submarine canyon south of Isabela Island, the seamount east of Santa Cruz Island, the waters between the islands of Pinzón, Isabela, and Santiago, and around Darwin and Wolf Islands (Figure 2A).

A total of 41 vessels associated with longline use were identified, of which seven were repeat offenders. Among the offending vessels, 69% had their AIS devices turned off at the time of the infraction, with repeat offenders and one-time offenders disabling AIS 83% and 62% of the time, respectively.

For the offending vessels transmitting AIS, the highest densities of transmissions occurred close to islands such as the north of Isabela, west of Santiago, west of Santa Cruz, and near Pinzón (Figure 2B). Some areas with high longline detection rates showed few AIS transmissions including the submarine canyon south of Isabela and the seamount east of Santa Cruz (Figure 2B).

3.4 Landing patterns of offending vessels

Overall, a large percentage of offending vessels (79%) recorded with longlines did not report their catch upon returning to port

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TABLE 1 Number and percentage of individuals of taxonomic groups caught by illegal longlines in the GMR.

Taxonomic group	2018	2019	2020	2021	2022	2023	2024	Total
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Sharks	0 (0)	0 (0)	8 (62)	4 (50)	0 (0)	3 (100)	7 (25)	22
Mobulas	0 (0)	0 (0)	2 (15)	1 (13)	0 (0)	0 (0)	14 (52)	17
Sea turtles	0 (0)	1 (100)	0 (0)	1 (12)	0 (0)	0 (0)	1 (4)	3
Other rays	0 (0)	0 (0)	0 (0)	2 (25)	0 (0)	0 (0)	1 (4)	3
Albatross	0 (0)	0 (0)	3 (23)	0 (0)	0 (0)	0 (0)	1 (4)	4
Others	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (11)	3

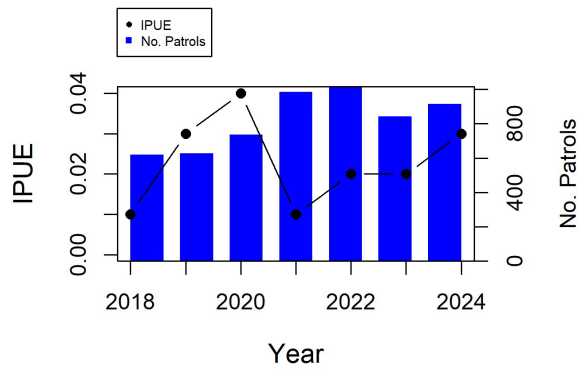

FIGURE 1
Number of control operations conducted by the GNPD from 2018-2024 (blue bars) and longline Infractions per unit effort (IPUE) (black line).

from the fishing trip that the infraction occurred. These percentages differed between repeat offenders (72%) and one-time offenders (82%).

A notable percentage of the artisanal fishing vessels (17%) engaged in pelagic fisheries in Galapagos had infractions related to longline use. The landings of pelagic species made by vessels associated with longline fishing represented between 22% and 38% (an average of 30%) of the total pelagic fish landed between 2018 and 2024. The percentage of pelagic fish landings reported by these vessels generally declined over years (Figure 3).

4 Discussion

This study presents a description of illegal longline use patterns within the GMR using four databases generated by the GNPD during monitoring and control operations over seven years (2018-2024). Notably, we provide a spatial description of the use of illegal longlines, the frequency of unreported catches and AIS transmission gaps by offending vessels (i.e., avoidance behaviors) and document the catch of protected and threatened species by illegal artisanal longlines in the GMR. Longlines were commonly recorded in areas where underwater features (seamounts, islands and drop-offs) promote high marine productivity and where targeted pelagic species tend to aggregate. Offending artisanal vessels exhibited suspicious behaviors commonly associated with illegal fishing, including deactivating their AIS and not reporting their catches, both of which are mandatory under the Special Law for the Conservation of the Galapagos (LOREG; Ecuador, 2015). Although not originally collected for scientific purposes, the monitoring data provides evidence of non-compliance and use of a prohibited fishing gear of low selectivity going against the GMR's regulations and conservation objectives.

4.1 Offending vessel behavior

Our findings suggest underreporting of fishery catches in the GMR associated with illegal longline fishing. Vessels identified as longline users were responsible for substantial landings of pelagic fish, yet did not report their catches for approximately 80% of the fishing trips where they were recorded by the GNPD with longlines. Although it was not possible to determine the individual vessel underreporting rate, the high percentage of offending trips in which no landings were reported suggests that underreporting may be a frequent behavior among these vessels.

In recent years (2020-2024), the percentage of pelagic fish landings recorded from offending vessels declined. This pattern could be a consequence of an increase in reporting by non-offending vessels. Alternatively, this could be explained by decreased compliance and reporting by offending vessels, possibly due to landing catches in locations and periods of reduced monitoring and control. The increase in IPUE (i.e., number of standardized longline detections per year) in recent years suggest the latter is likely to be the case. This suggests that the large pelagic fishery may be responsible for considerable IUU fishing activity within the GMR and that total catches in the official fishery statistics are likely underestimated. Further analysis to cross-reference data from fisheries landing monitoring with AIS vessel tracking data and vessel self-reported catches could help to evaluate compliance rates and further distinguish between these two scenarios.

In approximately 70% of the documented infractions, vessels associated with longlines had their AIS devices deactivated on the

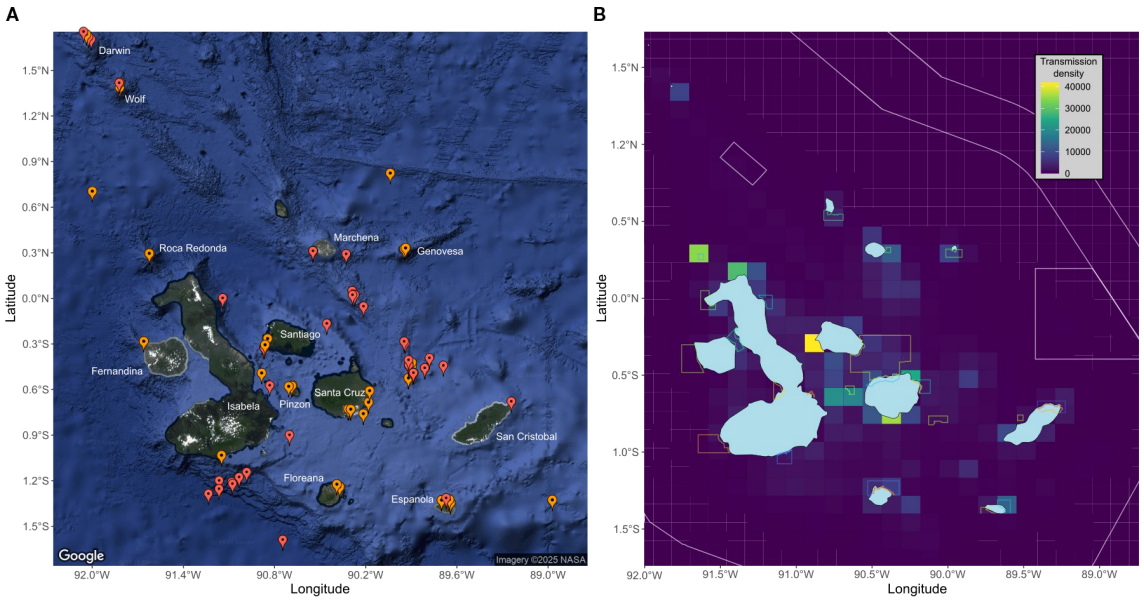

FIGURE 2
(A) Spatial distribution of illegal longlines recorded within the GMR by the GNPD (red: found in the water, orange: found onboard) Islands are labeled for reference. **(B)** Density of AIS transmissions (0.1 x 0.1 degrees) of offending vessels.

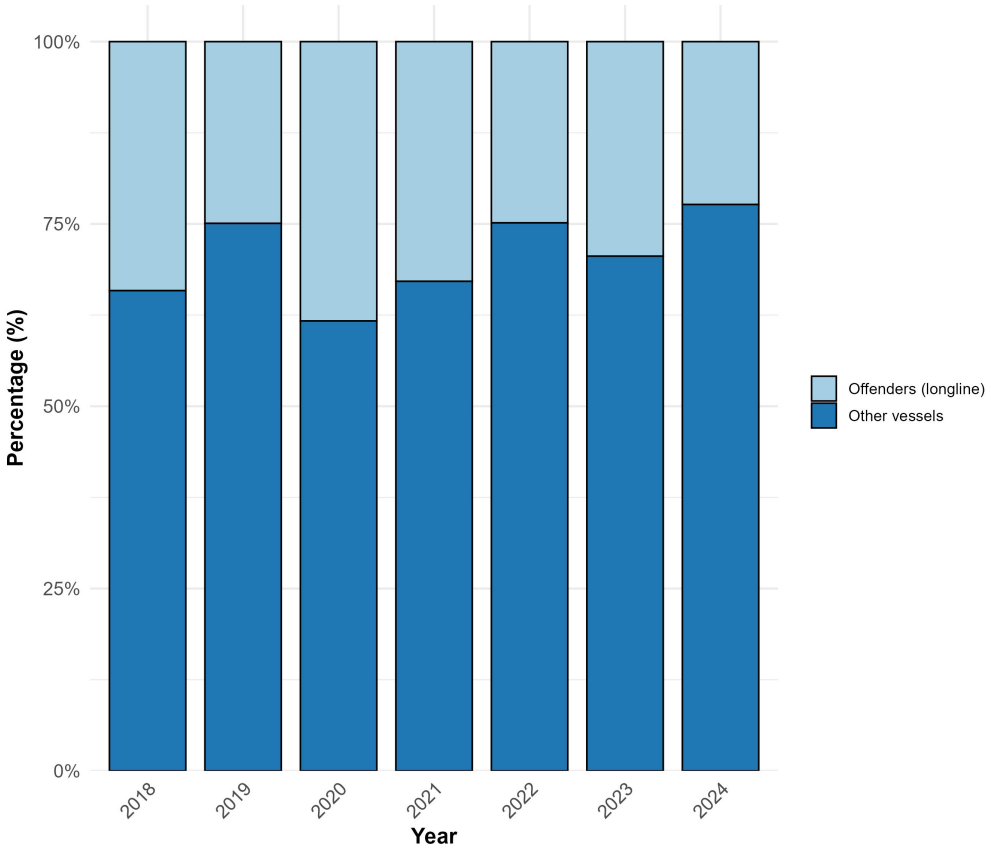

FIGURE 3
Reported landings (as percentage) of pelagic fish in the GMR made by local artisanal vessels.

day of the event. There was also a low density of AIS transmissions by offending vessels in areas where large numbers of longlines were physically detected by enforcement operations. This pattern suggests deliberate AIS deactivation during illegal longline fishing activities, despite mandatory continuous AIS use under LOREG and Ecuadorian Navigation Law (Ecuador, 2015; 2021). Automatic Identification Systems transmission gaps obscure up to 6% of fishing activity globally, often near IUU hotspots, with deliberate deactivation to conceal illegal operations being a key contributing factor (Ford et al., 2018; Welch et al., 2022). Therefore, monitoring AIS transmission patterns, including identifying vessels with reoccurring transmission gaps while away from port, could provide an effective indicator of potential illegal fishing activities and offending vessels. This monitoring could be supplemented through integration with port authority departure and arrival logs. Given the relatively small number of fishing vessels operating within the GMR - estimated to be around 139 (Castrejón and Defeo, 2024) - this would enable targeted operations on suspicious vessels and cost-effective use of the GNPD surveillance, control, enforcement and monitoring capacity.

Longline use appears to be frequent in areas where underwater features (seamounts, canyons and drop-offs) enhance shallow-water productivity. These areas include the submarine canyon south of Isabela Island, the seamount east of Santa Cruz Island, and the area between Pinzón, Isabela, and Santiago Islands. No-take zones also experience illegal activity, including Darwin and Wolf Islands and Roca Redonda (Ecuador, 2016). The spatial patterns observed in this study largely align with previous analyses of experimental longline fishing in the GMR (Cerutti-Pereyra et al., 2020). These areas likely attract illegal longline fishing because they are productivity "hotspots" where commercially valuable pelagic species aggregate, including tuna and swordfish, and their geographic remoteness, which decreases the likelihood of being detected by enforcement operations. However, these areas also serve as critical habitat for many protected and threatened species of sharks, manta rays, and seabirds. Enforcement operations as well as targeted remote surveillance focused in these areas are needed to reduce the catch of protected species by illegal longlining.

The IPUE varied over time, peaking in 2020. This peak is likely related to the COVID-19 pandemic, when disruptions in food supply chains led fishers to redirect their fishing efforts toward meeting the local Galapagos market demands (Viteri Mejía et al., 2022). The following year in 2021, saw a sharp decrease in IPUE, then a progressive annual increase to 2024. This upward trend corresponds with growing pressure from the fishing sector to legalize longlining within the GMR (Castrejón and Defeo, 2024), potentially explaining the increased use of this illegal fishing gear in recent years.

4.2 Impacted species

Sharks and manta rays were the taxa most frequently captured by longlines, despite being protected from fishing in the GMR (Ecuador, 2015; 2021). These findings align with selectivity longline catch composition studies in the GMR, which consistently show elasmobranchs are vulnerable to capture. For example, Cerutti-Pereyra et al. (2020) documented incidental capture of 16 protected megafauna species, with the most frequently caught being sharks, both coastal (e.g., blacktip, *Carcharhinus limbatus)* and oceanic (e.g., blue sharks, *P. glauca*), and the giant manta ray, *Mobula birostris*. Other studies estimate that sharks constitute averages between 11%–35% of incidental longline catch in the GMR, reaching up to 70% depending on the season (Murillo et al., 2004; CTI, 2018). Notably, our study documented the capture of the scalloped hammerhead shark (*S. lewini*), a species classified as Critically Endangered by the IUCN (IUCN SSC Shark Specialist Group, 2018) and subject to high bycatch fishing pressure in the region (Martínez-Ortiz et al., 2015). This species is known to have very low post-release survival rates from longline capture (Gallagher and Klimley, 2018).These findings suggest that illegal longline fishing in the GMR results in fishing mortality of protected sharks and rays, thereby reducing the effectiveness of the reserve in conserving populations of elasmobranchs.

The documented capture of Critically Endangered waved albatross (BirdLife International, 2018) by illegal longlines is also a significant conservation concern. This species faces heightened extinction risk due to their conservative life history traits (late maturity and low fecundity), small population size and high vulnerability to fisheries bycatch in the region and other anthropogenic pressures (Awkerman et al., 2006). Albatross captures by longlines generally occur during the daylight hours, when they forage for prey (Phalan et al., 2007). Therefore, best practice guidelines recommend longline fishing at night to prevent their incidental capture (Jiménez and Barrington, 2023). However, the presence of albatrosses in longlines found by the GNPD indicates illegal longline fishing during daylight hours, demonstrating a level of disregard for these bycatch reduction recommendations.

4.3 Limitations

Despite useful to describe several aspects of illegal longline fishing patterns, the datasets used in this study presented some inherent limitations, as the data derives from enforcement and control operations rather than systematic scientific sampling. Enforcement schedules are designed to monitor diverse illegal activities across a large marine reserve, with shifting operation targets and uneven effort, potentially more concentrated near accessible areas from GNPD bases and following administrative schedules, thus introducing spatial and temporal biases (Arias et al., 2016). The quality of records and species identification skills may have varied among the park rangers and also over time. For example, the availability of photographic evidence of captured species was only available for more recent enforcement reports, which limited our assessment of longline catch composition and biodiversity impacts from earlier years. While both AIS and fisheries landing data also have inherent limitations, including

vessel AIS transmission gaps in remote areas due to technical issues and unrelated to fisher detection avoidance (Robards et al., 2016) and underreporting of landings by fishers due to other factors than avoidance. Such limitations prevented us of more complex analysis and also limited the extend of inferences made from the data. Nevertheless, the combination and cross-analysis of four different datasets compiled by the GNPD was useful to provide novel data regarding the patterns of use of illegal artisanal longlines in Galapagos as well as useful information to assist managers to deter IUU fishing.

4.4 Fishing gear alternatives

To address the demands of fishers for better opportunities without increasing the impact on protected species within the GMR, various alternatives to longline use have been proposed, including the use of more selective fishing gear, such as pole-and-line fishing at tuna and swordfish "hotspots" (Cerutti-Pereyra et al., 2020). Additionally, the reorientation of fishing vessels and their crews towards a broader range of services has been suggested by the fishing sector itself (SPAG, 2024). Moreover, as well as a transition from export to local markets in collaboration with local restaurants and directing catches to improve food security for the Galapagos population has also being proposed as an alternative (Hearn and Bucaram, 2025). The combined implementation of these measures could facilitate the diversification of the fishing sector's activities, reducing the practice of IUU fishing in the GMR.

5 Conclusion

The analysis of the illegal use of artisanal longlines in the GMR reveals temporal and spatial patterns of illegal fishing activity, vessel behavior and compliance, as well as the bycatch species affected. The data provided an indication of the level of IUU fishing by local artisanal fishers involved in the large pelagics fishery within the GMR. These findings serve as a basis for discussing improvements in fisheries management, sector compliance and participatory governance of pelagic fishery in the GMR. They may also assist in improving efficiency of the GNPD surveillance, control, enforcement and monitoring programs by providing information for implementation of more targeted and cost-effective strategies. Non-compliance is a prevalent issue in MPAs globally, and reducing it requires continuous monitoring, adaptive management and tackling the complex drivers across planning, establishment, and management (Iacarella et al., 2021).

Oceanic MPAs that allow multiple uses are often established with the goal of marine conservation and effective fisheries management. However, their effectiveness largely depends on compliance with regulations by their stakeholders, including fishers (Arias et al., 2016). Despite the prohibition of longlining in the GMR, our data shows clear and regular use of illegal longlines by local artisanal vessels engaged in pelagic fishing, with signs of increasing use in recent years. Longlines pose a threat to many protected marine species in the GMR, including Critically Endangered species, such as scalloped hammerhead sharks and waved albatrosses, two species which already experience elevated bycatch fishing pressure outside the reserve.

Despite enforcement efforts, the persistence of illegal longline fishing and recurrent infractions underscore the need for more effective monitoring strategies, legislative adjustments, stakeholders compliance, and better traceability of catches. It also highlights the need for improvement of voluntary compliance with regulation by local fishers, which is particularly important given the environmental impacts and social opposition to longlines by the local population (Castrejón and Defeo, 2023a). Overall, GNPD monitoring and control data provided a better understanding of the patterns of illegal longline use in the GMR, including spatial and temporal utilization trends. The pursuit of the sustainable use of large pelagic fish is essential to contribute to the well-being of the Galapagos artisanal fishing community. Therefore, sustainable alternatives for large pelagic fishing must be sought, ensuring that they do not impact protected species within the GMR, as these species are not only ecologically important but also fundamental resources for industries vital to the Galápagos economy, such as tourism.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The datasets used in this study are confidential. Requests to access these datasets should be directed to Paola Buitron Lopez: pbuitron@galapagos.gob.ec.

Ethics statement

Ethical approval was not required for the study on animals because available dataset was used. Datasets were originally collected during enforcement operations by the GNPD not for scientific purposes. This research was conducted under Galapagos National Park Directorate (GNPD) research permit PC-03-24.

Author contributions

AR-C: Investigation, Writing – review & editing, Methodology, Software, Writing – original draft, Formal analysis, Data curation, Visualization. PB-L: Writing – review & editing. AT-J: Writing – review & editing, Data curation. SM: Writing – review & editing, Software, Formal analysis, Data curation, Methodology, Visualization. EC-B: Writing – review & editing. GS-C: Data curation, Writing – review & editing. JR-G: Data curation, Writing – review & editing. G-MSV: Methodology, Writing – review & editing, Conceptualization, Investigation, Writing – original draft, Supervision, Resources.

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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.

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