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EDITED BY
Randi D. Rotjan,
Boston University, United States

REVIEWED BY
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Fundação Oswaldo Cruz (Fiocruz), Brazil
Kelton W. McMahon,
University of Rhode Island, United States

*CORRESPONDENCE
Rafid A. Shidqi
✉ rafid.shidqi@duke.edu

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Exploring practical conservation measures for pelagic thresher sharks using local knowledge in Sunda Banda seascape

Rafid A. Shidqi[1,2]*, Yodhikson M. Bang[2], Samsul Basrun[2], Dewi Ratna Sari[2], Maria Bernadeth Y. Tukan[2] and Hollie Booth[3]

[1]Nicholas School of the Environment, Duke University, Durham, NC, United States, [2]Thresher Shark Indonesia, Kalabahi, Nusa Tenggara Timur, Indonesia, [3]Department of Biology, University of Oxford, Oxford, United Kingdom

The pelagic thresher shark (*Alopias pelagicus*) is an evolutionarily distinct and globally endangered species, with population declines primarily attributed to targeted fishing and bycatch in both small-scale and industrial fisheries. As the world's largest shark fishing nation, Indonesia is a global priority for pelagic thresher shark conservation. Recent studies have revealed that the Sunda Banda seascape in eastern Indonesia is a hotspot and migration route for this species. While many fisheries operate in this seascape, there is a lack of data regarding the interactions between these fisheries and pelagic thresher sharks in the area, which hinders efforts to mitigate overfishing and promote conservation. This study addresses this gap by utilizing local ecological knowledge from fishers in Banda, Central Maluku, Indonesia. We employed a mixed-methods approach, combining surveys ($N = 52$) and focus group discussions ($N = 25$), with fishers selected through purposive and snowball sampling. This methodology enabled us to explore Banda fishers' socio-economic attributes, knowledge, attitudes, and interactions concerning pelagic thresher sharks and their conservation. Our results identified 16 locations where fishers captured or sighted pelagic threshers, all of which overlap with Ay-Rhun and Banda Sea marine protected areas. We found that fishers primarily depended on fishing for their livelihoods, with some having participated in shark fisheries and trade in the past. However, pelagic threshers are not a target species due to their low economic value. Instead, they are accidentally caught in small-scale handlines and purse seine fisheries associated with fish-aggregating devices. The meat is consumed or sold locally as a cheap animal protein, particularly during times of low fish catch. Fishers highlighted the costs associated with pelagic thresher bycatch, such as increased expenses to repair broken nets. This suggests that potential win–win approaches, like incentive-based interventions to encourage bycatch release, can serve as feasible solutions to address this conservation issue.

KEYWORDS

pelagic thresher shark, marine protected area, bycatch, local ecological knowledge, shark conservation, small-scale fisheries, conservation measures, Sunda Banda seascape

1 Introduction

Sharks and their cartilaginous relatives (Class Chondrichthyes) are among the most threatened marine species, with a quarter of species facing elevated extinction risk (Dulvy et al., 2014). Their slow life history, characterized by low growth rates, late maturity, and low reproductive rates, increases their vulnerability to overfishing (Liu et al., 1999,

Simpfendorfer, 2000; Sulikowski et al., 2016). Recent estimates indicate that global shark biomass has declined by up to 89% relative to unexploited levels since the rise of industrial fishing (Dulvy et al., 2017). This decline is particularly notable in regions with dense coastal populations or significant shark and ray export industries (Davidson et al., 2016). Furthermore, mortality hotspots were identified in biodiverse areas like the northern Indian Ocean and the Coral Triangle, which includes Indonesia, the Philippines, Malaysia, and Papua New Guinea (Worm et al., 2024).

The global decline in shark populations has led to widespread advocacy for their conservation to prevent further losses (Dulvy et al., 2017; Shiffman et al., 2021). A range of conservation initiatives have been introduced, with considerable efforts made to encourage adoption. These include campaigns to end shark fin soup consumption (Braccini et al., 2020; Jeffreys, 2016), the creation of marine protected areas (MPAs) for sharks (Gallagher et al., 2021; Oposa and Techera, 2023; Ward-Paige, 2017), restrictions on fishing gear (Booth et al., 2022; Sybersma, 2015), fisheries quotas, and trade regulations (Ferretti et al., 2020; Hareide et al., 2007; Iloulian, 2017). International and regional fisheries organizations have also urged countries to comply with these policies, especially those linked to the global decline in shark populations (Fischer et al., 2012; Mundy-Taylor and Crook, 2013). While these interventions have shown some success, such as reduced shark fin trade and consumption (de Mitcheson et al., 2018; Whitcraft et al., 2014), managing shark fisheries remains challenging, especially in countries with complex socio-political structures, where competing priorities exist between conservation and socio-economic goals (Booth et al., 2019; Dharmadi, 2015; Eriksson et al., 2019; Jaiteh et al., 2017; Techera and Klein, 2011).

Pelagic thresher sharks (*Alopias pelagicus*), herein "pelagic threshers," are among the species most vulnerable to overexploitation, both as targeted and bycatch species (Cardeñosa et al., 2021; Shidqi et al., 2019; Tsai et al., 2010). Like many sharks, they grow slowly and have low reproductive rates (Liu et al., 1999). In 2019, the International Union for Conservation of Nature (IUCN) Red List reclassified the pelagic thresher from globally vulnerable to endangered (Rigby et al., 2019). The species is also listed in Appendix II of the Convention on International Trade in Endangered Species (CITES; Liu et al., 2013). Despite this urgency, pelagic threshers remain one of the least-studied shark species (Cardeñosa et al., 2021).

As both a hotspot of species diversity and a hotspot of fishing pressure, Indonesia is a global priority for shark conservation (Dulvy et al., 2017; Musick and Musick, 2011). Shark fishing has a long-standing tradition among coastal communities in Indonesia (Tull, 2014), gaining momentum in the early 20th century, especially under Indonesia's Dutch colonial rule when shark products like fins and meat were exported to Europe and Singapore (Tull, 2014). According to *Indische Gids*, a journal from the Royal Netherlands Institute, Indonesian waters were once so rich in shark resources that fully quantifying their potential was almost impossible (Osseweijer, 2007). This early commoditization, combined with foreign competition, fueled extensive shark exploitation and put Indonesia as a key player in global shark exports, of which the country has contributed ~13% to the global catch (Musick and Musick, 2011; Tull, 2014; Christensen and Tull, 2014). Pelagic threshers are one of many species threatened by this industry in the Indo-Pacific, wherein their population is estimated to have declined by 50 to 79% over the past three generations (55.5 years; Rigby et al., 2019).

Within Indonesia, a recent satellite tracking study revealed the Sunda Banda seascape—the epicenter of biodiversity—as an important hotspot and migration area for pelagic threshers (Supplementary Figure 1; Shidqi et al., 2024). Movement of pelagic threshers from the Savu Sea in East Nusa Tenggara (*Nusa Tenggara Timur*, NTT) to the Banda Sea in Maluku was documented, indicating potential connectivity between populations in these regions (Shidqi et al., 2024). The pelagic thresher was recently protected in East Nusa Tenggara province under a Governor's decree (Dis. Pkl.188.48/B1.57/VIII/2022), prohibiting capture and trade of the species within NTT. This province-wide decree is further reinforced by the spatial protections in the Selat Pantar and Sika MPAs, by protecting the identified critical habitats to reduce targeted fishing and mortality of the species (Shidqi et al., 2024; Dinas Kelautan dan Perikanan Provinsi Nusa Tenggara Timur, 2023). Additionally, programs have also been introduced to provide alternative livelihoods for communities to reduce the socioeconomic reliance of the communities in this shark fishery (Shidqi et al., 2025). However, due to the pelagic thresher's wide-ranging movements, local protections alone leave the species vulnerable to fishing pressure in other locations, which could undermine local conservation efforts unless suitable management measures are implemented in other jurisdictions within the pelagic threshers' range (Shidqi et al., 2024; Heupel et al., 2015; Oliver et al., 2019).

In the Banda Sea, the Ay and Rhun Islands were declared an MPA by Ministerial Decree No. 48/2021, which aims to *protect the biodiversity of coral reefs, seagrass meadows, mangrove forests, Napoleon fish, sea turtles, and marine mammals while promoting marine tourism to support local communities*. A work plan to support the implementation of Ay-Rhun MPA was subsequently developed to facilitate co-management among Banda stakeholders (Ihsan et al., 2020). However, due to the absence of formal documentation on pelagic threshers before the establishment of the MPA, they were not prioritized as conservation foci, excluding them from any targeted conservation measures within the MPA plan. This is a missed opportunity for pelagic thresher shark conservation in Eastern Indonesia.

Within this context, we provide the first information on pelagic threshers and their fisheries in Banda using local ecological knowledge (LEK) to inform integrated spatial and fisheries management in the Sunda Banda seascape and beyond. We structured this study to answer three main questions: (1) Is there any evidence of the presence of pelagic threshers in Banda, and interactions with Banda fisheries? (2) What are the perceptions and attitudes of fishers toward pelagic threshers and their conservation? (3) What kinds of management measures could feasibly be implemented to mitigate fishing mortality of pelagic threshers in the Banda Sea? Our results can be used to inform future management strategies for pelagic threshers, to meet conservation and fisheries management goals.

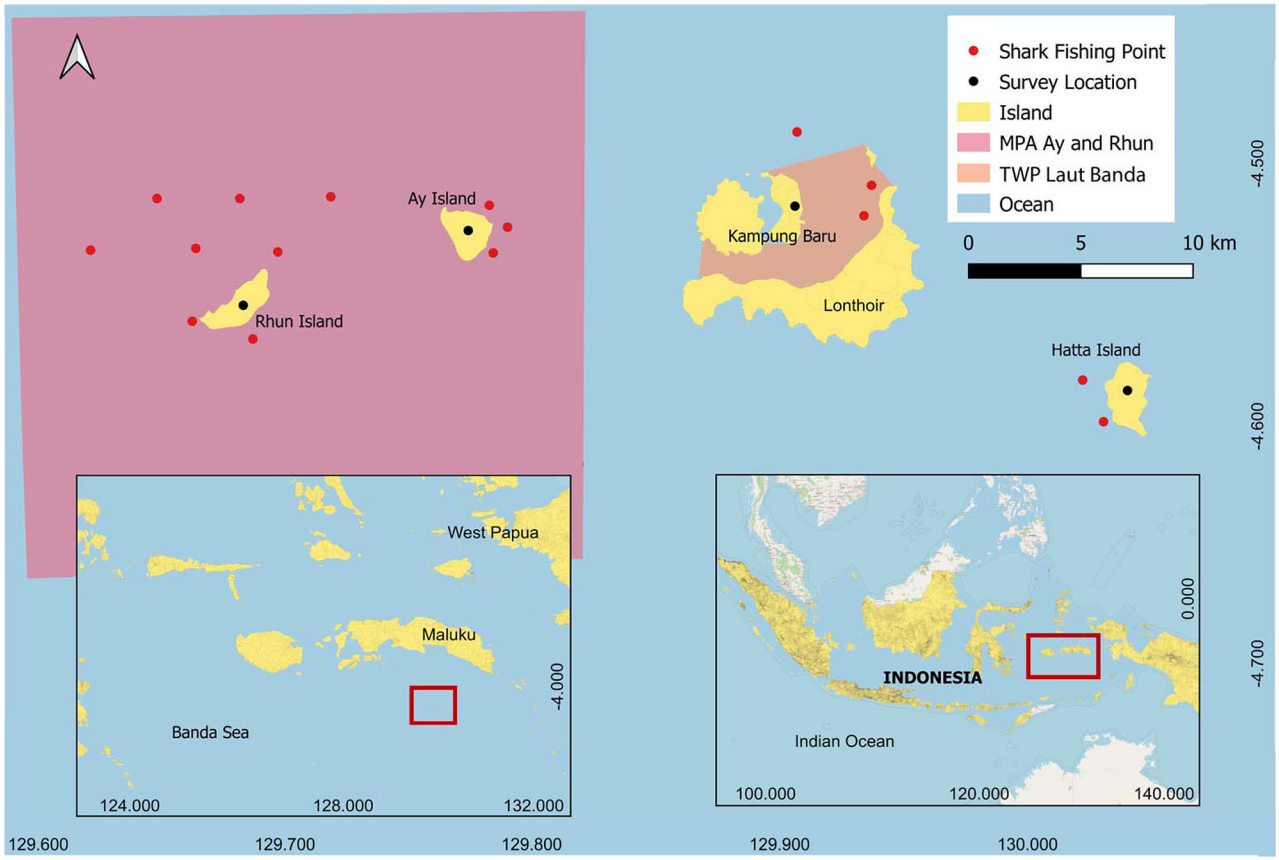

FIGURE 1
Map of study sites: black dots indicate the survey locations, and red dots represent areas where fishers reported catching or sighting pelagic threshers. Focus group discussions were only conducted in Naira (a village near Kampung Baru) and Rhun. Locally managed MPA around Hatta Island is not indicated on this map due to limited information on their boundaries.

2 Methods

2.1 Study sites

We conducted the study on four islands within the Banda district, Central Maluku Regency (Figure 1): Ay, Rhun, Naira (or Kampung Baru), and Hatta. As of 2024, the total population in these Islands was 6,856, with 1,576 households dependent on fishing (Badan Pusat Statistik Kabupaten Maluku Tengah, 2024; Pramudya, 2024). These study sites were chosen based on data collected during a preliminary scoping phase, which included unstructured interviews with key informants ($N = 3$) regarding the marine biodiversity of Banda, such as tourism operators, NGO members, and government members. The initial information about captured pelagic threshers was opportunistically gathered from social media posts (for example, Instagram photos) that had previously been shared with RS via personal message. We then contacted the individual to obtain additional details, such as the date, location, and how the threshers were seen or caught.

2.2 Data collection

Within the study sites, we used LEK as a low-cost approach for understanding the distribution of and threats to data-poor marine species, which can also serve as a foundation to engage communities in conservation (Haque et al., 2021; Gupta et al., 2023). LEK is defined as knowledge, practices, and beliefs regarding ecological relationships gained through extensive personal observation of interaction with local ecosystems and shared among local resource users (Charnley et al., 2007). Integration of LEK into marine science and conservation is increasingly recognized as a valuable approach for understanding data-poor fisheries, because fishers often hold extensive information on the biology and ecology of their target species (Gupta et al., 2023; Rasalato et al., 2010; Johannes, 1998; Silvano and Valbo-Jørgensen, 2008; Lopes et al., 2019; Murray et al., 2005).

To understand fishers' LEK regarding pelagic threshers, we explored broad socio-ecological narratives based on Banda fishers' experiences of, interactions with, and knowledge of the species. To accomplish this, we used a mixed-methods approach comprising socioeconomic surveys and focus group discussions (FGDs; Newing, 2010). The surveys included 81 closed- and open-ended questions organized into several topics: (1) socio-demographic information, (2) subjective wellbeing, (3) socio-economic conditions, (4) fishing practices, (5) perceptions of thresher sharks, (6) the fisheries value chain, (7) participation in decision-making processes, and (8) personal aspirations. For the FGDs, we explored topics including (1) fishers' interactions with pelagic threshers or other species, (2) knowledge of pelagic

threshers' fishing grounds and/or habitats, (3) perceptions of existing marine conservation policies in Banda, and (4) socio-economic and cultural aspects of fishing practices. These variables and questions were selected and adapted based on relevant published studies (Booth et al., 2022; Rasalato et al., 2010; Leduc et al., 2021; Ajzen, 1985; Mizrahi, 2021; Booth et al., 2023a); refer to the Supplementary material for the complete survey and FGD protocols.

We used purposive and snowball sampling to recruit participants for the surveys and focus group discussions (FGDs; Newing, 2010). Participants were selected based on two criteria identified during preliminary scoping: (1) they had interacted with pelagic threshers through fishing, or (2) they had collected, sold, or consumed shark products. Surveyed participants were then asked to recommend other fishers pertinent to the study. Snowball sampling is a distinct method suggested as an effective way to access hidden or hard-to-reach populations (Valdez and Kaplan, 1998). In this study, snowball sampling was particularly useful for locating, accessing, and involving individuals from specific subpopulations (Cohen and Arieli, 2011; e.g., those directly interacting with pelagic thresher sharks) by leveraging referrals from initial participants. This approach helped ensure a more representative sample, given the niche eligibility criterion.

Data were collected by a trained local research assistant, native to Rhun Island in Banda, following local institutional requirements and ethical principles (Belmont Report, 1974). Official research permits were obtained from provincial and district offices via Yayasan Teman Laut Indonesia, while customary approval was sought from village leaders (*Bapa Raja*). Socioeconomic data collection occurred from March to July 2023 and FGD in August 2023, with Free, Prior, and Informed Consent (FPIC) obtained from all participants. The study was conducted with ethical approval by the Interdivisional Research Ethics Committee at the senior author's (HB) institution (ref. R66416/RE001) and Indonesia's National Research and Innovation Agency (BRIN; ref. 407/E5/E5.4/SIP/2019, 39/SIP/IV/FR/1/2023 and 17/SIP.EXT/IV/FR/5/2023).

The survey and FGD data were supplemented with spatial data, with recorded GPS points by an observer where pelagic threshers were reported to be caught or seen in the past. We also collected self-reported shark catch data submitted via messaging or WhatsApp. This self-reporting initiative was communicated to fishers after an extensive outreach across the Islands. The outreach activities include poster distribution to public spaces, presentation to fisher groups and communities, and school seminars. To ensure the validity of the submission, we asked individuals to include at least one photo or video with accompanying information such as date, time, location, and fishing gear used.

2.3 Data analysis

We used RStudio v2024.09 to analyze responses to closed questions, generating simple descriptive statistics and visualizations to understand general trends. We used NVivo 14 to analyze responses to open-ended questions, transcribed FGD notes, field notes, and meeting notes (Phillips and Lu, 2018). We used thematic analysis and deductive and inductive approaches to identify codes and groups (Fereday and Muir-Cochrane, 2006). A deductive approach (Crabtree and Miller, 1992) was first used to construct a code template based on the research questions and relevant literature. The data were then coded against this initial list. Throughout the iterative process of reading, absorbing, and reflecting across the data sets, an inductive approach was applied by concurrently adding, deleting, or restructuring the initial codes, fitting the newly emergent patterns of narratives from the data (Azungah, 2018; Kiger and Varpio, 2020).

2.4 Positionality

RS, YMB, SB, and DRS conducted all fieldwork and data collection activities. We are all Indonesian nationals, but only SB is a resident and belongs to the Banda communities. RS and DRS are western-trained, early-career scientists. This places us in a position of power where we potentially contribute to perpetuating Western-centric academic practices that connected to colonial histories. Growing up with both Indigenous and non-Indigenous heritage, we were taught to recognize the enduring impacts of colonization on our country's history, especially on communities in Banda. These impacts have contributed to the oppression and marginalization of Indigenous peoples, whether through regulations that still reflect colonial legacies or other mechanisms. In conducting this research, we were aware of the risk of extracting valuable knowledge from the communities and using it primarily for personal, academic, and professional advancement. This could lead to benefits that serve only ours or the institutions we represent rather than the communities from which the knowledge originates. To address this, we are committed to designing the research to bring tangible benefits to the communities we work with. These may include creating employment opportunities for local and Indigenous peoples via research or using the knowledge to advocate for more inclusive and equitable marine policies. The results will be disseminated publicly to the relevant local and national decision-makers, such as indigenous or local leaders and government members.

3 Results

3.1 Participant demographics, socioeconomic traits, and perceived wellbeing

We conducted 52 surveys across four Banda Islands (Figure 1) and two FGDs in Rhun ($N = 10$) and Naira ($N = 15$), with "N" representing individual fishers who participated in the activities. Most survey respondents were from Rhun (42%, $N = 22$) and Ay Islands (40%, $N = 21$), with small numbers from Kampung Baru (6%, $N = 3$) and Hatta (6%, $N = 3$). Most respondents (69%, $N = 36$) identified as Butonese. Respondents' ages range from 35 to 65+, with the largest portion of respondents falling into the 36–45 age bracket (48%, $N = 25$). Of these (42%, $N = 22$), had 10–25 years of fishing experience, and 25% ($N = 13$) had 25–30 years. Among

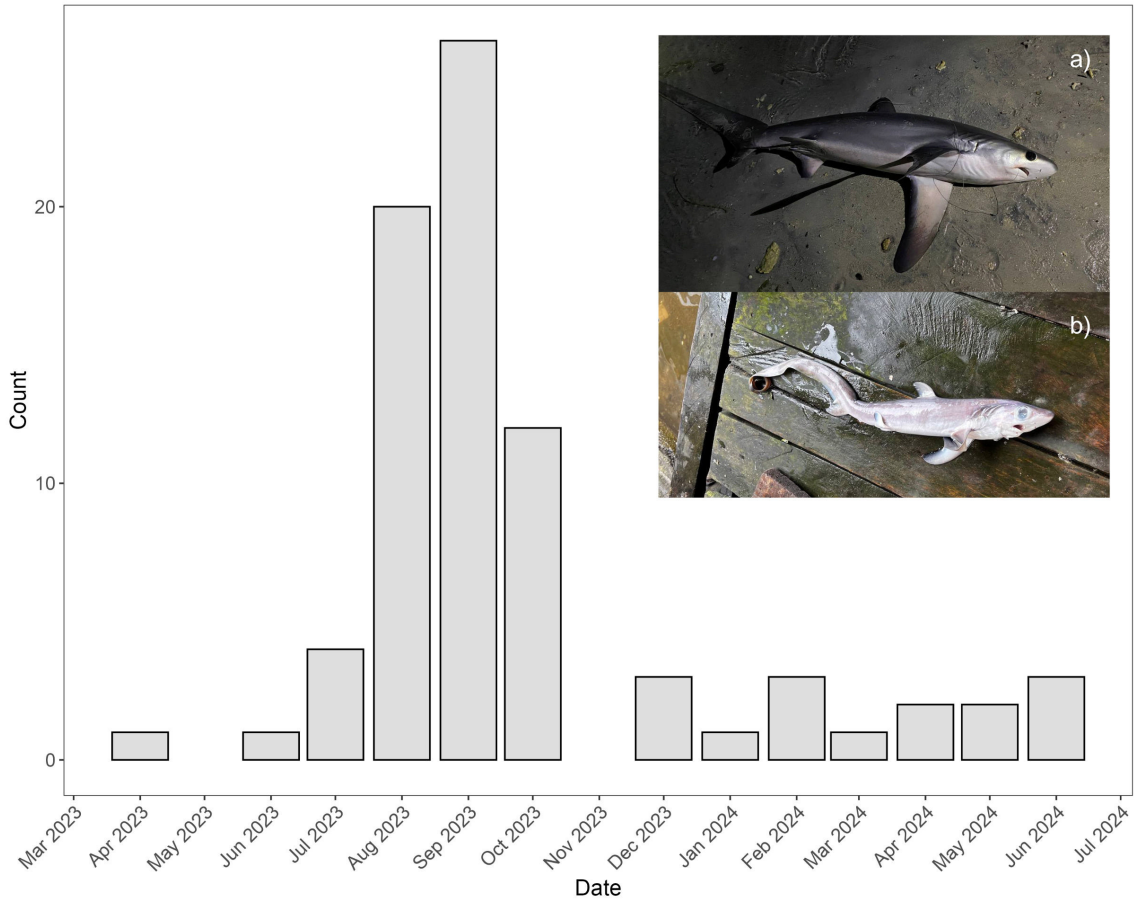

FIGURE 2
Catch data of pelagic thresher sharks based on fisher reports from March 2023 to July 2024; with evidence of juveniles **(A)** and pups from pregnant sharks **(B)** being caught.

all the surveyed respondents, 52% ($N = 27$) had only finished elementary school.

Relative to Maluku's poverty line (IDR 614,323 per month in 2024), the reported income of 58% ($N = 30$) of respondents fell below this threshold. About 87% ($N = 45$) relied only on fishing; while a small proportion had secondary livelihoods like farming (12%, $N = 6$, especially candlenut) and transportation (2%, $N = 1$). Twelve percentage ($N = 6$) of respondents indicated declining trends in economic wellbeing in recent years due to the uncertainty of income from fishing, weather impacts, and perceived decline in catches. Around 75% ($N = 39$) desired to leave fishing if other work was available, and 88% ($N = 46$) hoped their children or grandchildren would not follow their paths. One respondent noted: "Being a fisher is hard; let us, the older generation, bear it. If possible, our children should not become fishers" (Survey Ay Island, May 2023).

Nevertheless, most respondents admitted fishing was the only available occupation in their Islands, even for younger people who had attained higher education. While these responses imply the struggles of fishing, 81% ($N = 42$) still perceived they earned enough for basic food and income needs. Complete summaries are available in Supplementary Tables 1, 2.

3.2 Interactions with pelagic threshers: habitats, catch and fishing practices

Based on the survey, 63% ($N = 33$) reported catching pelagic threshers several times a year. Of these, 25% ($N = 13$) reported catching them at least once a month, typically capturing 1–4 sharks in a single trip. Based on self-reported catch occurrences from March 2023 to July 2024, we logged 78 pelagic thresher sharks captured from 16 fishers (Figure 2); however, this likely represents a small portion of total catches due to challenges with reporting and communication (e.g., fishers have no multimedia devices to take photos). While we did not specifically record lengths or sizes, photographic evidence, and fisher descriptions suggest the presence of pregnant female pelagic threshers, pups, and juveniles (Figure 2).

Locally, pelagic threshers are known as *eo bendera*; *eo,* meaning "shark," in local dialect, and *bendera,* meaning "flag," due to their long tails. Based on these data, we pinpointed 16 fishing grounds where fishers reported sightings or captures of pelagic threshers (Figure 1); these locations overlapped with the Ay-Rhun MPA and TWP Laut Banda.

In general, pelagic threshers were reportedly frequently sighted around *skaru*, a local term for "seamounts," with depths ranging

TABLE 1 Types of fishing gear used by fishers.

Fishing gear local name	Type	Description
Ulor or *Rompe-rompe**	Handline	The fishing line used for this gear is thick, and its target is large, deep-sea fish. The depth for this type of fishing can reach 80–100 meters. *Rompe-rompe* is used during the night.
Doda or *Doda Malam**	Handline	This gear uses more than one hook, and typically, *doda malam* targets mid-water fish. Meanwhile, the *doda luar* uses relatively small fishing lines and targets grouper. This gear is usually used at night and can reach depths of up to 30 meters.
*Umpan-umpan**	Handline	This gear uses live bait (*Decapterus* sp.). Fishers in Rhun use this fishing method in the early evening until nighttime, from 6 to 10 p.m. local time. The targets for this fishing gear are large fish, such as giant trevally (*Caranx* sp.), dogtooth tuna, and barracuda (*Sphyraena* sp.)
*Bobo**	Purse seine	This of net is usually operated in open waters. In Rhun, fishers use it with *rumpon* (artificial fish aggregating device) to attract small fish like scad (*Decapterus* sp.). Typically, fishers target 3–10 tons of fish aggregated around the *rumpon*. The *Bobo* net requires about 25–30 adult men to haul it in. The dimensions of the *Bobo* net are (215 m length; 70 m width). The mesh sizes vary, but the standard mesh sizes used for catching scads (*Decapterus* sp.) are top mesh (1/4 inch), middle mesh (1/5 inch), and foot mesh (2 inch)
Jarutu	Handline	Using jig, a type of artificial bait. Performed by jerking or twitching the line.
Salep-salep or *Tonda*	Handline	This gear is baited with lures or bait fish, and operated through dragging behind moving boat.
Menara goyang	Handline	This gear operates by shaking, mimicking the movement of a small fish to attract prey. Designed for bottom fishing, it targets species like small snapper and is effective at depths of 80 to 100 meters.

The (*) signifies gears that most often result in bycatch of pelagic threshers.

from 20 to 160 meters. These seamounts are named based on their topographic features and proximity to shore. For instance, *Skaru dekat* refers to the seamount closest to the island (e.g., within 3 km of Rhun), while *Skaru jauh* is the farthest, located about 5 km from Rhun. According to fishers, pelagic threshers are regularly observed early in the morning (4–6 a.m.) and occasionally at night (6–10 p.m.). They are often found feeding on schools of scads (*Decapterus* sp.). Oceanographic conditions also influence their occurrence, with reported increases in sightings during upwelling events. Respondents refer to this phenomenon as *air dingin* (cold water) or *air putih* (white water), which typically occurs between June and August, with a peak in July (Wirasatriya et al., 2021).

Respondents reported primarily using handlines and small-scale purse seines (*bobo*). All fishers use small- and medium-scale motorized and non-motorized (*katinting*) vessels. Handlines exhibit diverse local modifications tailored to target specific catches or to be used at particular times (Table 1). For instance, *doda* and *doda malam* signify the same gear, with *malam* meaning "night," indicating its typical usage from 6 to 10 p.m. Fishers reported that *ulor*, *doda*, *umpan-umpan*, and *bobo* had the highest possibility of catching pelagic threshers (Table 1). Banda fishers predominantly targeted larger deep-sea species, such as red snapper, at depths of 80–100 m, with pelagic threshers occasionally taking the lures at these depths. Conversely, *bobo* fishers mainly target small scads, but pelagic threshers often become entangled in the nets while they are feeding. Fishers indicated through the FGD that bycatch incidents frequently occur around *rumpon* or fish aggregating devices (FADs) in the identified fishing grounds, due to direct interactions between *bobo* or handline fishers with pelagic threshers while feeding (Figure 1).

In addition to pelagic threshers, we identified several responses on other shark and ray species caught unintentionally as bycatch (Table 2, Figure 3). Note that this question allowed respondents to list multiple species (total responses $N = 95$). This includes the scalloped hammerhead [*Sphyrna lewini*; reported by 16% ($N = 15$) responses] and the giant oceanic manta ray [*Mobula birostris*; reported by 11% ($N = 10$) of responses]. Notably, pelagic threshers accounted for 32% ($N = 31$) of bycatch incidents indicated by the overall responses. Generally, 44% ($N = 42$) of the bycatch species were classified as Endangered (EN), while 16% ($N = 15$) were classified as Critically Endangered (CR) based on the International Union for Conservation of Nature (IUCN; Figure 3). Other species not enumerated in the surveys were mentioned during the FGDs. For instance, respondents stated they have sighted or interacted with whale sharks (EN; *Rhincodon typus*) and green sea turtles (EN; *Chelonia mydas*) during fishing, with green turtles reportedly consumed locally.

Fishers reported that sharks and rays were once heavily exploited, with fishers historically participating in targeted shark fishing and trade, motivated primarily by high demand and high prices for shark fins. Manta rays were also sought after for their meat and gills, and though they are already protected in Indonesia, fishers signified that there was still illegal trade of the products in other parts of Maluku. Scalloped hammerheads were bought at high prices for their fins; however, they are now locally protected in Banda, particularly around Hatta Island (Figure 1). Outside Banda, on Serua Island, there is a local initiative where private entities provide an annual incentive of IDR 150,000,000 (USD 9,500) for the communities around the island to release hammerheads when accidentally captured.

3.3 Attitudes on pelagic threshers and their conservation

According to respondent fishers, pelagic threshers are caught incidentally with little to no economic value. Their meat sells for only IDR 10,000 (<USD 0.63) per kg or a maximum of IDR 100,000 (USD 6) for one individual (Table 2). Fishers describe them as *tangkapan sampah* ("rubbish catch"), "pesky," "bad luck,"

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TABLE 2 Identified bycatch species based on the surveys.

Common name	Species name	Local name	Count of responses	IUCN Status	Price per kg (IDR)	Target market
Pelagic thresher shark	*Alopias pelagicus*	*Eo bendera*	31	EN	10,000	Local
Scalloped hammerhead	*Sphyrna lewini*	*Eo penggayung*	15	CR	10,000–20,000	Local
Marlin	Istiophoridae	Marlin	12	DD	10,000–12,000	Middlemen
Oceanic manta ray	*Mobula birostris*	*Lawi-lawi*	10	EN	10,000	Local
Unidentified ray	-	*Pari dasar*	8	NE	10,000	Local
Unidentified shark	-	*Eo biasa*	8	NE	10,000	Local
Blacktip reef shark	*Carcharhinus melanopterus*	*Eo karang/sirip hitam*	3	NT	-	-
Indo-pacific Sailfish	Istiophoridae	*Layar*	3	VU	10,000	Middlemen
Dolphin	-	*Lumba-lumba*	2	LC	-	-
Whitetip reef shark	*Triaenodon obesus*	*Eo sirip putih*	2	VU	-	-
Napoleon wrasse	*Cheilinus undulatus*	*Mameng*	1	EN	-	-

Some species were not correctly named due to their vague descriptions (e.g., fishers referred to them as "common shark" or "common ray"). Greater confidence was assigned to species like the oceanic manta ray and hammerhead sharks, recognized and believed to be prevalent in the area. NE, not evaluated.

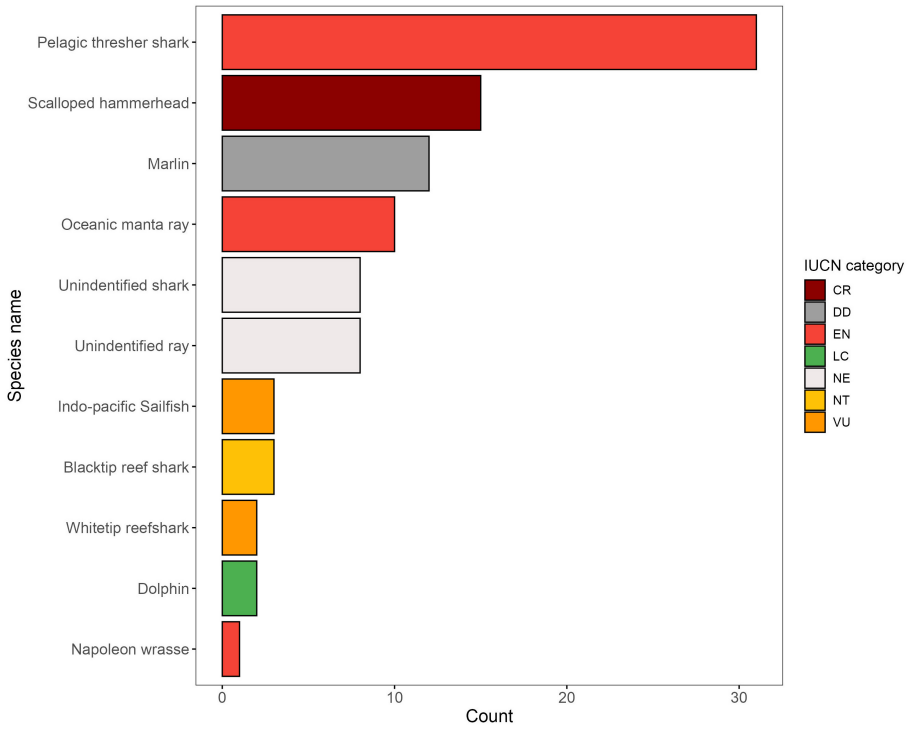

FIGURE 3
Bycatch composition based on responses. This question allowed multiple species to be listed by respondents; total responses ($N = 95$). The "unidentified shark and ray" was used because fishers provided general depictions, such as "white sharks" or "bottom rays." However, fishers expressed greater confidence in identifying scalloped hammerheads due to their local occurrences and oceanic manta rays, which they noted could have wingspans of up to 7 meters. Colors indicate their conservation status based on the IUCN Red List; NE, not evaluated.

or a "pest." In one FGD, one respondent explained that "if I catch a flag shark, sometimes I think, oh no, what bad luck!" (FGD Rhun, August 2023). Respondents elaborated that catching a pelagic thresher shark often adds significant weight to small vessels, frequently forcing fishers to return early due to limited capacity and space in their vessels. This is perceived as a loss of economic opportunity to catch other, more valuable species. Additionally, pelagic threshers are blamed for eating bait, which disrupts efforts to catch fishers' primary targets, such as red snapper, giant trevally, or grouper. As one fisher explained, "This thing [flag shark] often eats our bait, disrupting what we're trying to catch!" (FGD Rhun, August 2023). Some fishers expressed

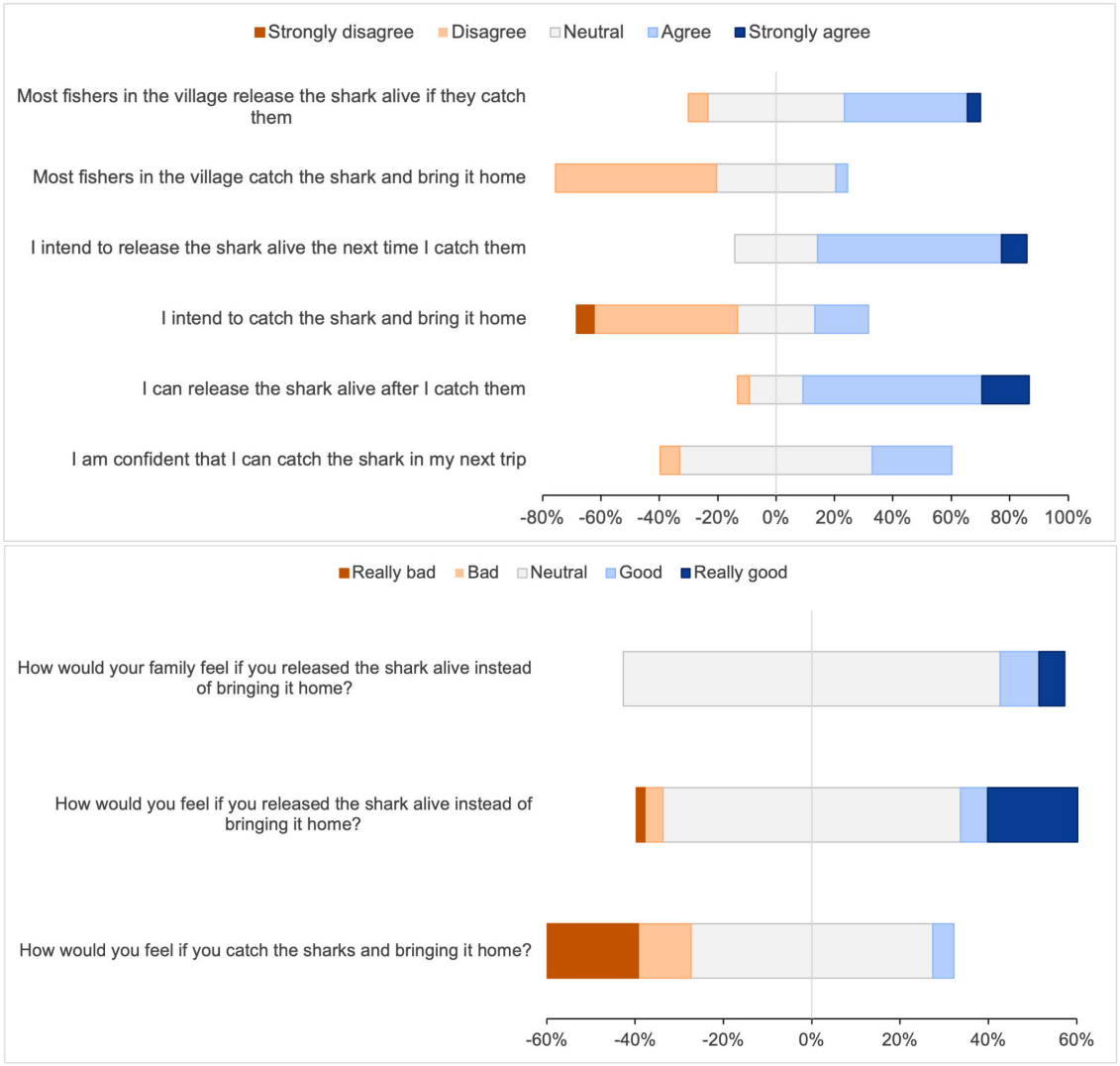

FIGURE 4
Fishers' perceptions and willingness to release pelagic threshers **(top)**. A high proportion of neutral responses suggests that fishers may opportunistically use the meat for local consumption, especially during seasons when the catch is difficult **(bottom)**.

frustration, stating they would be glad if there were "no more pelagic thresher sharks," because it would reduce disruptions to their fishing activities.

Based on fishers' salient beliefs regarding bycatch relevant behavior, a large proportion (55–85%) of respondents held neutral attitudes toward catching pelagic threshers (Figure 4, Supplementary Table 3). FGDs indicated that fishers generally dislike catching thresher sharks, but individual surveys revealed some of their values in specific contexts. For instance, fishers may take the sharks home for food if no other fish are caught that day, especially during periods of poor catches. This is also associated with religious beliefs such as *rahmat* (blessings from God) if the sharks took the lure that day. Additionally, fishers will likely retain the sharks rather than dispose of them if they are dead. Nonetheless, over 60% of fishers reported positive intentions and abilities to release live pelagic threshers if caught in the future (Figure 4, Supplementary Table 4). One respondent noted:

> *It all depends on who wants to eat it. We'll take it home if someone wants to buy it; if no one does, we might throw the meat away. Maybe we'll keep the fins if there's someone who wants to buy them. (FGD Naira, August 2023)*

Handline and *bobo* fishers reported that they occasionally release pelagic thresher sharks. *Bobo* fishers reported that they find it relatively easy to release threshers in the early netting process, by lifting the floating device (buoy) and waiting for them to flee the nets. However, releasing sharks that are already entangled is more challenging. In such cases, the vessel's captain must command the crew to swim in the water and cut the nets, which requires additional labor and costs, and often results in the sharks being dead before they can be freed. *Bobo* fishers emphasized the detrimental effects of accidentally catching or releasing pelagic threshers; this imposes an expense for net repair, reaching up to IDR 1,000,000 (USD 63). For small-scale handline fishers, live release imposes different costs, as they either need to lift the shark

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to the surface before release (labor) or immediately cut their fishing lines (equipment).

3.4 Adherence to conservation rules

Surveys and FGDs reveal that fishers generally hold positive opinions on conservation regulations and have developed a sense of adherence to them (Supplementary Table 1). About 71% ($N = 37$) agreed that protecting the ocean is the responsibility of fishers, while 63% ($N = 33$) agree and 12% ($N = 6$) strongly agree that current conservation regulations have been fair. FGDs further illuminated this, with fishers reporting that conservation efforts are useful to protect fish stocks, which are essential to their livelihoods. Some participants reported that the work of NGOs like the Coral Triangle Center, which has been active in the region for several years, has helped promote conservation awareness. However, conservation has also created divisions, with some supporting the efforts and others opposing them. Some also believed that conservation zones are disproportionately more extensive than the areas designated for fishing. One fisher noted in the FGD,

> *I support conservation efforts because they are aimed at sustainability, right? Sometimes, people misunderstand and think conservation will prevent us from fishing. Actually, the purpose of conservation is good. Certain conservation zones may restrict people, but zones designated for fishing can help. Opinions on conservation are mixed—some support it, and some don't. Those who don't (support) usually just want autonomy. For example, in Rhun, there are groups that support conservation and others that do not. (FGD Rhun, August 2023)*

We also asked fishers how they would respond if pelagic threshers were protected through conservation regulations. There was a positive attitude regarding such measures, especially among the *bobo* fishers in Naira. They noted that similar species-specific protections are already in place in Banda, such as the Napoleon wrasse (*Cheilinus undulatus*), an endangered species previously exploited in the region. One respondent particularly noted concern about the factors outside their control, such as when the sharks were already dead in the nets,

> *I thought they (pelagic threshers) were already banned. Besides, if they're already in the nets, what can be done? If we can release them, we'll do it. But if the shark is already dead, what can we do? If they (the government) have banned it, we'll just follow the rule. Otherwise, it's like harming ourselves. (FGD Naira, August 2023)*

Furthermore, respondents generally expressed a willingness to comply with conservation regulations, such as for pelagic threshers, with the condition that their livelihoods and wellbeing are considered. This creates varied perceptions and attitudes toward the local government, with some respondents voicing expectations for support, such as improvements to fishing vessels, gears, or reliable markets for their catch. Therefore, unless the fishers' interests are fulfilled, they will likely not listen to the government or may have negative attitudes toward regulations.

4 Discussion

4.1 Using LEK to understand the presence of pelagic thresher sharks and their habitats

Pelagic threshers are overexploited and under-managed across much of their range throughout the Indo-Pacific (Pacoureau et al., 2018; Arostegui et al., 2020). Our study has used LEK to contribute the first formal documentation on the presence of pelagic threshers in the Banda Sea and their interactions with the fisheries, including sightings of juveniles and pregnant females (Figure 2), with identified locations across all MPAs in the region (Figure 1). This supplements records from a previous tagging study, which indicated the movement of threshers from the Savu Sea into the Banda Sea, suggesting potential population connectivity (Shidqi et al., 2019, 2024). In addition to pelagic threshers, we documented fisher interactions with other threatened elasmobranch species (Figure 3), including oceanic manta rays, scalloped hammerheads, blacktip, whitetip, and whale sharks. The study also adds to the growing literature on the importance of LEK as a low-cost method for evaluating risks to threatened species and potential conservation strategies in data-poor contexts (Haque et al., 2021; Gupta et al., 2023; Nazareth et al., 2022).

Frequent sightings of pelagic threshers around *skaru* (coastal seamounts) and a perceived increase in occurrence during upwelling events suggest that Banda could be an ecologically important area for this species. Banda is recognized as one of Indonesia's strategic fishing regions due to its unique oceanographic and topographic features, such as regular upwelling events, which promote high ocean productivity (Tapilatu, 2016). The region also serves as a critical nursery for commercially important pelagic fish species, like tuna, and a migratory corridor for marine mammals (Kahn et al., 2016; Hariati, 2011; Satrioajie et al., 2018). Seamounts are known aggregation sites for highly migratory species due to their unique environmental characteristics (Tsukamoto, 2006; Wessel, 2007), which stimulate productivity by enhancing vertical nutrient fluxes and retaining materials that support higher trophic levels (Lueck and Mudge, 1997; Genin et al., 1986). Seamounts also have distinct "magnetic signatures," which may serve as rest stops or feeding grounds for migratory species, including sharks, whales, and other pelagic animals (Morato et al., 2009; Watson et al., 2007). This combination of factors makes seamounts ideal mating, feeding, and nursing habitats for many highly migratory pelagic species (Fréon and Dagorn, 2000; Morato et al., 2010). In addition, previous studies have shown that seamounts are hotspots for various pelagic shark species, including the porbeagle shark (*Lamna nasus*), short-finned mako shark (*Isurus oxyrhynchus*), and silky shark (*Carcharhinus falciformis*; Morato et al., 2010). The scalloped hammerhead (*Sphyrna lewini*) has also been observed to exhibit high residency around coastal seamounts off Japan, with its highest incidences in the Kuroshio Current, known for its strong coastal upwelling (Jacoby et al., 2022). In the Philippines, coastal seamounts in Monad Shoal have been renowned as critical habitats for pelagic threshers, where they regularly migrate from the open ocean to shallow coastal waters for cleaning (Oliver, 2023). The high dependency of pelagic threshers on these habitats emphasizes the potential importance of seamounts throughout threshers' life

history (Oliver et al., 2011). Notably, the presence of juveniles and pregnant pelagic threshers in Banda may also necessitate a study to understand their movement or habitat utilization (Shidqi et al., 2024; Andrzejaczek et al., 2022). This may bolster the biological and ecological benefits of Banda's existing spatial management measures.

4.2 Using LEK to design conservation responses

Our findings indicate pelagic threshers have limited economic value in the Banda Sea and are even seen as pests. This suggests that in this context, thresher shark bycatch can be characterized as undesirable incidental catch (as opposed to valuable secondary catch, which is often the case for other species of sharks and rays caught incidentally in Indonesia and beyond; Booth et al., 2023a; Collins et al., 2023). This is promising as it suggests that a regulation or low-cost technical fix could work since the opportunity costs to fishers of reducing thresher shark catches are limited, and bycatch mitigation would be aligned with the interests of fishers. Nonetheless, bycatch mitigation does come with several hidden costs regarding labor, safety, and the need to cut fishing nets and lines, as well as some norms-based barriers, such as the perception of being wasteful. The higher reported incidence of bycatch around *rumpons* (FADs) also highlights the need for targeted mitigation measures. However, these may be challenging to implement. Since *rumpons* are essential to the livelihoods of small-scale fishers, imposing a blanket ban (Castellanos-Galindo et al., 2021; Collins et al., 2020) or widespread restrictions could lead to significant socio-political and economic challenges.

Promoting the live release of bycaught thresher sharks could be a feasible conservation strategy for pelagic threshers in this region. This approach is supported by several factors. First, live release is occasionally performed by some *bobo* fishers, which suggests its practicality and has the potential to be adopted by broader fishing communities of Banda. Second, survey results reveal fishers' willingness and intention to release pelagic thresher bycatch (Figure 4). This willingness stems from the sharks' low economic value and the perception that they negatively impact fishing operations. Moreover, live release as a mitigation measure has been successfully applied to various marine species, including dolphins, whales, sea turtles, and other marine mammals, which has demonstrated its potential to reduce mortality (Wosnick et al., 2023; ISSF, 2014). For thresher sharks (*Alopiidae*) in Indonesia, bycatch mitigation is mandated under Ministerial Decree No. 58 Tahun 2020, based on the Indian Ocean Tuna Commission (IOTC) Resolution 12/09 (Fahmi et al., 2020). This policy requires fishing vessels to (1) release pregnant and juvenile threshers alive and (2) report bycatch incidents to port authorities. However, the Banda region falls outside the IOTC area of competence, leaving pelagic threshers unprotected under this policy.

Live release offers a cost-effective conservation solution, particularly in tropical, mixed-species fisheries where measures like area closures or gear modifications are not feasible (Gupta et al., 2020). Although government consultations indicated an interest in including pelagic threshers within the Ay-Rhun MPA management plan, bycatch release remains a prerequisite to complement this broader policy. For live release to succeed, it must be appropriately consulted, designed, and tailored to the local context (Booth et al., 2023b, 2021). Several factors can influence the adoption of bycatch release measures, which vary between the scale of the fisheries (Gupta et al., 2020; Booth et al., 2023b; Campbell and Cornwell, 2008). For instance, small-scale fishers prioritize economic benefits, weighing whether participating in bycatch release will still allow them to provide for their families (Booth et al., 2023b).

In addition, our results suggested that behavioral intentions depend on fishers' perceived control over factors that may facilitate or hinder their actions (Ajzen, 1985; Conner and Armitage, 1998). For example, fishers who feel they have control over the release process (Figures 4, 5) are more likely to engage in the practice. However, fishers also recognized barriers outside their control, such as situations where sharks are already dead in the nets or changes in the value of sharks under specific circumstances. These barriers may limit their participation in live releases. To address such challenges, providing incentives or compensation could encourage the adoption of this conservation behavior (Gupta et al., 2023; Milner-Gulland et al., 2018), particularly when there are tangible or intangible costs, such as lost food and income or time, labor, and safety concerns.

Yet it is essential to note that compensation should also be designed carefully to avoid any reverse impacts (Booth et al., 2021), such as creating new markets for pelagic threshers, which will motivate fishers to deliberately catch pelagic threshers in pursuit of compensation. While the effectiveness of compensation in marine conservation remains mixed (Booth et al., 2023b; Wilcox and Donlan, 2007), approaches that emphasize broader community benefits rather than individual payouts may offer the potential for success (Shidqi et al., 2025; Gjertsen and Niesten, 2010). For instance, compensation could be directed toward educational support for fishers' children (Gjertsen and Niesten, 2010) instead of providing direct cash payments. Such an approach could yield long-term benefits, addressing fishers' immediate struggles while supporting future socioeconomic development in Banda. This underscores the need for interventions that encourage compliance with conservation rules while addressing social and economic realities (Shidqi et al., 2025; Arias, 2015; MacKeracher et al., 2021), especially for small-scale handline fishers.

Some respondents also expressed varying attitudes toward the government, including a lack of trust from unresolved demands. For example, fishers have voiced expectations for additional incentives, such as improved facilities and better market access. These unmet expectations can erode the perceived legitimacy of conservation rules and interventions (Bennett, 2016; Paloniemi and Vainio, 2011; Oyanedel et al., 2020). Addressing this issue may require broader and long-term policy changes that prioritize development in Banda to help shift these attitudes. Moreover, fishers noted that conservation measures, such as MPAs, have led to community divisions. Many fishers feel that conservation zones are disproportionately allocated and restrict fishing rights. To address these concerns, empowering communities to participate in the political processes that establish conservation rules, e.g., allowing them to share their perspectives on what constitutes

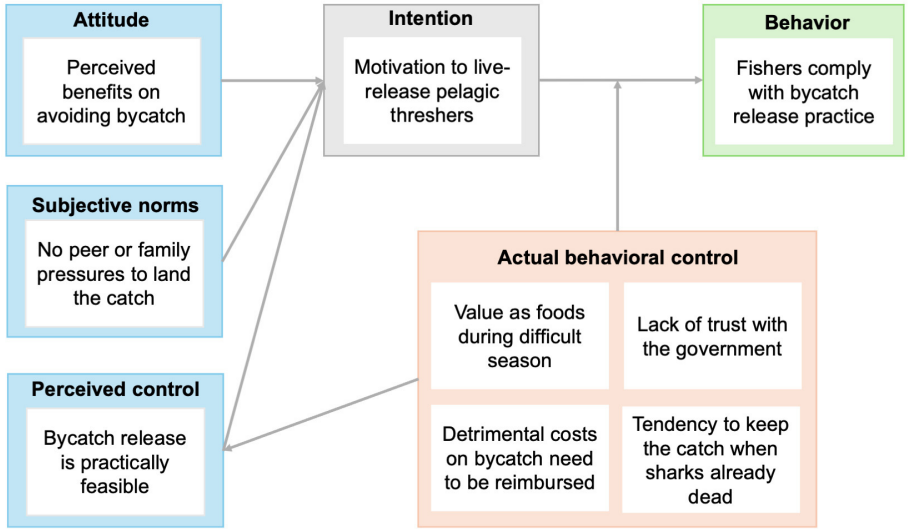

FIGURE 5
Simplified version of identified attitudes and their pathway on behavioral change to engage in bycatch-release intervention. The graph is adapted from the Theory of Planned Behavior (TPB; Ajzen, 1985).

"fair" in conservation outcomes, could enhance their willingness to voluntarily support conservation initiatives (Paloniemi and Vainio, 2011).

Alternatively, institutionalizing bycatch release interventions within customary regulations (*hukum adat*) could serve as an additional mechanism to promote compliance. Consultations with local government suggest Banda communities may respond more positively to this regulatory instrument. Customary management has increasingly been recognized as an effective tool for advancing marine resource conservation in local contexts (Cinner and Aswani, 2007). This approach could involve raising awareness and monitoring bycatch release through customary leaders (*Bapa Raja*) to stimulate pro-environmental behavior (De Groot and Steg, 2009). Furthermore, it could also include developing bottom-up rules by emphasizing fairness and justice, which can foster collective action and compliance (Shidqi et al., 2025; Gurney et al., 2021; Basurto, 2005).

4.3 Limitations

While LEK can help understand data-poor species such as pelagic threshers, it also presents certain limitations. These limitations can arise from biases due to fishers' practices, habits, and experiences (Gupta et al., 2023; Turvey et al., 2010), or from social desirability bias, where respondents tell the interviewer what they think is expected. This bias can be avoided or mitigated by ensuring a degree of social distance between respondents and interviewers (Nederhof, 1985). For instance, when the interviewer may have close social relationships with respondents, other team members outside of that social circle can facilitate the interview. There have also been instances where respondents provided vague descriptions of sharks and ray species, such as "a shark with white color" or "bottom-dwelling rays," making species-level identification challenging. Other difficulties include accurately identifying spatial information due to varying perceptions of scale and space between fishers and scientists (Gupta et al., 2023; Karnad, 2022). We also acknowledge the relatively low coverage of our surveys and focus group discussions, which may affect the external validity of the data and the capacity to generalize findings to non-surveyed islands in Banda (Davis and Ruddle, 2010).

5 Conclusion

Low- to middle-income countries, including Indonesia, have been spotlighted as the main contributors to the global decline in shark populations (Worm et al., 2024; Musick and Musick, 2011; Dulvy et al., 2021). Shark fisheries often hold considerable importance for small coastal fishing communities, serving as sources of income, food, and socio-cultural value (Oposa and Techera, 2023; Dharmadi, 2015; MacKeracher et al., 2021; Alfaro-Shigueto et al., 2010). These communities are frequently described as "marginalized" or "economically vulnerable," and implementing shark conservation measures, such as restricting or prohibiting catches (Castellanos-Galindo et al., 2021), can exacerbate their vulnerability by threatening livelihoods and food security (Dulvy et al., 2017; Jaiteh et al., 2017; Le Manach et al., 2012). This creates a trade-off between achieving biodiversity goals for shark conservation and protecting the wellbeing of dependent communities (Booth et al., 2019; MacKeracher et al., 2019). Such narratives are often viewed as impediments to advancing global shark conservation efforts (Dulvy et al., 2017, 2021). However, our study leveraging LEK in Banda has uncovered an alternative narrative for pelagic thresher sharks, which also highlights conservation opportunities: pelagic threshers are not highly valued, and fishers have neutral or negative attitudes toward catching them and positive attitudes toward pro-conservation behavior, such as live release. This highlights the importance of

context-specific research to understand threats and presents an opportunity to design and test feasible conservation measures for pelagic threshers without undermining the wellbeing of local fishing communities.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

The studies involving humans were approved by the Interdivisional Research Ethics Committee at the senior author's (HB) institution (ref. R66416/RE001) and Indonesia's National Research and Innovation Agency (BRIN; ref. 407/E5/E5.4/SIP/2019, 39/SIP/IV/FR/1/2023, and 17/SIP.EXT/IV/FR/5/2023). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. YB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. SB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. DS: Data curation, Investigation, Project administration, Writing – original draft, Writing – review & editing, Methodology. MT: Data curation, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing. HB: Conceptualization, Funding acquisition, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing, Methodology, Project administration.

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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.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/focsu.2025.1533340/full#supplementary-material

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